iE 250

intelligent Energy controller

Designer's handbook

4189341350A

Improve
Tomorrow

3. AC configuration

5. Breakers, synchronisation and de-loading

6. Regulation

8. SINGLE genset controller

9. GENSET controller

13. Hardware characteristics

14. Glossary

1. About the Designer's handbook

1.1 Intended users of the Designer's handbook

The Designer's handbook is intended for the designer of the system where the controllers are installed. It can also be used during commissioning to check the design drawings and the controller parameters. Operators may find the Designer's handbook useful for understanding the system and for troubleshooting.

1.2 Symbols and conventions

Symbols for hazard statements

DANGER!

This shows dangerous situations.

If the guidelines are not followed, these situations will result in death, serious personal injury, and equipment damage or destruction.

WARNING

This shows potentially dangerous situations.

If the guidelines are not followed, these situations could result in death, serious personal injury, and equipment damage or destruction.

CAUTION

This shows low level risk situation.

If the guidelines are not followed, these situations could result in minor or moderate injury.

NOTICE

This shows an important notice

Make sure to read this information.

Symbols for general notes

NOTE This shows general information.

More information
This shows where you can find more information.

Example

This shows an example.

How to ...
This shows a link to a video for help and guidance.

Functions

The Designer's handbook descriptions are based on functions. Each function description includes the associated input and output functions, and parameters.

Function or parameter path notation

A function or parameter path is stated in this document as follows:

`Generator > Nominal settings > Nominal settings 1 > Voltage (V)`

The above path is for the `Voltage (V)` parameter under `Nominal settings 1` for the `Generator`.

Inputs and outputs

The controller has configurable inputs and outputs. You can assign functions to inputs or outputs with either the display or PICUS. These functions are assigned to a hardware module and set of corresponding terminals. Only functions applicable for the type of terminal are listed. If an ECU is configured in Fieldbus, you can also see ECU functions.

Parameters

Parameters can be configured with either the display or PICUS.

Parameter visibility may depend on the hardware or input/output configuration.

Multi-function parameters and I/Os

Some parameters and inputs or outputs can be used by more than one function.

Parameter used by more than one function example

For a **GENSET** controller:

`Generator > Nominal settings > Nominal settings 1 > Voltage (V)`

This parameter is for the genset *Nominal voltage* for the first set of nominal settings. The *Nominal voltage* is the basis for all of the voltage alarms.

General names

Square brackets [ ] are used to create general names. General names are used to avoid repeating the same function description.

Use of square brackets examples

[Source] represents the *Generator* for a **GENSET** controller.

[Hardware module] represents the relevant controller hardware module.

[Breaker] represents the *Generator breaker* for a **GENSET** controller.

Numbers

The hash symbol # is used when there are several numbered possibilities.

Example

Nominal settings #

Where the # could be 1 to 4.

1.3 Software versions

The information in this document relates to software versions:

Software	Details	Version
iE 250	Controller application	2.0.1.x
PICUS	PC software	1.0.21.x

1.4 Need more information?

Get direct access to the resources that you need by using the links below.

DEIF website

Official DEIF homepage.

Documentation

See all the related iE 250 documentation.

Support

Self-help resources and how to contact DEIF for assistance.

Product

iE 250 product page.

Latest software

Download the latest software.

How to...

Learn how to use this product.

Give feedback

Help improve our documentation with your feedback.

AutoCAD

AutoCAD drawing

STP

Step STP drawing

3D PDF

3D PDF drawing *

Modbus

Modbus tables

NOTE * To view a 3D PDF you must enable multimedia and 3D content in your PDF viewer.

1.5 Warnings and safety

Safety during installation and operation

When you install and operate the equipment, you may have to work with dangerous currents and voltages. The installation must only be carried out by authorised personnel who understand the risks involved in working with electrical equipment.

DANGER!

Hazardous live currents and voltages

Do not touch any terminals, especially the AC measurement inputs, as this could lead to injury or death.

Controller power supply

It is recommended that the controller has both a reliable power supply and a backup power supply. The switchboard design must ensure sufficient protection of the system, if the controller power supply fails.

Connect the extension rack protective earth

DANGER!

Failure to ground

Failure to ground the extension rack could lead to injury or death.

You must ground the controller (or extension rack) to a protective earth.

Factory settings

The controller is delivered pre-programmed from the factory with a set of default settings. These settings are based on typical values and may not be correct for your system. You must therefore check all parameters before using the controller.

Automatic and remote-controlled starts

CAUTION

Automatic genset start

The power management system automatically starts gensets when more power is needed. It can be difficult for an inexperienced operator to predict which gensets will start. In addition, gensets can be started remotely (for example, via an Ethernet connection, or a digital input).

To avoid personal injury, the genset design, the layout, and maintenance procedures must take this into account.

Electrostatic discharge

Protect the equipment terminals from electrostatic discharge when not installed in a grounded rack. Electrostatic discharge can damage the terminals.

Shelving and taking alarms out of service

DANGER!

Shelved and out of service alarms are completely disabled.

These alarms cannot be activated by the operating conditions, and provide NO protection. Shelving or taking out of service also automatically acknowledges the alarm and resets the latch.

You can shelve and/or take selected alarms out of service. However, only qualified personnel should shelve and/or take alarms out of service. This must be done carefully, and only as a temporary measure, for example, during commissioning.

Do not circumvent active alarm actions

DANGER!

Circumventing a latched alarm action

If the alarm action is circumvented, a latched alarm does NOT provide any protection.

Do not circumvent the alarm action of an active alarm. An alarm may be active because it is latched, or because the alarm condition is still present.

Latched *Over-current* alarm example

The controller trips a breaker because of over-current. The operator then manually (that is, not using the controller) closes the breaker while the *Over-current* alarm is still latched.

If another over-current situation arises, the controller **does not trip the breaker again**. The controller regards the original *Over-current* latched alarm as still active.

Do not use unsupported hardware modules

Only use the hardware modules that are listed in the Technical specifications.

Cybersecurity

Admin password

To ensure security, change the administrator (User: admin) password the first time that you log in to the controller.

User activity logs

All activities that require a user login are logged with the username. The user can also use the controller for some actions without logging in (for example, selecting breaker open). These actions are logged without a username.

Untrusted networks

Connections to untrusted networks may require additional equipment and/or security counter-measures that are not included in the product.

Network configuration

The default is to use DHCP to obtain the IP address, subnet, netmask and DNS servers. If you use a manually configured (static) IP, be careful to make sure that the selected values match the network to which the controller is connected.

Inbound port 502 is opened to allow Modbus TCP communication.

Inbound port 443 is opened to allow communication with PICUS.

Inbound port 80 is opened and re-directed to port 443.

In addition, the controller may use the following ports for application and PLC communication: 123, 5353, 11740, 1217, 12345, 4321, 12346, 12350, 12351, 503, 1740, 1741, 1742, 1743, 4840, 8000, 8443.

Data security

While DEIF has taken great attention to data security and has designed the product to be a secure product, we recommend adopting Information Technology (IT) and Operational Technology (OT) security best practices when connecting the controller to a network.

To minimise the risk of data security breaches we recommend:

- Only connect to trusted networks and avoid public networks and the Internet.
- Use additional security layers like a VPN for remote access.
- Restrict access to authorised persons.

1.6 Legal information

Third party equipment

DEIF takes no responsibility for installation or operation of any third party equipment. In no event shall DEIF be liable for any loss of profits, revenues, indirect, special, incidental, consequential, or other similar damages arising out of or in connection with any incorrect installation or operation of any third party equipment.

Warranty

NOTICE
Warranty The warranty will be lost if the warranty seals are broken.

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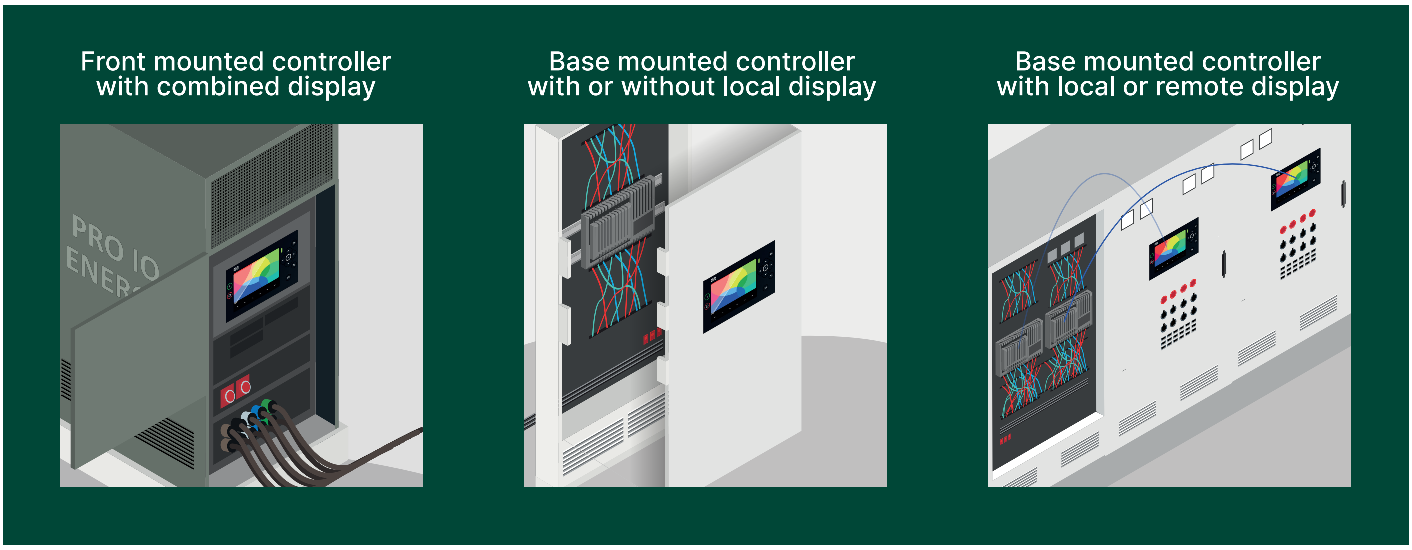
2. System principles

2.1 About the controllers

2.1.1 About the controller types

The iE 250 is a versatile and modular-designed controller for land applications. Its design enables you to tailor the installation to your needs.



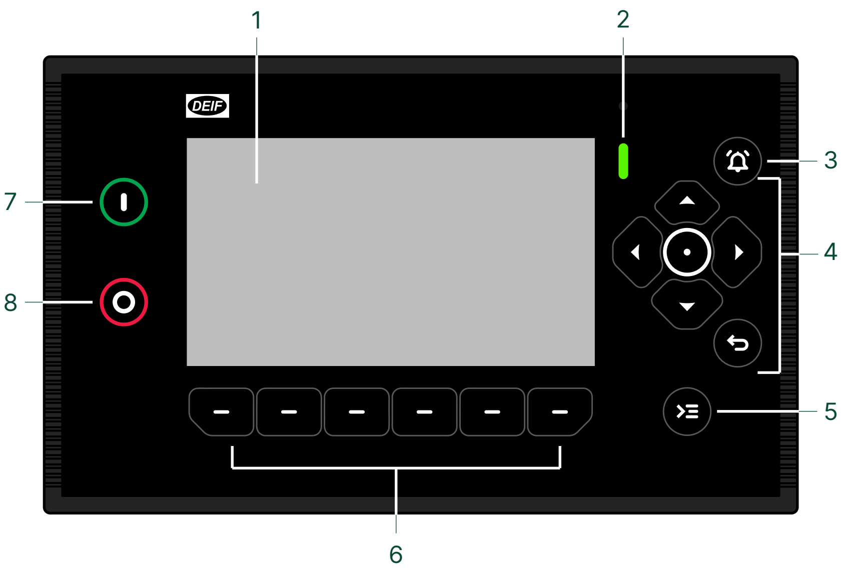
An extensive range of control, protection and supervision features. Applications range from generator control and protection to engineered energy management solutions with our market-leading fuel optimisation technology.

Each controller is assigned a type from the factory. You can the type of controller on the Application single-line drawing.

Controller type	Controls and protects
Single genset controller	• A prime mover, generator, generator breaker, mains connection, and mains breaker • A prime mover, generator, generator breaker, and mains connection • A prime mover, generator, and generator breaker
Generator controller	A prime mover, generator, and generator breaker.
Mains controller	• A mains connection, and mains breaker. • A mains connection, mains breaker, and a tie breaker.
Bus tie breaker controller	A bus tie breaker.

A power management system can include a number of controllers. The controllers work together to ensure effective power management.

2.1.2 Display layout



No.	Item	Notes
1	Display screen	7" colour touch screen.
2	Status LED	Multi-colour LED for status indication.
3	Notification centre button	Silences the alarm horn (deactivates the output), and opens the **Notification centre**, which shows alarms and events.
4	Navigation buttons	Up, down, left, and right arrows.
	Enter button	Confirms the selection.
	Back button	• Returns to the previous page • Shows the menu. • Hold: Change to Dashboard
5	Control centre button	Opens the **Control centre**.
6	Configurable buttons	Buttons are can be activated either by pressing the physical button or the soft key on the screen. *
7	Start button	In manual or local operation, it starts the asset. In a Power management system and in AUTO mode, it starts the Power management.
8	Stop button **	In manual or local operation, it stops the asset. In a Power management system and in AUTO mode, it stops the Power management.

NOTE * Dashboard pages can be created, copied and modified, to assign different functions to the buttons (with PICUS and the Display designer).
** Double press to override cooldown process. Press again to cancel **Idle run**, if configured.

2.2 Application as a system

2.2.1 Single-line application drawing

The system is defined by the application drawing created with PICUS:

- How many controllers
- What type of controllers

- How they are connected

Additional breaker settings, measurements, and feedbacks can also be configured.

You can create up to 4 different application drawings on the iE 250.

The active application is controlled by setting the parameter:

```
System > Plant > Active application
```

The application drawing is created in PICUS and must be written to all connected controllers in the same system. If different applications are detected in the system, the controller activates an alarm.

More information
See the PICUS manual for how to configure and write the Application drawing.

2.2.2 Applications

With power management, the controller can handle simple or advanced applications for a variety of power plant projects. Applications include synchronising generators, critical power, emergency standby, and power production.

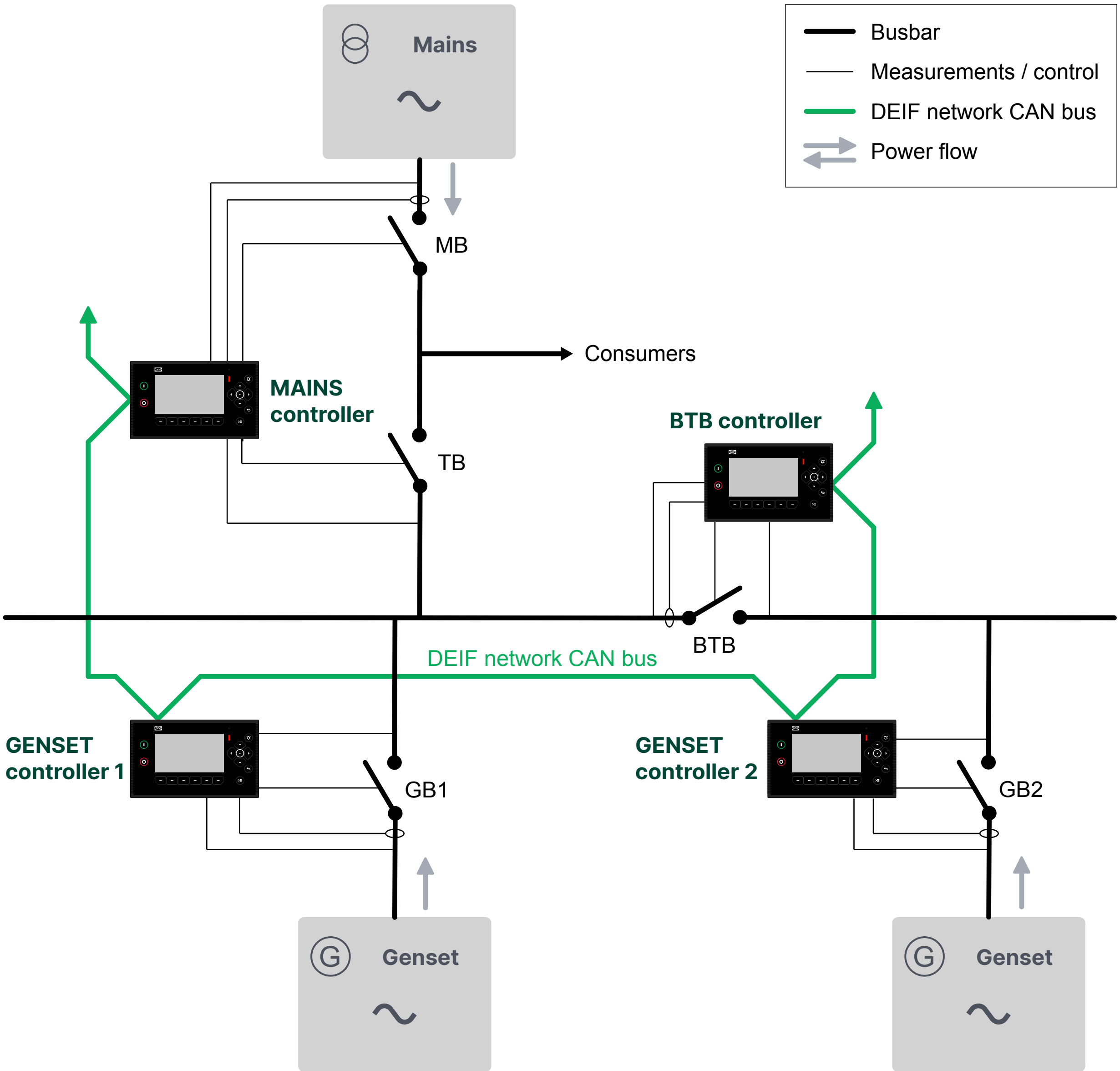
CAN bus based power management:
- 32 prime movers and generators (gensets)/mains with breakers.
- 8 bus tie breakers on the generator bus or load bus.
- 16 automatic sustainable controllers. *

Ethernet based power management: *
- Up to 1000 units on one busbar. *

NOTE * Contact DEIF for availability.

The complete power management system is easily monitored and controlled from PICUS through a graphical supervision page. The values that are presented in the intuitive and easy-to-use user interface include the running status, hours in operation, breaker status, condition of mains and busbars, and fuel consumption.

Example application



2.2.3 Change controller type

With the Premium software package, you can change the type of controller from the single-line application drawing. Remove the existing controller and replace it with a new controller type with the same Controller ID. This feature requires the necessary permission in order to access it.

Restrictions on changing type

You can only change the controller type if it is safe for commissioning:

1. The prime mover must be stopped.
2. The breaker must be open.

or

1. The controller is in emulation mode.

The controller type determines the range for the *Controller ID*. This ensures compatibility with other DEIF controllers.

Controllers	Controller ID range	Notes
SINGLE genset controller	0 or 1	Only 1 SINGLE genset controller
GENSET controller	1 to 32	Up to 32 GENSET controllers
MAINS controller	1 to 32	Up to 32 MAINS controllers
BTB controller	33 to 40	Up to 8 BTB controllers

Changing the controller type resets the default I/O configuration. The I/O configuration must checked and reconfigured as necessary after changing the controller type. It is recommended to take a backup of your settings before changing the controller type.

Change controller types

NOTICE

Configure controller IDs before application

A new controller has a **Controller ID** factory setting of **0** by default. It MUST be configured to the required ID number, otherwise the alarm *Controller ID not configured* becomes active.

Configure the *Controller IDs* on all connected controllers in the system BEFORE creating the single-line application drawing in PICUS.

Create the controller types as follows:

1. Use each display or PICUS to configure all the **Controller IDs.**
   a. Use `Tools > Communication` to configure the **Controller ID** for each controller.
   b. Give each controller a unique **Controller ID** as part of the system design.
2. Create a single-line application drawing for the system in PICUS.
   a. Use `Connect` in PICUS to connect and log on to all the controllers in the system.
   b. Use `Application`, drag icons for the controllers in the system onto the canvas.
3. Edit each controller and assign the correct **Controller ID**.
4. Write the single-line application drawing to all the controllers.
5. System response: For each **Controller ID**, if the controller type on the single-line application drawing does not match the controller, then the controller is changed to the new controller type.
   - The controller type change resets the controller. The default inputs, outputs, and parameters for the controller type are configured.

NOTICE

Configuration reset

If a Controller ID is assigned a new controller type on the single-line application drawing, then all of the controller's existing configuration is deleted, this also includes the log. The IP address configuration and permissions (both users and groups) are not deleted.

It is recommended to take a backup of your controller before changing controller type if you require the settings.

More information
See **Application** in the PICUS manual for how to create the application single-line application drawing.

2.3 Control and modes

2.3.1 About the controller mode

The iE 250 controllers operate in a controller mode. This mode decides which actions may be taken or how the controller reacts to operational situations.

Controller modes:

- **AUTO - Automatic mode**
  - The controller can automatically start, stop, connect, and disconnect the asset. The operator cannot start a sequence manually, unless the local control setting is enabled for the controller or section. The controllers use the power management configuration to automatically select the power management action.
- **MANUAL - Manual mode**
  - The operator can start, stop, connect and disconnect the asset. The controller automatically synchronises before closing a breaker, and automatically de-loads before opening a breaker.
- **LOCAL mode**
  - The operator can start, stop, connect and disconnect the asset. The controller automatically synchronises before closing a breaker, and automatically de-loads before opening a breaker. Remote commands for sequences are ignored.
- **REMOTE mode**
  - REMOTE mode uses command start sequences from digital inputs, PICUS, Modbus, and/or CustomLogic or CODESYS. Display push-buttons for sequences are ignored.
- **NO REG - No regulation mode**
  - Regulation is not controlled by the controller and must be done manually or externally.

2.3.2 Command sources

You can prohibit certain command sources from use in the system. For example, you could restrict the display function for the start or stop of the engine. Command sources can be configured as parameter settings or dynamically controlled with CustomLogic or Modbus.

You can configure different restrictions for when in either LOCAL or REMOTE mode.

Parameters

You can use parameters to enable or disable the display command sources.

`Local > Command sources > Active [mode] sources` *

Parameter	Range	Push-button	Notes
`PICUS commands`	Not enabled, Enabled	-	Allow or prohibit PICUS commands.
`Modbus commands`	Not enabled, Enabled	-	Allow or prohibit Modbus commands.
`I/O commands`	Not enabled, Enabled	-	Allow or prohibit I/O commands to be used.
`CustomLogic commands`	Not enabled, Enabled	-	Allow or prohibit CustomLogic commands to be used.
`CODESYS commands` **	Not enabled, Enabled	-	Allow or prohibit CODESYS commands to be used.

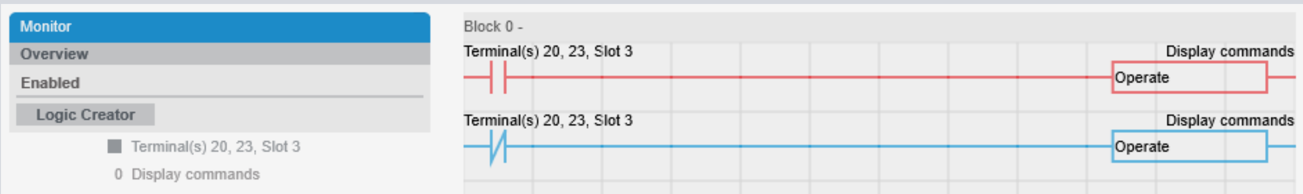
Parameter	Range	Push-button	Notes
`Display commands`	Manual/AUTO mode	-	Allow or prohibit the operator to use the display to change to Manual or AUTO mode.
	Mute alarm		Allow or prohibit the operator to mute alarms.
	Start/stop engine	I or O	Allow or prohibit the operator to start or stop the engine or power source.
	Open/close breaker	CLOSE or OPEN	Allow or prohibit the operator to open or close the breaker.
	Open/close mains breaker ***	CLOSE or OPEN	Allow or prohibit the operator to open or close the mains breaker. ***

NOTE * Where **[mode]** is either LOCAL or REMOTE.
** Only shown if CODESYS is installed and active on the controller.
*** Only on the **SINGLE genset** with mains breaker controller.

Dynamic control

You can use a CustomLogic function to dynamically enable or not enable the command source parameter by setting the value. The value is represented as a bits value.

Example CustomLogic project



In this example, a **GENSET** controller has a digital input is associated with an OPERATE block for the function *Display commands*. The value set in the OPERATE block relates to value for the command source.

When the digital input is not active the OPERATE value is set to 0. No push-buttons can be used.
When the digital input is active the OPERATE value is set to 31. All push-buttons can be used.

`Parameters > Local > Command sources > Active [source] sources *`

To enable these commands set the OPERATE value to 1.
To not enable these commands set the OPERATE value to 0.

Parameter	OPERATE value	Notes
`PICUS commands`	0 = Not enabled 1 = Enabled	Allow or prohibit PICUS commands.
`Modbus commands`	0 = Not enabled 1 = Enabled	Allow or prohibit Modbus commands.
`I/O commands`	0 = Not enabled 1 = Enabled	Allow or prohibit I/O commands to be used.
`CustomLogic commands`	0 = Not enabled 1 = Enabled	Allow or prohibit CustomLogic commands to be used.
`CODESYS commands`	0 = Not enabled 1 = Enabled	Allow or prohibit CODESYS commands to be used, only if CODESYS is installed on the controller.

NOTE * Where **[source]** is either REMOTE or LOCAL.

Display push-button commands

The display push-buttons commands are controlled by the bit value, which depends on the type of controller.

GENSET or SINGLE genset controllers

Command	Bit	OPERATE value
REMOTE/LOCAL	0	1
Mute alarm	1	2
Start/stop engine	2	4
Open/close breaker	3	8
Open/close mains breaker *	4	16

NOTE * Only on the **SINGLE genset** with mains breaker controller.

BUS TIE breaker controller

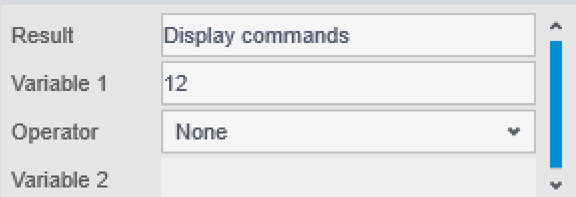
Command	Bit	OPERATE value
REMOTE/LOCAL	0	1
Mute alarm	1	2
Open/close breaker	2	4

Example 1

In this example, we enable only the *Start/stop engine*, and *Open/close breaker* push-buttons on a **GENSET** controller.

Command	Bit	OPERATE value
Start/stop engine	2	4
Open/close breaker	3	8

Bit 2 + Bit 3 = 4 + 8 = OPERATE value 12



2.3.3 Controller not powered

A controller is not powered if it loses power, for example, because the power supply is disconnected. When a controller has no power, none of its protections and functions are active.

A not powered controller does not communicate with the rest of the system, and is invisible to the rest of the system.

The following alarms activate when a controller detects that one of the system's controllers is not powered:

- *Missing controller ID #*
- *Missing any controller*

2.4 Controller functions

2.4.1 Control and command structure

Example: Commands to start sequences

The controller can receive external commands to start controller sequences. For example, a controller in remote control can respond to an external command to close the breaker. If the controller is in local control, then the controller displays an information message and ignores the external command.

An external command can only start a sequence if all the conditions are met, and the controller mode allows the external command to start the sequence.

The controller provides several different ways in which to start the same sequence.

Command	Mode	Type	Notes
The controller starts the sequence.	AUTO	Internal	For this example, the controller parameters are set so that the controller automatically starts the genset when the available power is too low.
The operator presses a push-button on the display folio or a configurable key on the display.	Manual	External	For this example, the operator presses the **Start** button on the display. When the controller detects that the button has been pressed, it starts the sequence to start the genset.
A digital input, which is assigned an external command function, is activated.	Manual	External	A button on the switchboard can be wired to a digital input of the controller. For this example, the digital input is assigned the `Engine > Command > Start engine` function. The operator can press the button on the switchboard, to activate the digital input. When the controller detects that the digital input is activated, it starts the sequence to start the genset.
The operator selects a virtual push-button on the **Supervision** page in PICUS.	Manual	External	For this example, the operator selects the controller **Start** button on the **Supervision** page in PICUS. When the controller detects that the button has been selected, it starts the sequence to start the genset.
CustomLogic activates an external command function.	Manual	External	A function is programmed in CustomLogic. The CustomLogic rung has the conditions that need to be met. For this example, there is a **Normally open coil** with the function `Engine > Command > Start engine` at the end of the rung. When the conditions are met, then CustomLogic activates the function. When the controller detects that the function is activated, it starts the sequence to start the genset.
Using Modbus communication, an operator, a SCADA system, or a PLC sets a Modbus address in the function group *Command* to **1** (True).	Manual	External	A PLC must have a Modbus connection to the required controller. For this example, the PLC writes **1** (True) to Modbus address 1000 in the discrete output coil using the Modbus function code 05 or 15. When the controller gets the command, it starts the sequence to start the genset.

The controller ignores the command and displays an information message if the controller cannot execute the command. For example, if a controller is in local control, it ignores a remote *Start engine* command. The controller displays the information message *Not under remote control*.

2.4.2 Controller input and output functions

Each type of controller has a default configuration. After you assign a function to an input or output, you can assign parameters to that function.

Most of the controller inputs and outputs can be assigned any function. Functions are **not** restricted to specific hardware.

The controllers allow the same function to use a number of alternative types of inputs and/or outputs. This makes the controllers very versatile and compatible with a wide range of assets and systems.

For example, a generator breaker close can be initiated by the power management for a **GENSET** controller in AUTO mode. Alternatively, if the **GENSET** controller is in Manual mode, an operator using the display, PICUS, a digital input, CustomLogic, or an external system using a Modbus command can initiate the generator breaker close. Similarly, the generator speed can be controlled using an analogue output, or CAN bus communication to the engine.

2.4.3 Input source precedence

Each controller can receive inputs from a number of sources. The guidelines for when a source can be used, as well as how the controller handles conflicting inputs, are described below.

Digital input functions

Digital input functions can be activated by wiring connected to hardware, Modbus and/or CustomLogic coils.

Guidelines for digital input functions:

1. If a digital input function is assigned to hardware, you cannot assign that function to a CustomLogic coil (that is, a normally open or normally closed coil).
2. If a digital input function is assigned to a CustomLogic coil, you cannot assign that function to hardware.
   - If you try to assign a digital input that is already assigned to a CustomLogic coil to hardware, it may seem possible. However, if you refresh the hardware view, you will see that the input has not been assigned.
3. For pulse functions:
   a. If there is a command from Modbus, then the controller can activate the function. This is true even if the function is assigned to hardware.
   b. The controller always responds to the most recent input, without considering the source.
4. For continuous functions:
   a. If the function is assigned to hardware: If Modbus sends a command, then the command is not allowed and has no effect.
   b. If the function is not assigned to hardware: If Modbus and CustomLogic send conflicting signals, then the controller uses the CustomLogic signal.

Commands from display unit push-buttons have the same precedence as wiring connected to hardware.

Analogue input functions

Analogue input functions can receive inputs from wiring connected to hardware, Modbus, and/or CustomLogic coils.

Guidelines for analogue input functions:

1. If the analogue input function is assigned to hardware, Modbus can only read the input value. Modbus and CustomLogic cannot modify the input value.
2. If the analogue input function is not assigned to hardware, Modbus and CustomLogic can modify the input value.
3. If Modbus and CustomLogic send conflicting signals, then the controller uses the CustomLogic signal.

2.5 Nominal settings

2.5.1 About the nominal settings

The controller nominal settings are used in a number of key functions. These include power management and protections. Many protection settings are based on a percentage of the nominal settings.

Each controller can store four sets of nominal settings. You can easily change the active set of nominal settings by changing the parameter, using a digital input, analogue input, or an external source (for example, Modbus).

Always check that the conditions are safe to change the nominal settings. Changing nominal settings while a genset is running with a load could lead to unexpected actions. For example, the generator breaker can trip due to an under frequency alarm when changing the nominal frequency from 50 Hz to 60 Hz.

The nominal settings for the controller are mainly the alternating current (AC) settings. Changing the nominal settings set also changes the engine nominal speed, and analogue governor and AVR offsets.

More information
See **each controller type** for more information about the regulation for more information about the analogue regulator offsets.

More information
See Genset nominal settings and Mains nominal settings for the SINGLE genset controller parameters.
See GENSET controller nominal settings for the GENSET controller parameters.
See MAINS controller nominal settings for the MAINS controller parameters.
See BUS TIE breaker nominal settings for the BUS TIE breaker controller parameters.

Input and output functions

Function	I/O	Type	Details
`Local > Nominal settings > Controller nominal setting > Nominal settings #*`	Digital input	Pulse	The controller changes the active nominal setting group to the nominal setting group assigned to the digital input.
`Local > Nominal settings > Controller nominal setting > Nominal settings # selected*`	Digital output	Continuous	Activated if the active nominal setting group is the same as the nominal setting group configured to the output.
`Local > Nominal settings > Controller nominal setting > Nominal setting selected`	Analogue output	0 to 3	The controller outputs a number correlating to the active nominal setting group. Where *Nominal setting 1* is zero.

NOTE * # is 1 to 4.

Parameters

`Local > Nominal settings > Controller nominal setting`

Parameter	Range	Notes
`Selection`	• Nominal settings 1 • Nominal settings 2 • Nominal settings 3 • Nominal settings 4	The selected nominal setting group for the controller. Changing the nominal setting group using a digital input, analogue input, or external command changes this parameter.

2.5.2 Nominal power calculations

Reactive power (Q) nominal

Some alarms and regulators use the nominal reactive power (Q). However, Q is not defined in the controller's nominal settings. The controller therefore always calculates Q. You can select the method that the controller uses here.

`[A-side] > Nominal settings > Nominal settings #* > Calculation method`

Parameter	Range	Notes
`Reactive power (Q) nominal`	• Q nominal calculated • Q nominal = P nominal • Q nominal = S nominal	**Q nominal calculated**: The controller calculates Q nominal based on S nominal and the power factor. **Q nominal = P nominal**: The controller uses the nominal power as the nominal reactive power. **Q nominal = S nominal**: The controller uses the nominal apparent power as the nominal reactive power.
`P or S nominal`	• No calculation • P nominal calculated • S nominal calculated	**No calculation**: *P nominal* has the value entered in the Power (P) nominal parameter. *S nominal* has the value entered in the Apparent power (S) nominal parameter. **P nominal calculated**: The controller uses the nominal apparent power (S) and nominal power factor (PF) to calculate the nominal power. **S nominal calculated**: The controller uses the nominal power (P) and the nominal power factor (PF) to calculate the nominal apparent power.

NOTE * # is 1 to 4.

2.5.3 Power transformer

You can use a step-up or step-down power transformer.

Parameters

`Power transformer > Nominal settings #*`

Parameter	Range	Notes
`Winding nominal voltage source`	• Use nominal voltages • User defined	**Use nominal voltages**: The controller uses the nominal voltage settings. **User defined**: The controller uses the values configured below for voltage settings.
`[B-side] side winding nominal voltage` **	10.0 V to 1500 kV	Voltage on the B-side.
`[A-side] side winding nominal voltage` **	10.0 V to 1500 kV	Voltage on the A-side.
`Phase shift`	-180.0 to 180.0°	Phase shift value in degrees (°)

NOTE * # is 1 to 4.

** These parameters are only visible if `Winding nominal voltage source` is set as `User defined` and written to the controller.

2.6 CODESYS (optional)

More information
See the CODESYS guidelines for a description of how to use CODESYS with the controller.

2.6.1 Inputs and outputs

Assign the CODESYS inputs and outputs with the I/O configuration. These inputs and outputs must first be defined in the CODESYS program, and written to the controller before they can be used.

Function	I/O	Type	Details
`Local > CODESYS > CODESYS digital input (× 40)`	Digital input	Pulse/ continuous	If this input is activated, then the controller activates the corresponding CODESYS digital input function.
`Local > CODESYS > Outputs > CODESYS digital output (× 40)`	Digital output	Pulse/ continuous	If CODESYS activates the digital output function, then the controller activates the digital output.
`Local > CODESYS > State > CODESYS application OK`	Digital output	Continuous	If the **CODESYS_application_OK** output value is "True" and there are no communication errors, then the controller activates the digital output.
`Local > CODESYS > CODESYS analogue input (× 40)`	Analogue input	-	As the value of this input changes, the corresponding CODESYS analogue input value changes.
`Local > CODESYS > CODESYS analogue output (× 40)`	Analogue output	-	As CODESYS changes the value of this analogue output, the corresponding analogue output value on the controller changes.

2.6.2 Activating controller outputs

CODESYS cannot directly activate controller outputs that are configured for controller functions. For example, CODESYS cannot activate the *[Breaker] > Control > Open* digital output.

However, CODESYS can activate external commands, for example, the *[Breaker] > Open* command. The CODESYS command has the same effect as, for example, the *[Breaker] > Command > Open* digital input. The controller only follows the command if the controller is under remote control.

2.7 Alarms and protections

2.7.1 How alarm processing works

CAUTION

Incorrect alarm configuration

Incorrect configuration of the alarm parameters could result in unwanted operational conditions and possible injury to personnel or damage to the equipment.

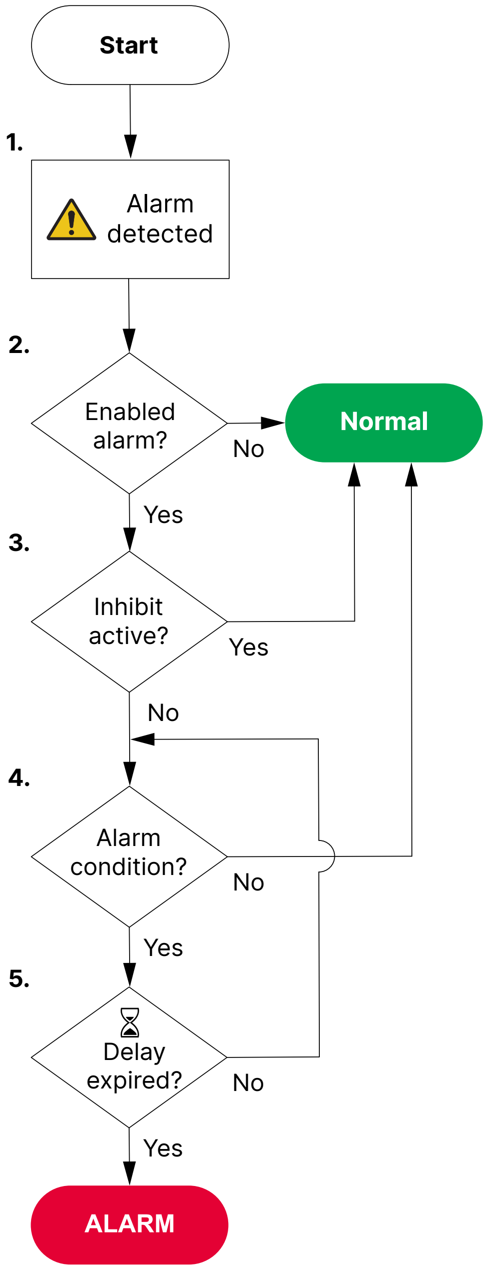
You can not configure some alarms, as the system must maintain a basic level of protection.

Alarm detection

The controller alarms prevent unwanted, damaging, or dangerous situations from occurring. The alarm handling is an adaptation of the ISA 18.2 standard. You can configure alarm parameters to suit your design and operational needs.

Some of the alarms are **Enabled** by default in the controller. You can enable or disable certain alarms and configure their alarm settings (typically the *Set point* and *Delay*) as required.

An alarm is detected when the **Alarm condition** is met (typically, the operating value reaches the *Set point*), the controller starts the *Time delay*. During this period the controller checks whether the **Alarm condition** remains active. If the **Alarm condition** is not longer active, the alarm is not activated. If the **Alarm condition** continues after the time delay has expired the **Alarm action** is activated.



1. The controller detects an **Alarm condition**.
2. The controller checks if the alarm is enabled:
   - If the alarm is not enabled the controller ignores the alarm.
3. The controller checks if the alarm has an active inhibit.
   - If the alarm has an active inhibit the controller ignores the alarm.
4. The controller checks if the **Alarm condition** is still active:
   - If the **Alarm condition** is no longer active the controller ignores the alarm.
5. While the **Alarm condition** is active, the controller checks if the *Time delay* has expired:
   - If the **Alarm condition** is no longer active before the *Time delay* expires, the controller ignores the alarm.
   - If the **Alarm condition** continues and the *Time delay* expires, the controller activates the alarm and the **Alarm action.**

The alarm results in both a visual and audible indication (subject to design of your system) for the operator. The system controls the alarm states as necessary based upon the operational conditions.

Some alarms can be configured to be automatically acknowledged. *Auto acknowledge* can be useful during commissioning and troubleshooting. However, DEIF does not recommend *Auto acknowledge* during normal operation.

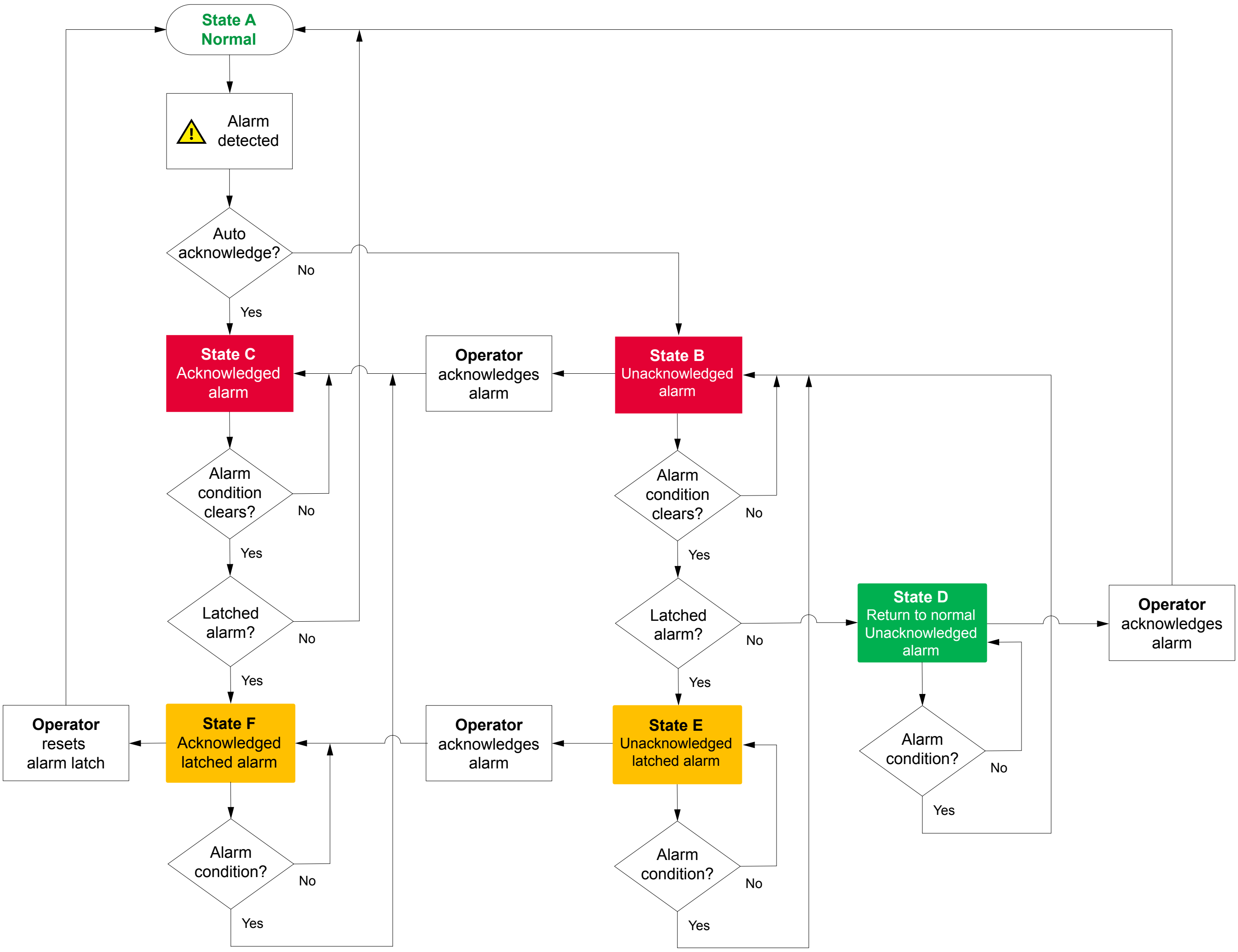
During operation the system continues to monitor the **Alarm condition(s)** and moves alarms between different states as necessary. Operator action can also move the alarm(s) to other states.

Alarm processing states

Alarms can be active in the system in different states:

State	Symbol	Alarm condition	Alarm action	Acknowledge	Notes
State A	-	Not active	Not active	-	Normal state • The alarm is not active in the system.
State B	 or 	Active	Active	Unacknowledged	Unacknowledged alarm • An alarm condition occurred. • An alarm action is active. • An alarm requires acknowledgement. • An alarm requires action to clear the alarm condition.
State C	 or 	Active	Active	Acknowledged	Acknowledged alarm • An alarm condition occurred. • An alarm action is active. • An alarm is acknowledged. • An alarm requires action to clear the alarm condition.
State D	 or 	Not active	Not active	Unacknowledged	Normal state but unacknowledged • An alarm condition occurred, but was cleared. • An alarm action is inactive. • An alarm requires acknowledgement.
State E	 or 	Not active	Active	Unacknowledged	Unacknowledged latched alarm • An alarm condition has cleared. • An alarm action is active. • An alarm requires acknowledgement. • An alarm latch requires reset.
State F	 or 	Not active	Active	Acknowledged	Acknowledged latched alarm • An alarm condition has cleared. • An alarm action is active. • An alarm is acknowledged. • An alarm latch requires reset.
State G	 or 	Active or Not active	Not active	-	Shelved alarm • An alarm is shelved for a period of time. • An alarm returns automatically after the period has expired.
State I	 or 	Active or Not active	Not active	-	Out of service alarm • An alarm is marked *out of service* for an indefinite period. • An alarm does not return automatically and must be returned to service manually.
State H	 or 	Active or Not active	Not active	-	An alarm is inhibited to occur.

The three special **Shelve** (Stage G), **Inhibited** (Stage H), and **Out of service** (State I) are not shown in this diagram.



NOTE Alarms configured with a *Latch* continue to have the **Alarm action** active even if the **Alarm condition** is no longer active. The alarm requires first acknowledgement and then reset by an operator before the alarm can be cleared and return to normal.

Inhibited, **Shelved**, or **Out of service** alarms are forced to be not active in the system, even if the **Alarm condition** is present.

Automatic actions

The controller controls the following automatic actions:

- Horn/siren output
- Inhibits alarms (if applicable)
- Auto-acknowledges alarms (if configured)
- Controls the alarm state
- Suppress action (if configured)

Operator alarm actions *

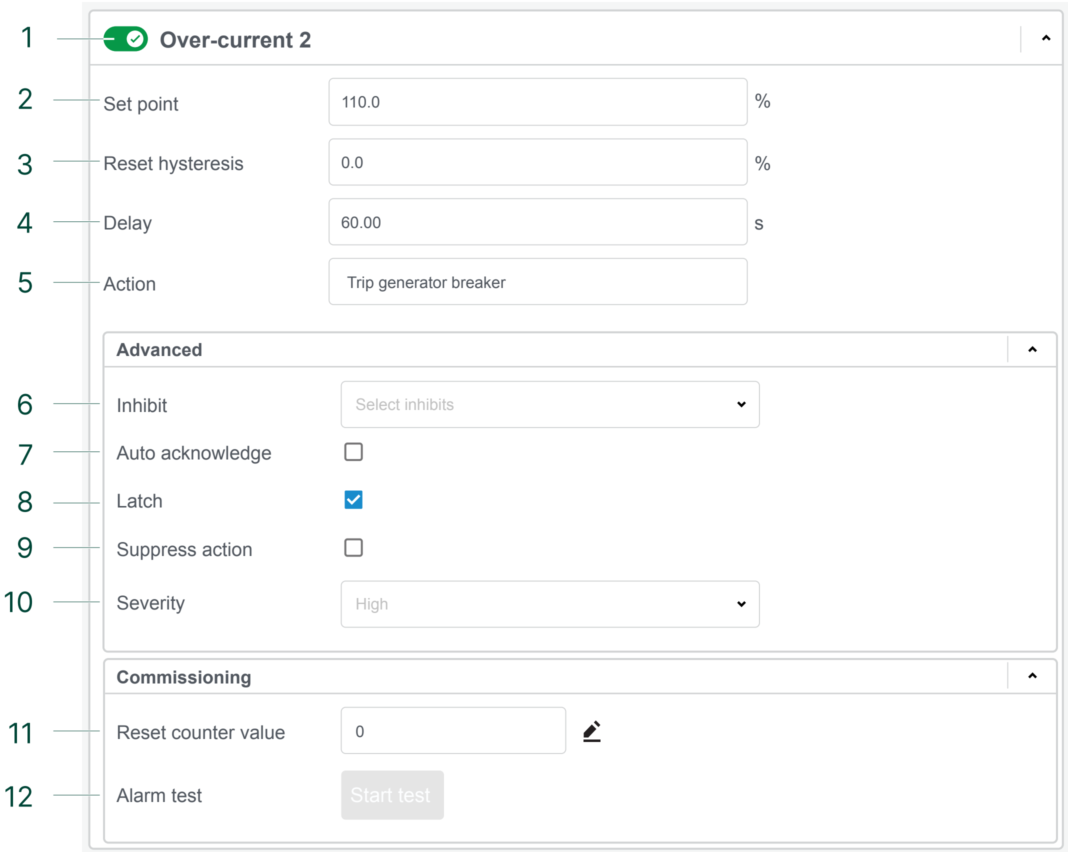
An operator controls the following alarm actions:

- Acknowledge
- Shelve
- Out of service
- Latch reset
- Silence alarm horn/siren

NOTE * The actions an operator can use are controlled by the group and user permissions granted to their login.

2.7.2 Alarm parameters

The alarm settings are configured as parameter settings in the controller. Some alarm settings are not configurable.



#	Parameter	Range	Notes
1	`Enable`	Not enabled, Enabled	Enabled alarms activate in the system if the **Alarm condition** occurs.
2	`Set point`		The setting at which the alarm activates.
3	`Reset hysteresis`	Varies	See **Reset hysteresis** for more information.
4	`Delay`	Varies	A time delay before the **Alarm action** becomes active.
5	`Action`	Varies	The **Alarm action** to be taken.
6	`Inhibit(s) #1 to #32`	Varies	Inhibit(s), that if active, can inhibit the alarm from becoming active.
7	`Auto acknowledge`	Not enabled, Enabled	If **Enabled** the alarm is automatically acknowledged when it occurs. *
8	`Latch`	Not enabled, Enabled	If **Enabled** the alarm is latched when it occurs and requires both acknowledgement and reset (unlatch) to clear the **Alarm action**.
9	`Suppress action`	Not enabled, Enabled	If **Enabled** the alarm action is suppressed. The alarm message will appear in the alarm list.
10	`Severity`	High Medium Low	Set the severity of the alarm placement in the alarm notifications.

#	Parameter	Range	Notes
11	`Reset counter`		Set or reset the alarm counter value.
12	`Alarm test`	Start test, Stop test	Select **Start test** to start an alarm test. Starting an alarm test also activates the alarm action. Select **Stop test** to stop the alarm test.

Set point

The *Set point* is the reference value that is compared by the controller to decide whether the **Alarm condition** is present in the system.

When the operating value, that the alarm is based on, reaches the *Set point*, the controller starts the *Time delay* (if applicable) for the alarm. The *Set point* is often a percentage of the controller's nominal setting. Most alarms require a *Set point* to be configured.

For example, the *Set point* for the *Over-current 1* alarm can be 100 %. This means that the current from the asset must be 100 % (or more) of the nominal current to activate the alarm.

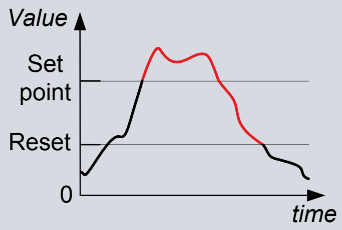
Reset hysteresis

The *Reset hysteresis* prevents the operating value from being too close to the alarm *Set point* when the alarm is reset. The *Reset hysteresis* makes the system more stable by imposing hysteresis on the alarm *Set point*. The *Reset hysteresis* is a value that is subtracted from the set point of high alarms (and added to the *Set point* of low alarms).

A *Reset hysteresis* can only be used where the alarm is based on an analogue value.

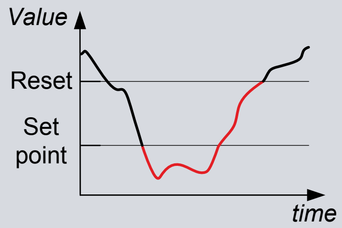
Overspeed example

An *Overspeed* alarm with a *Set point* of 110 % of nominal speed and a *Reset hysteresis* of 10 %. The alarm cannot be reset until the operating value falls below 100 % of nominal speed. The red line in the figure shows that the alarm is activated when the value exceeds the *Set point*. The alarm is only deactivated when the value drops below the reset value.



Under-speed example

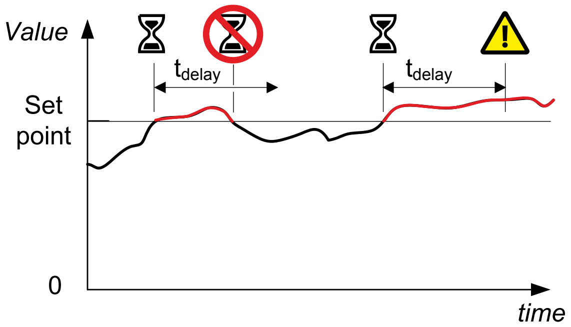
An *Under-speed* alarm with a *Set point* of 80 % of the nominal speed and a *Reset hysteresis* of 5.0 %. The alarm is only reset when the operating value is above 85.0 % of the nominal speed.



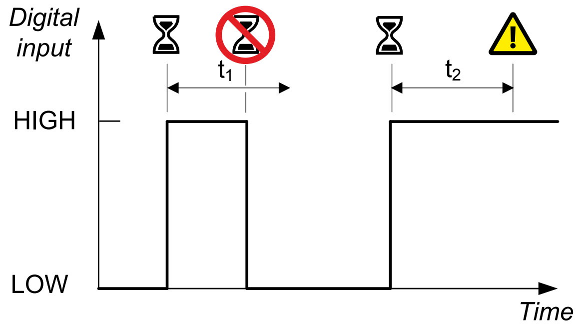
Delay

When the alarm *Set point* is exceeded and an alarm *Delay* is configured, the controller starts the timer for the alarm. If the operational value stops exceeding the *Set point*, the timer is stopped and reset. If the value exceeds the alarm *Set point* for the whole of the *Delay*, the controller activates the alarm.

Delay for a high alarm based on an analogue operating value



Delay for a high alarm based on a digital input



The total delay before the alarm *Action* is activated is the *Operate time* for the alarm plus the *Delay* parameter.

Trigger level

If the reference value must be equal to or higher than the *Set point* to activate the alarm, a **High** *Trigger level* is selected in the alarm configuration.

Similarly, if the reference value must be equal to or lower than the *Set point* to activate the alarm, a **Low** *Trigger level* is selected in the alarm configuration.

For most alarms the *Trigger level* is set and cannot be changed. Custom I/O alarms can be configured for **High** or **Low** setting of the *Trigger level*.

Auto acknowledge

When *Auto acknowledge* is selected, the alarm is immediately marked as acknowledged in the alarm display when the alarm is activated.

Alarms that have a *Latch* configured, even if automatically acknowledged, still require unlatching by the operator.

Action

The **Alarm action** is the response that you allocate to the **Alarm condition.** Each alarm can only be assigned one **Alarm action**. The controllers are delivered with pre-defined alarm actions. You can change the **Alarm action** for most alarms.

Alarm actions are used to assign a set of responses for each alarm. Each **Alarm action** consists of a group of actions that the system takes when the **Alarm condition** is met. **Alarm actions** act as a type of alarm categorisation. Minor alarm situations may be assigned warnings, while a critical situation may trip the breaker and shutdown the genset.

The **Alarm actions** are effective as long as the operating value exceeds the alarm *Set point* (including the *Reset hysteresis* if configured) or the alarm is latched.

Priority of alarm action

If two or more alarm actions are active for the same asset at the same time, the controller performs the **Alarm action**with the highest priority. A later **Alarm action**with a lower priority does not change the controller's execution of the earlier **Alarm**

actionwith the higher priority. Similarly, if a more severe **Alarm action** is activated after a less severe **Alarm action**, the controller performs the more severe **Alarm action**.

Alarm action priority example

One alarm activates *Trip generator breaker and stop engine*, and at the same time another alarm activates *Trip generator breaker and shutdown engine*. *Trip generator breaker and stop engine* includes a cooldown period, while *Trip generator breaker and shutdown engine* does not. The controller shuts down the engine without cooling, regardless of the order of the alarms.

Inhibits

Inhibits stop the **Alarm action**. When an inhibit is active, the controller does not activate the **Alarm action**, even if all the other alarm conditions are met. Inhibits are automatic and are not controlled by the operator.

If an inhibit with active conditions is created for an active, unacknowledged alarm (with or without a latch), then the alarm state changes to an inactive, unacknowledged alarm (with or without a latch). The alarm must be acknowledged (and unlatched) before it is removed from the alarm list.

Inhibited alarms are not shown in the alarm list, unless they have occurred and are unacknowledged before they were inhibited.

The controller types are delivered with default inhibits for each alarm. You can remove these inhibits, and/or add more inhibits. In addition to the default inhibits, you can also configure three customisable I/O inhibits for selection.

More information
See Customised inhibits for how to configure customisable I/O inhibits.

For example, for a **GENSET** controller, for generator under-voltage, the inhibits *Engine not running* is selected. This means that if the genset is either starting up, or if there is no running detection, the generator under-voltage alarm is disabled.

In addition to the default inhibits available, some alarms include permanent inhibit conditions. These inhibits are not configurable, and are described under the alarm that uses them.

For some alarms, inhibits are not applicable. The controller will not allow you to select any inhibits for these alarms.

Suppress action

For all controller types, an alarm action is suppressed when *Suppress action* is **Enabled** for the alarm, and the function `Alarm system > Additional functions > Suppress alarm action` is activated by a digital input, PICUS, Modbus, and/or CustomLogic.

If the **Alarm action** is suppressed, when the alarm is activated, the alarm is shown in the alarm handling system, but the **Alarm action** is only *Warning*.

Severity

You can configure the *Severity* for each alarm, to make sure that the most severe alarms are the most prominent to the operator. By default, all alarms have a **High** severity.

Latch

You can configure a *Latch* on any alarm. When an alarm with a *Latch* is activated, the **Alarm action**remains in force until the alarm is acknowledged and then reset (unlatched). Alarm latching provides an extra layer of safety.

For example, you can create a low oil pressure alarm with a latch and a *Trip generator breaker and shutdown engine* alarm action. Then, if there is low oil pressure, the controller trips the breaker and stops the engine. The engine remains stopped and will not be able to start until the alarm is reset.

NOTICE
Effective action with latch Enabling a *Latch* on an alarm is not enough for safety protection. To be effective, the alarm must also be **Enabled**, and the alarm *Action* must be effective against the unsafe situation. For example, a *Latch* on an alarm with the action **Warning** offers little extra protection.

Enable *

Some alarms can be **Not enabled** or **Enabled**, according to your requirements.

If the alarm is **Not enabled**, it does not respond to changes in the operating values, and is never activated.

If the alarm is **Enabled**, it is activated when the alarm *Set point* and *Delay* are exceeded. However, if the conditions for one or more inhibits are met, then the alarm and its *Action* are inhibited, and not activated.

Do not change an active alarm to **Not enabled.** If you change an active alarm to **Not enabled** the **Alarm action** continues. The **Alarm action** cannot be reset until after the alarm is enabled again.

NOTE * Some alarms settings are not configurable. You can not configure some alarms, as the system must maintain a basic level of protection.

Alarm test

The alarm test activates the alarm and its **Alarm action**. You can use the alarm test parameter to test individual alarms, for example, during commissioning.

Alarm tests of individual alarms can be stopped one at a time using the parameter, or at the same time using the *Stop test* button on the **Alarms** page in PICUS.

Additional alarm information

The additional alarm information provides information about the state of the alarm. This information can be useful during commissioning and trouble shooting.

Information	Notes
Reset counter value	Changes the *Counter* parameter value to the selected value.

2.7.3 Common alarm actions

Warning	
Controller types	All
Priority	Low
Effect	The controller activates a warning alarm.

Block [Breaker]	
Controller types	All
Priority	-
Effect	**Breaker closing is blocked**: If the breaker is open, the controller will not close it. (If the breaker is closed, this **Alarm action** does not open the breaker.)

PMS-controlled stop	
Controller types	**GENSET** controllers
Priority	Medium
Effect	The breaker is de-loaded and then opened. The controller then initiates the stop sequence. If the power management system cannot de-load the breaker (for example, because there is not enough power), nothing happens. This alarm action **only** opens the breaker when it is de-loaded.

Trip [Breaker]	
Controller types	All
Priority	High
Effect	The controller trips the [Breaker] (that is, without de-loading).

Trip generator breaker and stop engine	
Controller types	
Priority	High
Effect	The controller trips the genset breaker (that is, without de-loading). After the cooldown period, the controller stops the engine.

Trip generator breaker and shutdown engine	
Controller types	
Priority	Highest
Effect	The controller trips the genset breaker (that is, without de-loading). The controller shuts down the engine, **without** a cooldown period.

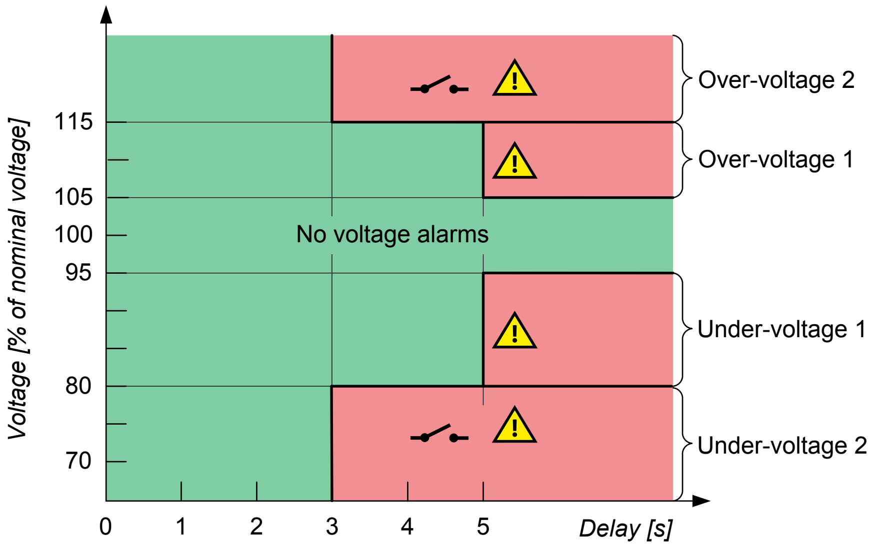
Controlled stop	
Controller types	**GENSET** controllers
Priority	Medium
Effect	The breaker is de-loaded and then opened. The controller initiates the stop sequence. If the breaker cannot be de-loaded (for example, because there is not enough power), nothing happens. This alarm action **only** opens the breaker when it is de-loaded.

2.7.4 Alarm levels

Alarm levels refers to configuring a number of alarms for one reference value. For each alarm level, the *Set point*, *Delay*, *Alarm action* and other parameters are configured.

Example of alarm levels

This example shows the B-side voltage alarms that are present by default, that is, *Busbar over-voltage 1*, *Busbar over-voltage 2*, *Busbar under-voltage 1* and *Busbar under-voltage 2*.



If the operation is in the green area, the controller does not activate any busbar voltage alarms.

In the example, an over-voltage *Warning* alarm is activated if the busbar voltage has been over 105 % of the busbar's nominal voltage for 5 seconds. If the busbar voltage is over 115 % of the nominal voltage for more than 3 seconds, the controller activates the *Trip [Breaker]* alarm action. Both alarms will be active if the busbar voltage is over 115 % of the nominal voltage for more than 5 seconds. The alarm action *Trip [Breaker]* has a higher priority than *Warning*.

The graph shows two protection levels for under-voltage. In the example, if the busbar voltage is under 95 % of the nominal voltage for more than 5 seconds, a *Warning* is activated. If the busbar voltage is under 80 % of the nominal voltage for more than 3 seconds, the *Trip [Breaker]* **Alarm action** is activated.

2.7.5 Operate time

The operate time is the total time that the controller takes to respond to a change in the operating conditions. A part of the operate time is determined by the controller hardware characteristics. The rest of the operate time can be adjusted by changing configurable controller parameters.

The controller operate time is listed for each AC protection. The operate time starts when the AC conditions change so that the alarm set point is exceeded. The operate time is completed when the controller has changed its output accordingly.

```
Operate time = measurement time + calculation time + time to change the controller output + delay
```

Operate time example

The over-voltage protection has an operate time of **< 100 ms** listed on the data sheet. For *Over-voltage 1*, you can configure a delay from 0.00 to 3600.00 s.

If the delay is **5.00 s**, the controller does the *Over-voltage 1* alarm action **5.10 s** after the alarm *set point* is exceeded.

2.7.6 Acknowledge an alarm

Alarms must be acknowledged. The operator must take action regarding the **Alarm condition**. The operator can mark the alarm as *acknowledged*. Alarms that have *Auto-acknowledge* do not require acknowledge by operator action.

NOTICE
Active alarm action Acknowledging an alarm has no influence on the alarm *Action*.

Table 2.1 Acknowledgement status and operator actions

<table>
<tr><th>Acknowledged?</th><th>Latch?</th><th>Alarm condition?</th><th>Alarm action *</th><th>Required operator actions</th></tr>
<tr><td rowspan="4">Unacknowledged</td><td rowspan="2">Latch</td><td>Active</td><td>Active</td><td>• The alarm condition must be corrected.
• The alarm must be acknowledged.
• The alarm must be reset (unlatched).</td></tr>
<tr><td>Inactive</td><td>Active</td><td>• The alarm must be acknowledged.
• The alarm must be reset (unlatched).</td></tr>
<tr><td rowspan="2">No latch</td><td>Active</td><td>Active</td><td>• The alarm condition must be corrected.
• The alarm must be acknowledged.</td></tr>
<tr><td>Inactive</td><td>Inactive</td><td>• The alarm must be acknowledged.</td></tr>
<tr><td rowspan="4">Acknowledged</td><td rowspan="2">Latch</td><td>Active</td><td>Active</td><td>• The alarm condition must be corrected.
• The alarm must be reset (unlatched).</td></tr>
<tr><td>Inactive</td><td>Active</td><td>• The alarm condition must be corrected.
• The alarm must be reset (unlatched).</td></tr>
<tr><td rowspan="2">No latch</td><td>Active</td><td>Active</td><td>• The alarm condition must be corrected.</td></tr>
<tr><td>Inactive</td><td>Inactive</td><td>• No further action is required.</td></tr>
</table>

NOTE * Alarm action is controlled automatically by the controller.

Inhibited, shelved, and out of service alarms all have an inactive alarm *Action*.

Digital inputs

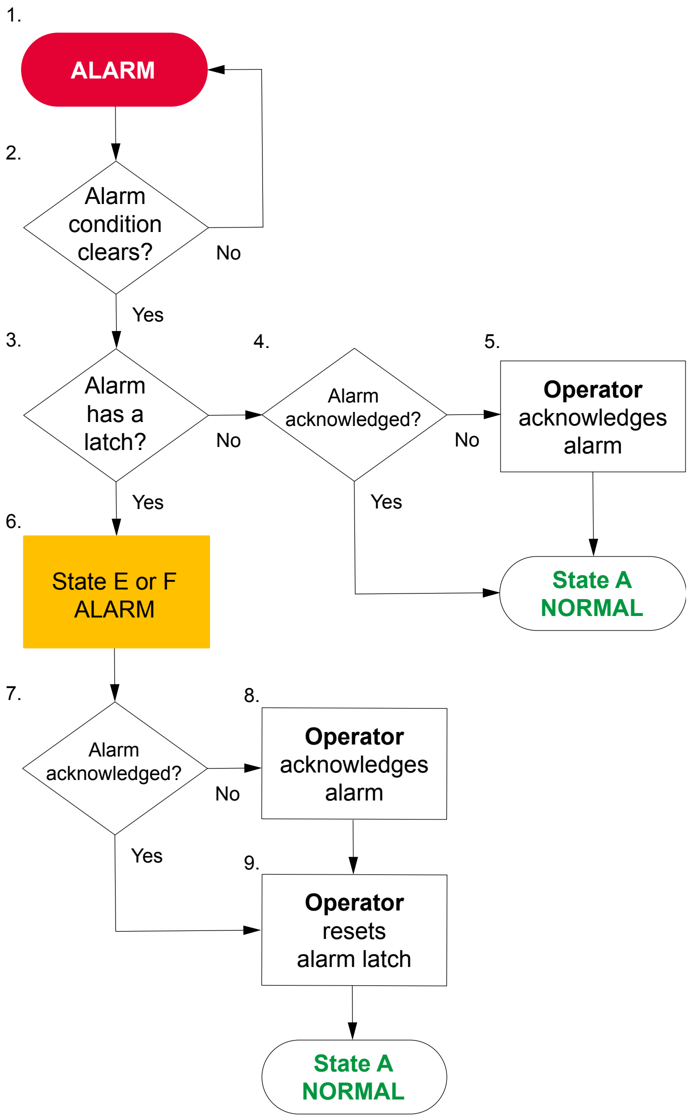
Function	I/O	Type	Details
`Alarm system > Command > Acknowledge all alarms`	Digital input	Pulse	When this input is activated, the controller acknowledges all its alarms.
`Power management > Acknowledge all alarms in system`	Digital input	Pulse	When this input is activated, the controller acknowledges all its own alarms, along with all the alarms in all the other controllers in the system.

2.7.7 Alarm latch and reset

An additional layer of protection can be added by using a *Latch* on most alarms. When a *Latch* is **Enabled** on an alarm, there is an extra confirmation that must be made by the operator, before the alarm can be cleared. The **Alarm action** remains active, even if the **Alarm condition** clears, until the operator resets the latched alarm.

A latched alarm can only be reset by an operator after both the alarm has been acknowledged and the **Alarm condition** has cleared. Acknowledging the alarm does not *Reset* the alarm latch.

For example, you can configure a low oil pressure alarm with a latch enabled, with a *Trip generator breaker and shutdown engine* alarm action and an *Engine not running* inhibit. If there is low oil pressure, the controller trips the breaker and shuts down the engine. The engine remains stopped and will not be able to start until the operator acknowledges the alarm AND resets the latch.



1. An alarm activates in the system as either:
   - Unacknowledged (**State B**)
   - Acknowledged (**State C**) *
2. The controller checks if the **Alarm condition** has cleared.
   - If the **Alarm condition** continues, the **Alarm action** remains active.
3. The controller checks if the alarm has a latch configured:
   - If the alarm has a latch configured, the controller continues from step 6.
4. The controller checks if the alarm is acknowledged:
   - If the alarm is acknowledged the alarm returns to normal **State A**.
5. The operator acknowledges the alarm. After the acknowledgement the alarm returns to normal **State A**.
6. A latched alarm in the system is either:
   - Unacknowledged (**State E**)
   - Acknowledged (**State F**)
7. The controller checks if the alarm is acknowledged:
   - If the alarm is acknowledged, the controller continues from step 9.
8. The operator acknowledges the alarm, and the alarm the latch can then be reset.
9. The operator resets the latch on the alarm, and the alarm returns to normal **State A**.

NOTE * The alarm may have *Auto-acknowledge* configured. *Auto-acknowledge* can be useful during commissioning and troubleshooting. However, DEIF does not recommend the use of *Auto acknowledge* during normal operation.

Digital input (optional)

Function	I/O	Type	Details
`Alarm system > Command > Reset all latched alarms`	Digital input	Pulse	The controller resets all latched alarms (that are ready to be reset) when this input is activated.

2.7.8 Shelve an alarm

The operator can shelve each alarm for a period of time, during any alarm state (except if the alarm is already *Out of service*).

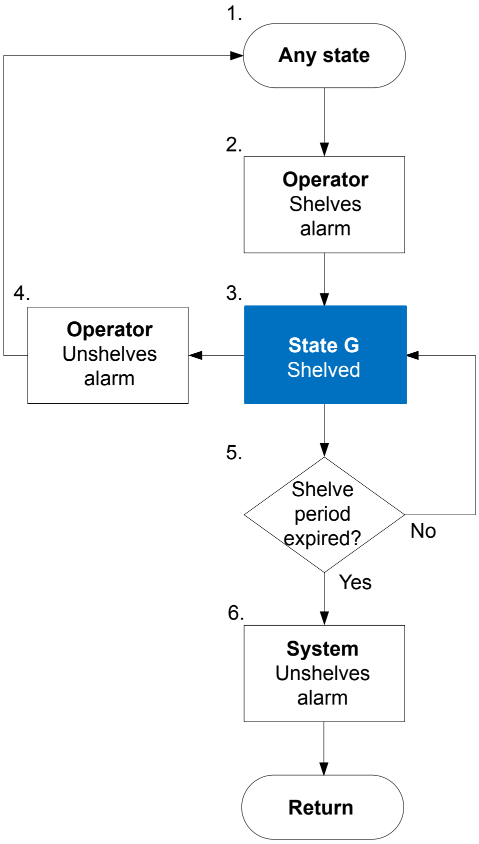
If an unacknowledged alarm is shelved, the alarm is automatically acknowledged. If a latched alarm is shelved, the latch on the alarm is reset. While the alarm is shelved, the alarm action is not active.

When the period expires, the alarm is automatically unshelved. Alternatively, an operator can manually unshelve the alarm. The alarm then responds as normal to alarm conditions.

CAUTION

Shelved alarms

Shelving certain alarms can disable critical protections. In addition, shelving automatically acknowledges the alarm and resets the latch.



1. The alarm can be in any state.
2. The operator shelves the alarm for a specific period of time.
3. The alarm is now shelved (**State G**).
4. The operator unshelves the alarm, the alarm returns back to its original state.
5. The controller checks if the shelve period has expired:
   - If the shelve period has not expired, the alarm remains as shelved.
6. The system unshelves the alarm if the shelve period has expired.

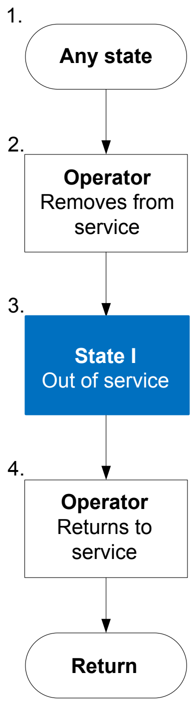
2.7.9 Out of service an alarm

You can take any alarm *Out of service*, during any alarm state (except if the alarm is already *Shelved*). When an alarm is *Out of service*, the alarm is suspended indefinitely.

CAUTION

Out of service alarms

Taking certain alarms *Out of service* can disable critical protections. In addition, taking *Out of service* automatically acknowledges the alarm and resets the latch.



1. The alarm can be in any state.
2. The operator removes the alarm from service.
3. The alarm is now out of service (**State I**).
4. The operator returns the alarm to service, the alarm returns back to its original state.

NOTE The system does not automatically return an *Out of service* alarm, an operator must perform this action.

2.7.10 Alarm test

An alarm test activates the controller alarms and all their **Alarm actions**. You can activate alarm tests from the PICUS **Alarms** page, or by starting an alarm test for an individual alarm using the alarm's **Alarm test** parameter.

More information
See **Alarms** in the **PICUS manual** for the alarm test buttons available on the **Alarms** page in PICUS.

Before the test

Make sure that a blackout is acceptable, before you use the alarm test function. Be aware that it may take you some time to get the system back to normal after an alarm test.

During the test

When the test is *Enabled*, the alarms appear on the display and in the alarm list, and are recorded in the log. Test alarms appear in green text on the display, and are marked with a grey dot in the **T** column in the PICUS alarm list.

If an alarm was acknowledged before the test, the alarm status changes to unacknowledged during the alarm test.

If an alarm is acknowledged during the test, the alarm remains on the alarm list, and the alarm action continues until the alarm test stops.

- **Latched alarms**: Alarms with latches can be acknowledged and the latches reset manually during the test. If an alarm latch is reset during the test, then the alarm is removed from the alarm list, and the alarm action stops.
- **Shelved alarms**: The alarm test unshelves these alarms, and they remain unshelved after the test.
- **Out of service alarms**: The alarm test returns these alarms to service. These alarms remain in service after the test.

After the test

When the test is *Not enabled*, the tested alarms remain active until they are acknowledged and, if required, their latches are removed. The alarms are rechecked, and reactivated if the alarm conditions are still present. All the test alarms remain in the log, and are indicated with a grey dot in the **T** column.

Alarms that were acknowledged before the alarm test are still acknowledged when the alarm test stops.

2.7.11 Alarm status digital outputs

You can configure a digital output with a function for an alarm status. The controller activates the digital output if the alarm status is present.

Applications

A digital output with an alarm status may be wired to a switchboard light, to help the operator. For example, you can configure an output with the `Alarm system > State > Any latched alarm` function, and wire it to a light on the switchboard. When there are any alarms with active latches, the light is lit. The operator then knows that there are alarms that must be checked and unlatched.

Alarm test

The alarm test activates these outputs. Acknowledging the test alarms deactivates the outputs.

2.7.12 Customising alarms

You can customise the alarms for your system by configuring the alarm parameters. The parameters that you can configure are restricted for some alarms.

You can also create custom alarms for the input/output configurations for both analogue and digital terminals.

Limitations on alarm parameters that cannot be customised

Not customisable	Notes
Additional alarms	The list of alarms is fixed, and you cannot add more alarms. If an alarm is not available, you can set it up in CustomLogic. However, it will not be part of the alarm list, or the alarm management system.
Certain alarms	Some alarms cannot be disabled. For example, the *Phase sequence error* protection (which prevents synchronisation when the phase sequence is not the same on either side of the breaker) is always *Enabled*.
Certain alarm actions	You cannot change certain alarm actions. For example, for *Voltage or frequency not OK*, the action is always *Block*, to stop the breaker from closing.
Additional alarm actions	You cannot create additional alarm actions. You can only choose alarm actions from the list of alarm actions. You can set up responses to operating values or conditions in CustomLogic, but these will not be available as alarm actions to the alarms.
Inhibits that are not configured for the controller type	You cannot add more inhibits to the list of inhibits available for selection for the controller type. For example, you cannot select the *Tie breaker closed* inhibit, as this is not applicable to the **GENSET** controller. However, there are three custom inhibits for each controller. You can activate a custom inhibit using a digital input, Modbus, and/or CustomLogic.
Change the *Trigger level* for certain alarms	Most alarms have a fixed *Trigger level*. For example, *Busbar over-voltage* is always a *High* alarm, while *Busbar under-frequency* is always a *Low* alarm.

2.7.13 Customised inhibits

In addition to the default inhibits, you can also use three custom inhibit functions (*Inhibit 1*, *Inhibit 2* and *Inhibit 3*). You can activate a custom inhibit using a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.

Digital input

Function	I/O	Type	Details
`Alarm system > Inhibits > Activate inhibit #` *	Digital input	Continuous	When the digital input is activated, then the controller applies *Inhibit #* *

NOTE * Where # is 1 to 3.

If you use CustomLogic, you do not have to wire up a digital input, and assign the *Activate inhibit #* function to the input.

Parameters

Select the customised inhibit:

```
[Alarm] > Inhibit > #[number]
```

Where `[Alarm]` represents any alarm, and `[number]` represents the number of the inhibit field.

Table 2.2 Inhibit parameters

Range	Notes
The controller inhibits, plus *Inhibit #*, where # is 1 to 3	If you select *Inhibit #*, and the digital input *Activate inhibit #* is activated, then the controller inhibits the alarm.

2.7.14 Suppress action inhibit

It can be useful to use a digital input function to suppress the alarm action for certain alarms. You can activate the function using a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.

Digital input

Function	I/O	Type	Details
`Alarm system > Additional functions > Suppress alarm action`	Digital input	Continuous	When the digital input is activated, then the controller suppresses all the alarms with *Suppress action* enabled.

2.8 Engine interface communication

The controller can receive information from an ECU using CAN bus communication. The information can be used as input for the controller functions. The controller also uses the information as display values, alarms, and as values to be transmitted through Modbus.

Most of the engine communication protocols are based on the SAE J1939 standard. J1939 is a very large standard, and most of it is irrelevant to engine communication. The controller supports only relevant parts of J1939, as described in Generic J1939.

The ECU is wired to the CAN bus communication to the controller, and the ECU is added using the Fieldbus configuration.

More information
See the Engine interface communication manual for how to wire and configure an ECU to the controller.

Once added to your controller, the ECU can be accessed from PICUS or the display as an additional hardware selection. For example, you can configure the ECU input or output settings, functions, or alarms. You can also include the ECU on the I/O status page to see the status of the analogue inputs, or see the ECU on Live data. Alarms (DM1) and logs (DM2) can also be accessed.

2.9 CustomLogic

2.9.1 Use CustomLogic

CustomLogic is used in PICUS to create and configure customised logical operations for use in the system. These functions are built using ladder logic elements and can include interaction with external equipment, or more advanced logic interfaces.

When CODESYS is installed on the controller, it is no longer possible to use CustomLogic on the controller.

More information
See **CustomLogic** in the **PICUS manual** for how to use CustomLogic.

2.9.2 Enable CustomLogic

`Local > CustomLogic > Configuration`

Parameter	Range	Default	Comment
`Enable`	Not enabled, Enabled	Not enabled	**Not enabled**: The controller ignores the CustomLogic projects. The inputs and outputs remain assigned to CustomLogic and cannot be used elsewhere. **Enabled**: The controller executes the CustomLogic project.

2.9.3 Digital inputs and outputs (optional)

Function	I/O	Type	Details
`Local > CustomLogic > CustomLogic digital input` *	Digital input	Pulse/ continuous	If this input is activated, then the controller activates the corresponding CustomLogic digital input function. The controller can execute the logic in a CustomLogic Project once every 200 milliseconds. If an input signal is not available for at least 200 milliseconds there is a risk that the input signal will not be detected by the controller.
`Local > CustomLogic > Outputs > CustomLogic digital output` *	Digital output	Pulse/ continuous	If CustomLogic activates the digital output function, then the controller activates the digital output.
`Local > CustomLogic > State > Is enabled`	Digital output	Continuous	If the parameter `Configure > Parameters > Local > CustomLogic > Configuration > Enable` is **Enabled**, then the controller activates this output.

NOTE * There are 20 available CustomLogic digital inputs or outputs.

2.9.4 Custom parameters

Custom parameters can be used with CustomLogic for reading, comparing, or writing values. Up to 50 customer parameters can be configured.

Configure custom parameters under `Custom parameters`.

`Custom parameter # *`

Parameter	Range	Default	Comment
`Enable #`	Not enabled, Enabled	Not enabled	**Not enabled**: The parameter is not used.

Parameter	Range	Default	Comment
			Enabled: The parameter can be used in a CustomLogic project.
`Integer #`	- 2147483647 to 2147483647	0	The range for the integer value to be stored.
`Float #`	- 2147480000 to 2147480000	0.0000	The range for the float value to be stored.

NOTE * Where # is the parameter number from 0 to 49.

2.9.5 Activate controller outputs

CustomLogic cannot directly activate controller outputs that are configured for controller functions. For example, CustomLogic cannot activate the `[Breaker] > Control > Open` digital output.

However, CustomLogic can activate external commands, for example, the `[Breaker] > Open` command. The CustomLogic command has the same effect as, for example, the `[Breaker] > Command > Open` digital input. The controller only follows the external command if the controller is in remote control.

2.9.6 CustomLogic and Modbus

Each controller has 20 Modbus signals that can be assigned to contacts and coils.

When a Modbus signal is assigned to a contact, the contact can be activated and deactivated using the correct Modbus address for the signal number.

When a Modbus signal is assigned to a coil, the state of the coil can be read using the correct Modbus address for the signal number. It is not possible to use a Modbus interface to write a value to a Modbus signal that has been assigned to a coil.

2.9.7 Constraints

CustomLogic reset on save

If you make a change to the CustomLogic and then save the change to the controller, all the CustomLogic states and timers are reset.

2.10 Emulation

With emulation you can run your controllers in a virtual operating mode. During emulation you can simulate various real-world actions, such as starting or stopping the genset without actually having any genset connected. You can also test and configure your controller, and mimic inputs or outputs that are configured.

More information
See **Emulation** in the **PICUS manual** for how to use and configure the emulation feature.

2.11 Custom parameters

You can configure up to 50 custom parameters for use in CustomLogic or Modbus.

Configure custom parameters under `Custom parameters`.

`Custom parameter # *`

Parameter	Range	Default	Comment
`Enable #`	Not enabled, Enabled	Not enabled	**Not enabled**: The parameter is not used.

Parameter	Range	Default	Comment
			Enabled: The parameter can be used in a CustomLogic project.
`Integer #`	- 2147483647 to 2147483647	0	The range for the integer value to be stored.
`Float #`	- 2147480000 to 2147480000	0.0000	The range for the float value to be stored.

NOTE * Where # is the parameter number from 0 to 49.

2.12 Date and time

2.12.1 About date and time settings

The date and time can be set manually from PICUS or the display, or automatically obtained from an external time server.

The time is stored locally on each controller, and automatically synchronised between all DEIF controllers connected in the same network. The alarms, logs, and display unit use the time.

Time master

The time master's time is synchronised to all the other controllers. The synchronisation is achieved by using a Network Time Protocol (NTP) client and server system. The controller that has been powered ON for the longest time on the Ethernet network is the time master. When a new controller is added to the network, it fetches the time from the time master in the network.

If two Ethernet networks with DEIF controllers are joined, then the time from the network with the controller that has been powered on for the longest is used.

If the time master fails, the controllers in the network determine which controller has been ON the longest. The controller that has been on the longest, then becomes the new time master.

Synchronisation interval and performance

Each controller checks the time from the time master at regular intervals. The frequency of these checks adapts to the synchronisation quality. If the synchronisation is poor, then the controller uses shorter intervals between checks.

The time difference can initially be a few seconds. This is adjusted down over time. The time synchronisation can take some time (for example, 30 minutes) to synchronise the controllers.

Table 2.3 Date and time settings

Setting	Range	Default	Notes
Date format	• YYYY-MM-DD • YY-MM-DD • DD-MM-YYYY • DD-MM-YY • MM-DD-YYYY • MM-DD-YY	YYYY-MM-DD	
Date	2018-01-01 to 2100-12-31		If an NTP server is configured, then you are not able to change the date manually.
Time zone	Selectable list	Etc/UTC	The adjustment for daylight saving is based on the time zone, and is automatically applied by the controller. Daylight savings is not applied to the controller when you select the **Etc/UTC** time zone.

Setting	Range	Default	Notes
Time format	• 12 hour clock • 24 hour clock	24 hour clock	The *AM/PM* selector for *Time* is only visible when 12 hour clock is selected.
Time	• 00:00:00 to 23:59:59 • 12:00:00 AM to 11:59:59 PM		If an NTP server is configured, then you are not able to change the time manually.

NOTE If a setting is changed on any controller in the network, the new setting is synchronised to all controllers in the network.

Table 2.4 Network time protocol settings

Setting	Range	Default	Notes
Host *		-	Type the IP address or server address of the NTP server in this field. When either of the *Host* fields have data inside them, it is no longer possible to configure the date or time manually.
Mode *	• Unicast • Multicast	Unicast	**Unicast**: The controller sends requests to the specified host and to request the date and time. The controller updates the date and time when the host responds to the request. **Multicast**: The controller waits for a date and time to be broadcast from a server on the host location. The controller updates the date and time when a broadcast is received.

NOTE * You can configure 1 or 2 NTP servers.

2.12.2 Set the time manually

Use the `Configure > Time settings` page in PICUS or the display to set the time manually.

When you change the time on any controller in the network, the new time is shared with all the controllers in the network through the time master.

2.12.3 Use external NTP servers

To use external NTP servers, the network design must allow the controllers to access the NTP server(s).

If two NTP servers are configured, then the NTP server with the lowest **Stratum** is the server used. If the NTP servers have the same **Stratum**, then the NTP server configured in **Server 1** is the server used.

2.13 About permissions

The controllers' configuration and functionality is protected with permission access. Only users with the correct permission may access, configure, or update the configuration or controller settings.

Permission structure

The permissions consist of **Roles** and **Users** in each controller configuration. These are stored locally on each controller, or can be written to all connected and logged in controllers.

Each **user** is a member of a **role**. The **role** gives the **user** permissions to associated features or functions of the controller. You can also remove access from a user as required.

Permissions access enables you to easily control which user can access which function. This provides a layer of control for the operation of the controller.

NOTICE

Permissions access

You can only access the user permissions option if you are a member of a role that has access to that function.

2.13.1 Role settings

Role settings include both **Role information** and **Role permissions**.

Role information

The **Role information** contains the name and automatically recorded changelog.

Setting	Type	Format	Notes
Name	Manual	Text	The Role name.
Created	Automatic	Date	Date the role was created.
Changed	Automatic	Date	Date the role was changed.
Editor	Automatic	Text	The user who created or changed the role.

Role permissions

The **Role permissions** allow or remove access to features in the software.

Parent permissions are required for any child permissions. For example, to allow access to the feature **Emulation** (a child), the role must also have access to **Application** (the Parent). If you remove a parent permission, all child permissions are automatically removed.

Some features can be configured for **Read** and/or **Write** access. With **Read** only access the user cannot write or update any information. **Read** access is mandatory if you allow **Write** access.

Area	Feature
Live Data	Live Data

Application	• Plant configuration
	  ◦ Read
	  ◦ Write
	• Emulation
	• Supervision
	  ◦ Read
	  ◦ Write

Alarms	• Alarms
	  ◦ Alarms
	  ◦ Alarm acknowledge
	  ◦ Alarm reset latch
	  ◦ Alarm out of service
	  ◦ Alarm shelve

Log	• Event log • Engine interface J1939 DM2 • Engine interface J1939 DM2 clear
I/O status	I/O status
Tools	• Print setup

Area	Feature

	• Backup restore
	• Backup
	• Restore
	• Restore configuration
	• Trending
	• Regulator status
	• Alarm test
	• Firmware
	• User management
	  ◦ Read
	  ◦ Write
	• Role management
	  ◦ Read
	  ◦ Write

Configure	• Date and time
	  ◦ Read
	  ◦ Write
	• Communication
	  ◦ Read
	  ◦ Write
	• Input/output configuration
	  ◦ Read
	  ◦ Write
	• Parameters
	  ◦ Read
	  ◦ Write
	• Counters
	  ◦ Read
	  ◦ Write
	• CustomLogic
	  ◦ Read
	  ◦ Write
	• Modbus
	  ◦ Read
	  ◦ Write
	• Fieldbus configuration
	  ◦ Read
	  ◦ Write
	• Fieldbus supervision
	• Dashboard configuration
	  ◦ Read
	  ◦ Write
	• Header configuration
	  ◦ Read
	  ◦ Write

2.13.2 User settings

Setting	Type	Notes
User name	Required	Minimum 2 characters.
Organisation	Optional	
Roles	Required	Selectable from list.
Mobile number	Optional	
Direct number	Optional	
Email (primary)	Optional	
Email (secondary)	Optional	
Password	Required	Minimum 8 characters.

2.13.3 Default user

NOTICE

Secure your system

Ensure that all default passwords are changed to reduce any security risk to your system. Additionally, it is recommended to adjust or edit the role and user permissions according to your own operational needs.

NOTICE

Lost passwords

Lost passwords cannot be recovered. If you have lost your password you can not configure your controller or system.

If you have lost your password, contact DEIF Technical support for assistance.

Default user

User	Password	Role
admin	admin	Admin

2.14 Event log

The controller stores a maximum of 2000 log entries. When the log is full, the controller discards the excess log entries using *first in, first out*.

If an ECU has been configured, you can also switch to see the DM2 logs.

2.15 Lamp test

The lamp test lights all the LEDs on the display. The test cycles through the LED colours for the time configured in the lamp test parameters.

During the lamp test a message box is shown on the display.

Digital inputs (optional)

Function	I/O	Type	Details
`Test functions > Lamp test > Start lamp test`	Digital input	Pulse	Activating this input has the same effect as enabling the lamp test *Activate* parameter.
`Test functions > Lamp test > Stop lamp test`	Digital input	Pulse	If this input is activated while a lamp test is in progress, the controller stops the lamp test.

Parameters

`Test functions > Lamp test`

Parameter	Range	Default	Comment
`Activate`	Not enabled, Enabled	Not enabled	**Not enabled**: There is no lamp test. **Enabled**: When the parameter is saved, the lamp test starts. After the lamp test, the controller automatically changes the parameter to *Not enabled*. Alternatively, you can start the lamp test from the display unit (**Tools > Advanced > Lamp test**) or a digital input (see above).
`Duration`	1 s to 1 h	18 s	The time for the lamp test.
`Color cycle time`	1 s to 1 h	3 s	The time that each colour is lit. The colour cycle is green, yellow, red. The color cycle repeats for the duration of the lamp test. For the default settings, the lamp test will cycle through all the colours twice.

2.16 Alive

To confirm that the controller is operational, a digital output can be configured to activate for a specified amount of time in a time period. If the signal does not repeat within the defined time period, then the controller is no longer operational.

Digital output (optional)

Function	I/O	Type	Details
`Local > Alive > Alive`	Digital output	Pulse	The output is set to high for the *Duty cycle* time each *Period*. For example, if the *Duty cycle* is set to 50 % and the *Period* is set to 2 s, then the output is high for 1 s and low for 1 s. This signal repeats while the controller is operational.

Parameters

`Local > Alive > Alive configuration`

Parameter	Range	Default	Comment
`Duty cycle`	0 to 100 %	50 %	The percentage of the *Period* that the signal is high. If the *Duty cycle* is set to 0 %, then the I/O output is always low. If the *Duty cycle* is set to 100 %, the output is always high.
`Period`	0.1 s to 60 s	2 s	The time between the start of a high signal to the start of the next high signal.

3. AC configuration

3.1 AC configuration

Phase configuration: AC configuration

This parameter must be the same for all the controllers in the system.

`[A-side] > AC setup > Phase configuration`

Parameter	Range	Notes
`AC configuration`	• Three-phase • Split-phase L1-L3 • Split-phase L1-L2 • Single-phase L1	**Three-phase**: The A-side and B-side are three-phase, and there are current measurements on all three phases. Voltage and current measurement on the neutral phase (N) is optional. **Split-phase L1-L3**: The waveforms are offset by a half-cycle (180 degrees) from the neutral wire. This is sometimes called single-phase in the USA. **Split-phase L1-L2**: The waveforms are offset by a half-cycle (180 degrees) from the neutral wire. This is sometimes called single-phase in the USA. **Single-phase L1**: The A-side and B-side are single-phase. Use the L1 terminal for the voltage and current measurements (not the L2 or L3 terminals). The current measurement on the neutral phase (N) is optional. Some of the controller protections are irrelevant in a single-phase configuration (for example, *Current unbalance*, *Voltage unbalance* and *Phase sequence*).

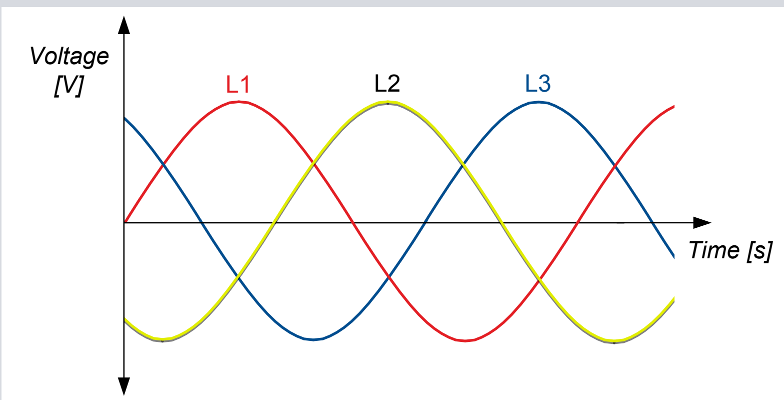
More information
See **System AC configuration** in the **Installation instructions** for examples of three-phase, single-phase wiring, and split-phase wiring.

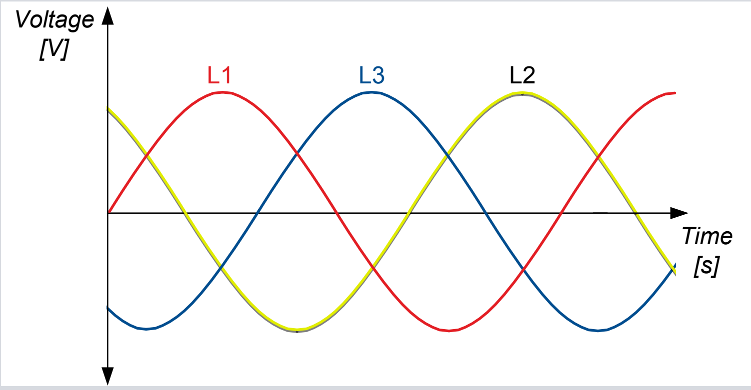
Phase direction: AC phase rotation

Set this parameter if the AC phase rotation is not L1-L2-L3.

This parameter must be the same in all the controllers in the system.

`[A-side] > AC setup > Phase direction`

Parameter	Range	Notes
`AC setup`	• L1-L2-L3 • L1-L3-L2	**L1-L2-L3**: The global standard phase rotation is L1-L2-L3. Using an alternative wiring can lead to confusion, fatal accidents and serious damage to equipment. 

Parameter	Range	Notes
		L1-L3-L2: We do not recommend that you wire the system L1-L3-L2, due to the potential for confusion. However, this parameter allows the controller to function correctly even though the generator is wired L1-L3-L2. 

DANGER!

Different phase rotation

Never attempt to connect assets to the same busbar if they do not have the same phase rotation.

CAUTION

Incorrect parameter use

Do not use this parameter to attempt to correct for incorrect wiring of the controller's AC measurement terminals. Rewire the terminals correctly.

Voltage measurement

By default, the controller uses the phase-to-phase voltages for alarms. For relevant AC protections, you can use the `AC setup` parameter, to select phase-to-neutral voltages instead. Note that the nominal voltages are always phase-to-phase voltages.

`Phase-phase`: Measurements from the neutral line can be present for phase-to-phase measurements.

`Phase-neutral`: Measurements from the neutral line must be present in a phase-to-neutral system. If you select *Single-phase L1*, you must also select *Phase-neutral*.

3.1.1 [A-side] and [B-side] for each controller type

The names used for [A-side] and [B-side] for the AC configuration of each controller type:

Controller type	[A-side] (MIO terminals 78 to 81)	[B-side] (MIO terminals 83 to 86)
SINGLE genset (no mains)	Generator	Busbar
SINGLE genset (with mains)	Generator	Mains
GENSET	Generator	Busbar
MAINS	Mains	Busbar
BUS TIE breaker	Busbar A	Busbar B

3.1.2 [A-side] AC configuration

Voltage transformer

Set these parameters for the voltage transformer on the [A-side]'s voltage measurement.

If *Primary*:*Secondary* ratio is 1, the controller uses the voltage measurement without any correction for a voltage transformer.

The controller does not need information about the voltage transformer type (for example, open delta, star-star, and so on).

`[A-side] > AC setup > Voltage transformer`

Parameter	Range	Notes
`Primary`	100 V to 25000 V AC	The voltage transformer primary side (asset side) value.
`Secondary`	17 to 690 V AC	The voltage transformer secondary side (controller side) value. **NOTE** Phase shift is not allowed in the voltage transformer. The phase must be the same on the high and low voltage sides of the voltage measurement transformer. **NOTE** The minimum normal operating voltage for the controller is 100 V.

More information
See **[A-side] AC configuration** in the **Installation instructions** for an example of generator voltage transformer wiring.

Current transformer

CAUTION

Current transformer changes

Changing the current transformer settings changes the protection range for all the protections that depend on the current measurements. This includes power protections.

If you change the current transformer values and the set points for the over-current and fast over-current protections are out of the set point range, then the **Protection set point out of range** alarm activates. The alarm action is warning, and cannot be configured.

You must set these parameters for the current transformer on the current measurement. These parameters only apply to the current measurements on L1, L2 and L3.

`[A-side] > AC setup > Current transformer`

Parameter	Range	Notes
`Primary`	5 to 9000 A	The current transformer primary side (asset side) nominal current.
`Secondary`	1 or 5 A	The current transformer secondary side (controller side) nominal current. You can select either 1 A or 5 A.

Voltage and frequency OK

The controller uses these parameters to calculate whether the voltage and frequency from the [A-side] measurements are OK, so that the breaker can close.

`[A-side] > AC setup > Voltage and frequency OK`

Parameter	Range	Notes
`Voltage and frequency OK`	0.0 s to 1 h	If the voltage and frequency are OK for this time in seconds, then the equipment's LED becomes steady green. The breaker is not allowed to close before the LED is steady green (that is, not flashing).
`Minimum OK voltage`	70 to 100 %	The voltage must be above this voltage (as a percent of nominal voltage) for the breaker to start to synchronise and close.
`Maximum OK voltage`	100 to 120 %	The voltage must be below this voltage (as a percent of nominal voltage) for the breaker to start to synchronise and close.
`Minimum OK frequency`	70.00 to 100.00 %	The frequency must above this frequency (as a percent of nominal frequency) for the breaker to start to synchronise and close.
`Maximum OK frequency`	100.00 to 110.00 %	The frequency must below this frequency (as a percent of nominal frequency) for the breaker to start to synchronise and close.

Voltage or frequency not OK

For the **SINGLE genset** and **GENSET** controller.

`[A-side] > AC setup > Voltage or frequency not OK`

Parameter	Range	Notes
`Delay`	1 s to 1 h	If no inhibits are activated, then, if the voltage or frequency are not okay, this alarm is activated after the delay.

3.1.3 [B-side] AC configuration

Voltage transformer

Set these parameters if there are voltage transformers on the B-side voltage measurement.

If *Primary*:*Secondary* ratio is 1, the controller uses the voltage measurement without any correction for a voltage transformer.

The controller does not need information about the voltage transformer type (for example, open delta, star-delta, and so on).

`[B-side] > AC setup > Voltage transformer`

Parameter	Range	Notes
`Primary`	100 V to 25000 V AC	The voltage transformer primary side value.
`Secondary`	17 to 690 V AC	The voltage transformer secondary side (controller side) value. Note: No phase shift is allowed in the voltage transformer. That is, the phase must be the same on the high and low voltage sides of the B-side voltage measurement transformer. Note: The minimum normal operating voltage for the controller is 100 V.

More information
See **[B-side] AC configuration** in the **Installation instructions** for an example of B-side voltage transformer wiring.

Blackout detection

`[B-side] > AC setup > Blackout detection`

Parameter	Range	Notes
`Blackout delay`	0.0 s to 3600 s	After detecting the blackout, the controller does not respond, unless the blackout is still present after this time. All the *Blackout delay* timers in the section must run out before any controller can allow a blackout close.

Voltage and frequency OK

The controller uses these parameters to calculate whether the voltage and frequency from the B-side measurements are OK.

`[B-side] > AC setup > Voltage and frequency OK`

Parameter	Range	Notes
`Voltage and frequency OK`	0.0 s to 3600.0 s	If the B-side voltage and frequency are OK for this time in seconds, then the B-side LED becomes steady green. The breaker is not allowed to close before the B-side LED is steady green (that is, not flashing).
`Minimum OK voltage`	70 to 100 %	The voltage must be above this voltage (as a percent of nominal voltage) for the breaker to start to synchronise and close.
`Maximum OK voltage`	100 to 120 %	The voltage must be below this voltage (as a percent of nominal voltage) for the breaker to start to synchronise and close.
`Minimum OK frequency`	70.00 to 100.00 %	The frequency must above this frequency (as a percent of nominal frequency) for the breaker to start to synchronise and close.
`Maximum OK frequency`	100.00 to 110.00 %	The frequency must below this frequency (as a percent of nominal frequency) for the breaker to start to synchronise and close.

3.1.4 Voltage and frequency as digital outputs

For the [A-side] and the [B-side], you can configure digital outputs with functions for *Voltage and frequency OK* and *No voltage and frequency*. These functions are based on the AC measurements and parameters, and can be useful for troubleshooting.

Digital output functions

Function	I/O	Type	Details
`[A-side] > State > Voltage and frequency OK`	Digital output	Continuous	Activated if the voltage and frequency from the A-side are within the range specified in: `Configure > Parameters > [A-side] > AC setup > Voltage and frequency OK`
`[A-side] > State > No voltage and frequency`	Digital output	Continuous	Activated if the phase-to-phase voltage from the A-side is less than 10 % of the nominal voltage.
`[B-side] > State > Voltage and frequency OK`	Digital output	Continuous	Activated if the voltage and frequency at the [B-side] are within the range specified in: `Configure > Parameters > [B-side] > AC setup > Voltage and frequency OK`
`[A-side] > State > No voltage and frequency`	Digital output	Continuous	Activated if the phase-to-phase voltage at the [B-side] is less than 10 % of the nominal voltage.

3.1.5 4th current input configuration

Nominal current

Local > 4th current input > Nominal settings > Nominal settings #* > Current (I4)

Parameter	Range	Notes
`Nominal`	1.0 to 9000.0 A	The maximum 4th current flow during normal operation.

NOTE * # is 1 to 4.

Current transformer

Set these parameters if there is a current transformer on the 4th current input measurement.

Local > 4th current input > Current transformer (I4)

Parameter	Range	Notes
`Primary`	5 to 9000 A	The current transformer primary side (measurement side) nominal current.
`Secondary`	1 or 5 A	The current transformer secondary side (controller side) nominal current. Select either 1 A or 5 A.

More information
See the **Installation instructions** for examples of 4th current input wiring for the neutral phase.

3.2 AC measurement filters

3.2.1 About AC measurement filters

You can configure average filtering on the primary AC measurements for smooth measurement readout on noisy or oscillating systems.

The AC filtered measurements are used on the values shown in Live data, CustomLogic, Modbus, and other shown operational values. The internal calculations and protections continue to use the actual values.

AC measurement filters can be configured as:

- **No filter**: Always show the actual value.
- **Averaged (200 ms)**: Show a value averaged over 200 ms.
- **Averaged (800 ms)**: Show a value averaged over 800 ms.

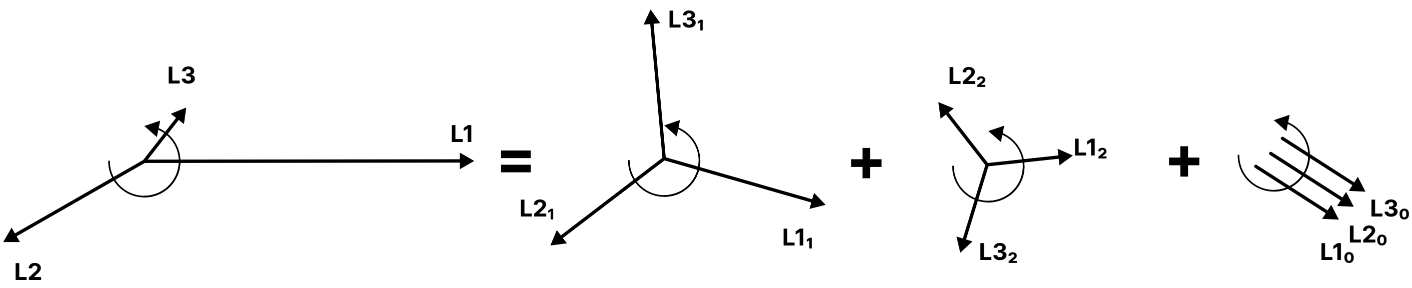
3.2.2 AC measurement filters

Local > AC measurement filters > Primary AC measurements

Parameter	Range
`Voltage`	No filter, Averaged (200 ms), Averaged (800 ms)
`Current`	No filter, Averaged (200 ms), Averaged (800 ms)
`Active power`	No filter, Averaged (200 ms), Averaged (800 ms)
`Reactive power`	No filter, Averaged (200 ms), Averaged (800 ms)
`Apparent power`	No filter, Averaged (200 ms), Averaged (800 ms)
`Power factor and cos phi`	No filter, Averaged (200 ms), Averaged (800 ms)
`Frequency from voltage`	No filter, Averaged (200 ms), Averaged (800 ms)
`Frequency from current`	No filter, Averaged (200 ms), Averaged (800 ms)

3.3 Symmetrical components

Any rotating set of voltage or current phasors for a three-phase system can be expressed as a positive sequence set, a negative sequence set, and a zero sequence set. These symmetrical components offer a simplified approach to analyse AC systems, especially for unbalanced load or fault conditions.



Positive sequence

The positive sequence is a balanced (equal magnitude and 120° apart) set of three phasors, rotating with the normal phase rotation.

Negative sequence

The negative sequence set is a balanced set of three phasors, rotating with a negative phase sequence.

Zero sequence

The rotating phasors of the zero sequence set are aligned in phase and magnitude.

3.4 AC measurements as analogue outputs

3.4.1 About AC measurements as analogue outputs

You can configure an analogue output with the function for an alternating current (AC) operating value. This value may be measured directly or calculated from the AC measurements. The controller then adjusts the analogue output to reflect the AC operating value.

Applications

An analogue output with a function for an alternating current (AC) operating value may be wired to a switchboard instrument, to help the operator. For example, the total kW from a generator can be displayed.

Alternatively, an analogue output may be wired to a switchboard instrument, to help troubleshooting. For example, the voltage unbalance between two phases (*Busbar | L-L unbalanced [V]*) can be displayed.

3.4.2 [A-side] AC measurements

Function names

The [A-side] AC measurement function names follow these formats:

```
[A-side] > [Physical quantity] > [Asset] | [Measurement] [[unit]].
```

[A-side] AC measurement function names for each controller type

Controller type	[A-side]	[Asset]
SINGLE genset	Generator	Generator
GENSET	Generator	Generator

Controller type	[A-side]	[Asset]
MAINS	Mains	Mains
BUS TIE breaker	Busbar A	Busbar A

[A-side] voltage analogue output functions

`[A-side] > Voltage (V)`

Function	Details
`[Asset]	L1-N [V]`	The controller outputs the L1-N voltage from the A-side.
`[Asset]	L2-N [V]`	The controller outputs the L2-N voltage from the A-side.
`[Asset]	L3-N [V]`	The controller outputs the L3-N voltage from the A-side.
`[Asset]	N [V]`	The controller outputs the N voltage from the A-side, relative to the star point.
`[Asset]	L-N min. [V]`	The controller outputs the lowest L-N voltage (that is, for the phase with the lowest L-N voltage).
`[Asset]	L-N max. [V]`	The controller outputs the highest L-N voltage (that is, for the phase with the highest L-N voltage).
`[Asset]	L-N unbalanced [V]`	The controller outputs the L-N unbalanced voltage from the A-side, relative to the neutral.
`[Asset]	L1-L2 [V]`	The controller outputs the L1-L2 voltage from the A-side.
`[Asset]	L2-L3 [V]`	The controller outputs the L2-L3 voltage from the A-side.
`[Asset]	L3-L1 [V]`	The controller outputs the L3-L1 voltage from the A-side.
`[Asset]	L-L min. [V]`	The controller outputs the lowest L-L voltage (that is, for the phases with the lowest L-L voltage).
`[Asset]	L-L max. [V]`	The controller outputs the highest L-L voltage (that is, for the phases with the highest L-L voltage) from the A-side.
`[Asset]	L-L unbalanced [V]`	The controller outputs the L-L unbalanced voltage between the phases of the A-side.
`[Asset]	Positive sequence [V]`	The controller outputs the magnitude of the positive sequence voltage.
`[Asset]	Negative sequence [V]`	The controller outputs the magnitude of the negative sequence voltage.
`[Asset]	Zero sequence [V]`	The controller outputs the magnitude of the zero sequence voltage from the A-side.

[A-side] frequency analogue output functions

`[A-side] > Frequency (f) (from voltage)`

Function	Details
`[Asset]	L1 [Hz]`	The controller outputs the L1 frequency (based on the voltage measurement).
`[Asset]	L2 [Hz]`	The controller outputs the L2 frequency (based on the voltage measurement).
`[Asset]	L3 [Hz]`	The controller outputs the L3 frequency (based on the voltage measurement).
`[Asset]	Min. [Hz]`	The controller outputs the frequency of the phase with the lowest frequency (based on the voltage measurement).
`[Asset]	Max. [Hz]`	The controller outputs the frequency of the phase with the highest frequency (based on the voltage measurement).

`[A-side] > Frequency (f) (from current)`

Function	Details
`[Asset]	L1 [Hz]`	The controller outputs the L1 frequency (based on the current measurement).
`[Asset]	L2 [Hz]`	The controller outputs the L2 frequency (based on the current measurement).
`[Asset]	L3 [Hz]`	The controller outputs the L3 frequency (based on the current measurement).
`[Asset]	Min. [Hz]`	The controller outputs the frequency of the phase with the lowest frequency (based on the current measurement).
`[Asset]	Max. [Hz]`	The controller outputs the frequency of the phase with the highest frequency (based on the current measurement).

[A-side] current analogue output functions

`[A-side] > Current (I)`

Function	Details
`[Asset]	L1 [A]`	The controller outputs the L1 current from the A-side.
`[Asset]	L2 [A]`	The controller outputs the L2 current from the A-side.
`[Asset]	L3 [A]`	The controller outputs the L3 current from the A-side.
`[Asset]	Min. [A]`	The controller outputs the lowest phase current.
`[Asset]	Max. [A]`	The controller outputs the highest phase current.
`[Asset]	Unbalanced nominal [A]`	The controller outputs the unbalanced current from the A-side, calculated using the nominal method.
`[Asset]	Unbalanced average [A]`	The controller outputs the unbalanced current from the A-side, calculated using the average method.
`[Asset]	Positive sequence [A]`	The controller outputs the magnitude of the positive sequence current.
`[Asset]	Negative sequence [A]`	The controller outputs the magnitude of the negative sequence current.
`[Asset]	Zero sequence [A]`	The controller outputs the magnitude of the zero sequence current from the A-side.

[A-side] power analogue output functions

`[A-side] > Power (P)`

Function	Details
`[Asset]	L1 [kW]`	The controller outputs the L1 power.
`[Asset]	L2 [kW]`	The controller outputs the L2 power.
`[Asset]	L3 [kW]`	The controller outputs the L3 power.
`[Asset]	Min. [kW]`	The controller outputs the power of the phase with the lowest power.
`[Asset]	Max. [kW]`	The controller outputs the power of the phase with the highest power.
`[Asset]	Total [kW]`	The controller outputs the total power.
`[Asset]	Total [%]`	The controller outputs the total power, as a percentage of the A-side's nominal power.
`[Asset]	Available [kW]`	The controller outputs the available power for the A-side in kW. Available power = Nominal power - Total power
`[Asset]	Available [%]`	The controller outputs the available power for the A-side, as a percentage of the A-side's nominal power. Available power = Nominal power - Total power

[A-side] reactive power analogue output functions

`[A-side] > Reactive power (Q)`

Function	Details
`[Asset] | L1 [kvar]`	The controller outputs the L1 reactive power.
`[Asset] | L2 [kvar]`	The controller outputs the L2 reactive power.
`[Asset] | L3 [kvar]`	The controller outputs the L3 reactive power.
`[Asset] | Min. [kvar]`	The controller outputs the reactive power of the phase with the lowest reactive power.
`[Asset] | Max. [kvar]`	The controller outputs the reactive power of the phase with the highest reactive power.
`[Asset] | Total [kvar]`	The controller outputs the total reactive power.
`[Asset] | Total [%]`	The controller outputs the total reactive power, as a percentage of the A-side's nominal reactive power.
`[Asset] | Available [kvar]`	The controller outputs the available reactive power for the A-side in kvar. Available reactive power = Nominal reactive power - Total reactive power
`[Asset] | Available [%]`	The controller outputs the available reactive power for the A-side, as a percentage of the A-side's nominal reactive power. Available reactive power = Nominal reactive power - Total reactive power

[A-side] apparent power analogue output functions

`[A-side] > Apparent power (S)`

Function	Details
`[Asset] | L1 [kVA]`	The controller outputs the L1 apparent power.
`[Asset] | L2 [kVA]`	The controller outputs the L2 apparent power.
`[Asset] | L3 [kVA]`	The controller outputs the L3 apparent power.
`[Asset] | Min. [kVA]`	The controller outputs the apparent power of the phase with the lowest apparent power.
`[Asset] | Max. [kVA]`	The controller outputs the apparent power of the phase with the highest apparent power.
`[Asset] | Total [kVA]`	The controller outputs the total apparent power.
`[Asset] | Total [%]`	The controller outputs the total apparent power, as a percentage of the A-side's nominal apparent power.
`[Asset] | Available [kVA]`	The controller outputs the available apparent power for the A-side in kVA. Available apparent power = Nominal apparent power - Total apparent power
`[Asset] | Available [%]`	The controller outputs the available apparent power for the A-side, as a percentage of the A-side's nominal apparent power. Available apparent power = Nominal apparent power - Total apparent power

[A-side] power factor analogue output functions

`[A-side] > Power factor (PF)`

Function	Details
`[Asset] | cos phi []`	The controller outputs the power factor, calculated as cos phi.
`[Asset] | Power factor []`	The controller outputs the power factor.

[A-side] phase angle analogue output functions

[A-side] > Phase angle

Function	Details
`[Asset] | Phase angle L1-L2 [°]`	The controller outputs the phase angle between L1 and L2.
`[Asset] | Phase angle L2-L3 [°]`	The controller outputs the phase angle between L2 and L3.
`[Asset] | Phase angle L3-L1 [°]`	The controller outputs the phase angle between L3 and L1.
`[Asset] | A-B phase angle L1 [°]`	The controller outputs the phase angle between L1 of the A-side and L1 of the B-side.
`[Asset] | A-B phase angle L2 [°]`	The controller outputs the phase angle between L2 of the A-side and L2 of the B-side.
`[Asset] | A-B phase angle L3 [°]`	The controller outputs the phase angle between L3 of the A-side and L3 of the B-side.

3.4.3 [B-side] AC measurements

Function names

the B-side AC measurement function names follow these formats:

`[B-side] > [Physical quantity] > [Asset] | [Measurement] [[unit]].`

[B-side] AC measurement function names for each controller type

Controller type	[B-side]	[Asset]
SINGLE genset	Mains	Mains
GENSET	Busbar	Busbar
MAINS	Busbar	Busbar
BUS TIE breaker	Busbar B	Busbar B

[B-side] voltage analogue output functions

[B-side] > Voltage (V)

Function	Details
`[Asset] | L1-N [V]`	The controller outputs the L1-N voltage from the B-side.
`[Asset] | L2-N [V]`	The controller outputs the L2-N voltage from the B-side.
`[Asset] | L3-N [V]`	The controller outputs the L3-N voltage from the B-side.
`[Asset] | N [V]`	The controller outputs the N voltage from the B-side.
`[Asset] | L-N min. [V]`	The controller outputs the lowest L-N voltage (that is, for the phase with the lowest L-N voltage).
`[Asset] | L-N max. [V]`	The controller outputs the highest L-N voltage (that is, for the phase with the highest L-N voltage).
`[Asset] | L-N unbalanced [V]`	The controller outputs the L-N unbalanced voltage.
`[Asset] | L1-L2 [V]`	The controller outputs the L1-L2 voltage from the B-side.
`[Asset] | L2-L3 [V]`	The controller outputs the L2-L3 voltage from the B-side.
`[Asset] | L3-L1 [V]`	The controller outputs the L3-L1 voltage from the B-side
`[Asset] | L-L min. [V]`	The controller outputs the lowest L-L voltage (that is, for the phases with the lowest L-L voltage).

Function	Details
[Asset] | L-L max. [V]	The controller outputs the highest L-L voltage (that is, for the phases with the highest L-L voltage).
[Asset] | L-L unbalanced [V]	The controller outputs the L-L unbalanced voltage.
[Asset] | Positive sequence [V]	The controller outputs the magnitude of the positive sequence voltage.
[Asset] | Negative sequence [V]	The controller outputs the magnitude of the negative sequence voltage.
[Asset] | Zero sequence [V]	The controller outputs the magnitude of the zero sequence voltage.

[B-side] frequency analogue output functions

[B-side] > Frequency (f) (from voltage)

Function	Details
[Asset] | L1 [Hz]	The controller outputs the L1 frequency (based on the voltage measurement).
[Asset] | L2 [Hz]	The controller outputs the L2 frequency (based on the voltage measurement).
[Asset] | L3 [Hz]	The controller outputs the L3 frequency (based on the voltage measurement).
[Asset] | Min. [Hz]	The controller outputs the frequency of the phase with the lowest frequency (based on the voltage measurement).
[Asset] | Max. [Hz]	The controller outputs the frequency of the phase with the highest frequency (based on the voltage measurement).

[B-side] phase angle analogue output functions

[B-side] > Phase angle

Function	Details
[Asset] | Phase angle L1-L2 [°]	The controller outputs the phase angle between L1 and L2.
[Asset] | Phase angle L2-L3 [°]	The controller outputs the phase angle between L2 and L3.
[Asset] | Phase angle L3-L1 [°]	The controller outputs the phase angle between L3 and L1.

3.4.4 4th current input

Assign the AC measurement function to an analogue output.

Analogue outputs

Function	Details
Local > 4th current input > Current (I) > L4 [A]	The controller outputs the 4th current (based on the 4th current measurement).
Local > 4th current input > Frequency (f) > L4 [Hz]	The controller outputs the 4th frequency (based on the 4th current measurement).
Local > 4th current input > Power (P) > L4 [kW]	The controller outputs the 4th power (based on the 4th current measurement and the [Busbar] L1 voltage).
Local > 4th current input > Reactive power (Q) > L4 [kvar]	The controller outputs the 4th reactive power (based on the 4th current measurement and the [Busbar] voltage).
Local > 4th current input > Apparent power (S) > L4 [kVA]	The controller outputs the 4th apparent power (based on the 4th current measurement and the [Busbar] voltage).
Local > 4th current input > Power factor (PF) > L4 | cos phi []	The controller outputs the power factor, calculated as cos phi (based on the 4th current measurement and the [Busbar] voltage).

Function	Details
`Local > 4th current input > Power factor (PF) > L4 | Power factor []`	The controller outputs the power factor (based on the 4th current measurement and the [Busbar] voltage).
`Local > 4th current input > Phase angle > L4 [°]`	The controller outputs the phase angle between the 4th current measurement and the [Busbar] L1 voltage measurement.

3.5 A-side AC protections

3.5.1 About AC protections

This section describes the AC protections based on the controller's measurements on the [A-side] of the breaker.

Controller type	[A-side]	[Breaker]
SINGLE genset	Genset	GB and MB
GENSET	Genset	GB
MAINS	Mains	MB and TB*
BUS TIE breaker	Busbar A	BTB

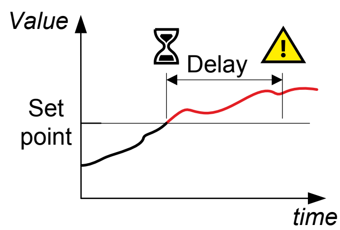
NOTE * TB is only for a **MAINS** controller with a tie breaker.

The controllers include the following alternating current (AC) protections, according to IEEE Std. C37.2TM-2022.

3.5.2 [A-side] over-voltage (ANSI 59)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Over-voltage	U>	59	< 100 ms

The alarm response is based on the highest phase-to-phase voltage, or the highest phase-to-neutral voltage, from the A-side, as measured by the controller.



`[A-side] > Voltage protections > Over-voltage #*`

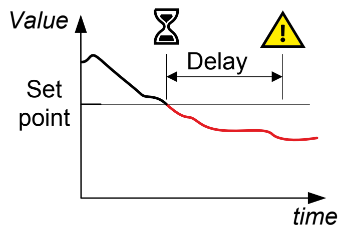
Parameter	Range
`AC setup`	Phase-phase, Phase-neutral
`Set point`	80.0 to 120.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 or 2.

3.5.3 [A-side] under-voltage (ANSI 27)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Under-voltage	U<	27	< 100 ms

The alarm response is based on the lowest phase-to-phase voltage, or the lowest phase-to-neutral voltage, from the A-side, as measured by the controller.



`[A-side] > Voltage protections > Under-voltage #*`

Parameter	Range
`AC setup`	Phase-phase, Phase-neutral
`Set point`	10.0 to 100.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 to 3.

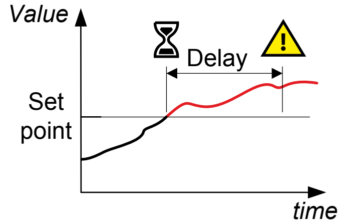
3.5.4 [A-side] voltage unbalance (ANSI 47)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Voltage unbalance (voltage asymmetry)	UUB>	47	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The method is based on the ANSI C84.1-2016 calculation method to determine voltage unbalance. The alarm response is based on the highest difference between any of the three A-side phase-to-phase voltage or phase-to-neutral true RMS values and the average voltage, as measured by the controller.

If phase-to-phase voltages are used, the controller calculates the average phase-to-phase voltage. The controller then calculates the difference between each phase-to-phase voltage and the average voltage. Finally, the controller divides the maximum difference by the average voltage to get the voltage unbalance. See the example.



`[A-side] > Voltage protections > Voltage unbalance`

Parameter	Range
`AC setup`	Phase-phase, Phase-neutral
`Set point`	0.0 to 50.0 %
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

Voltage unbalance example

A **GENSET** controller controls a genset with a nominal voltage of 230 V. The L1-L2 voltage is 235 V, the L2-L3 voltage is 225 V, and the L3-L1 voltage is 210 V.

The average voltage is 223.3 V. The difference between the phase-to-phase voltage and the average is 12.7 V for L1-L2, 2.7 V for L2-L3 and 13.3 V for L3-L1.

	The voltage unbalance is 13.3 V/223.3 V = 0.06 = 6.0 %.

3.5.5 Positive sequence under-voltage (ANSI 27D)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Positive sequence under-voltage	U_1<	27D	< 60 ms

The alarm response is based on the voltage state of the positive sequence voltage part of the voltage phasors of the A-side. The positive sequence represents the symmetrical part of the system. For more information, see Symmetrical components.

The positive sequence under-voltage alarm protects, for example, generators from running at a voltage that is too low.

Parameters

`[A-side] > Voltage protections > Positive sequence under-voltage`

Parameter	Range
`Set point`	10.0 to 110.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.02 s to 1 h

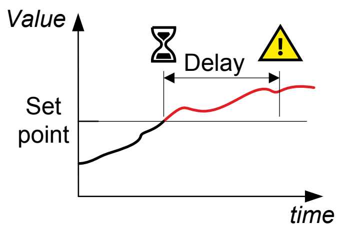
3.5.6 Negative sequence over-voltage (ANSI 47)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Negative sequence voltage	U_2>	47	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the voltage state of the negative sequence voltage part of the voltage phasors of the A-side. For more information, see Symmetrical components.

Negative sequence voltage typically occurs due to unbalanced loads, or a broken conductor. The negative sequence over-voltage protection protects against unbalanced voltage conditions.



`[A-side] > Voltage protections > Negative sequence voltage`

Parameter	Range
`Set point`	1.0 to 100.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

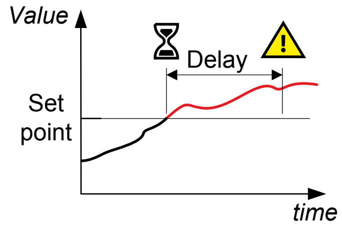
3.5.7 Zero sequence over-voltage (ANSI 59U_0)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Zero sequence voltage	U_0	59U_0	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the voltage state of the zero sequence voltage part of the voltage phasors of the A-side. For more information, see Symmetrical components.

Zero sequence voltage typically occurs due to earth faults or unbalanced loads. The detection of any zero sequence voltage depends on the controller measuring relative to earth or neutral. That is, the controller's neutral voltage terminal (N) must be connected to earth or neutral.



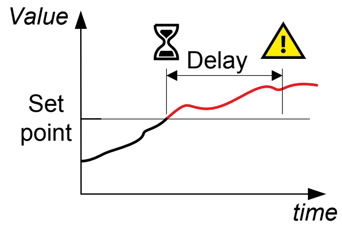
`[A-side] > Voltage protections > Zero sequence voltage`

Parameter	Range
`Set point`	0.0 to 100.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

3.5.8 Over-current (ANSI 50TD)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Over-current	3I>	50TD	< 100 ms

The alarm response is based on the highest phase current true RMS values from the A-side, as measured by the controller.



`[A-side] > Current protections > Over-current #*`

Parameter	Range
`Set point`	Variable. Depends on current transformer settings.
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

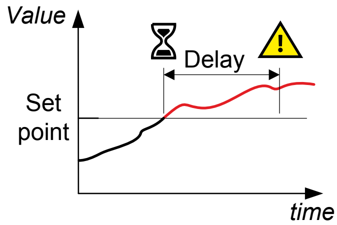
NOTE * # is 1 to 4.

3.5.9 Fast over-current (ANSI 50/50TD)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Fast over-current	3I>>>	50/50TD *	< 50 ms

NOTE * ANSI **50** applies when the *Delay* parameter is 0 s.

The alarm response is based on the highest phase current true RMS values from the A-side, as measured by the controller.



`[A-side] > Current protections > Fast over-current #*`

Parameter	Range
`Set point`	Variable. Depends on current transformer settings.
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

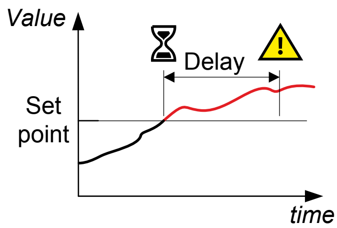
NOTE * # is 1 or 2.

3.5.10 Current unbalance (ANSI 46)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Current unbalance	IUB>	46	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the highest difference between any of the three phase current true RMS values, as measured by the controller. You can choose either the *Average method* (ANSI) or the *Nominal method* to calculate the *Current unbalance*.



`[A-side] > Current protections > Current unbalance ([average/nominal] calc.)`

Parameter	Range
`Set point`	0.0 to 100.0 %
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

Average method

The *Average method* is based on the ANSI C84.1-2016 calculation method to determine *voltage* unbalance. The controller calculates the average current for the three phases. The controller then calculates the difference between each phase current and the average current. Finally, the controller divides the maximum difference by the average current to get the current unbalance.

Average method example

A **GENSET** controller controls a genset with a nominal current of 100 A. The L1 current is 80 A, the L2 current is 90 A, and the L3 current is 60 A.

The average current is 76.7 A. The difference between the phase current and the average is 3.3 A for L1, 13.3 A for L2 and 16.7 A for L3.

The current unbalance is therefore 16.7 A / 76.7 A = 0.22 = 22 %.

Nominal method

The controller calculates the difference between the phase with the highest current, and the phase with the lowest current. Finally, the controller divides the difference by the nominal current to get the current unbalance.

Nominal method example

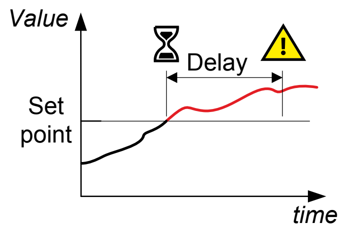
A **GENSET** controller controls a genset with a nominal current of 100 A. The L1 current is 80 A, the L2 current is 90 A, and the L3 current is 60 A.

The current unbalance is (90 A - 60 A) / 100 A = 0.3 = 30 %.

3.5.11 Directional over-current (ANSI 67)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Directional over-current	I> →	67	< 100 ms

The alarm response is based on the highest phase current true RMS value, with the direction from the active power from the A-side, as measured by the controller.



`[A-side] > Current protections > Directional over-current #*`

Parameter	Range
`Set point`	Variable. Depends on current transformer settings.
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 or 2. For BUS TIE breaker controller # is 1 to 4.

For a positive set point, the alarm trigger level is *High*. When a negative set point is written to the controller, then the controller automatically changes the alarm trigger level to *Low*.

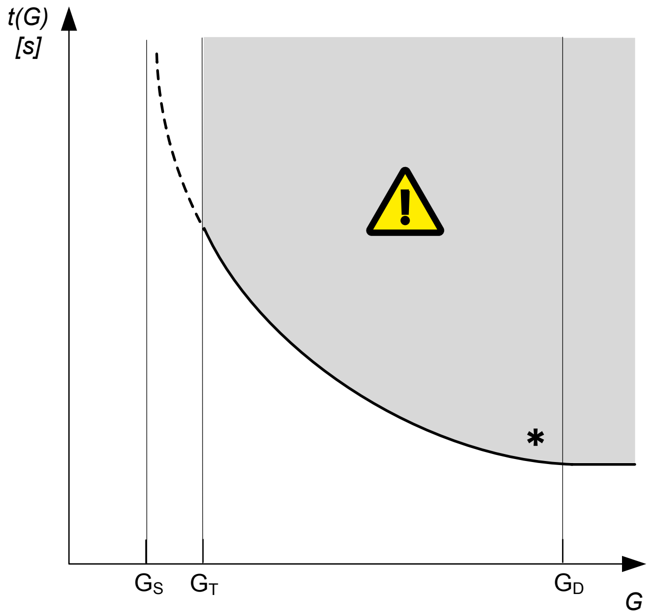
3.5.12 Inverse time over-current (ANSI 51)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Inverse time over-current	It>	51	-

The inverse time-over current protection is based on IEC 60255-151:2009. The alarm response is based on the highest phase current true RMS values, as measured by the controller.

The alarm response time depends on an approximated integral of the current measurement over time. The integral is only updated when the measurement is above the activation threshold (indicated in the diagram to the right by the value G_T). See the description below for more details.

Note: The diagram on the right is a simplified representation of this alarm and does not show the integral over time.



Inverse time over-current calculation method

The controller uses this equation from IEC 60255-151 to calculate the time that the current measurement may be over the set point before the inverse time over-current alarm is activated:

$$t(G) = TMS\left(\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha}-1}+c\right)$$

where:

t(G)	Theoretical operating time constant value of G, in seconds
k, c and α	Constants for the selected curve (*k* and *c* in seconds, *α* (alpha) has no unit)
G	Measured value, that is, highest phase current true RMS value (I_{phase})
G_S	Alarm set point ($G_S = I_{nom}$ * LIM / 100 %)
TMS	Time multiplier setting

Parameters

`[A-side] > Current protections > Inverse time over-current`

Parameter	Range
`Curve`	See the table below
`Limit (the set point, also known as LIM)`	2.0 to 200.0 % of nominal current
`Time multiplier setting (TMS)`	0.01 to 100.00
`Threshold (`G_T`)`	1.000 to 1.300
`k` *	0.001 s to 2 min
`c` *	0.000 s to 1 min
`alpha (α, or a)` *	0.001 to 60.000

NOTE * Only used if *Custom characteristic* is selected.

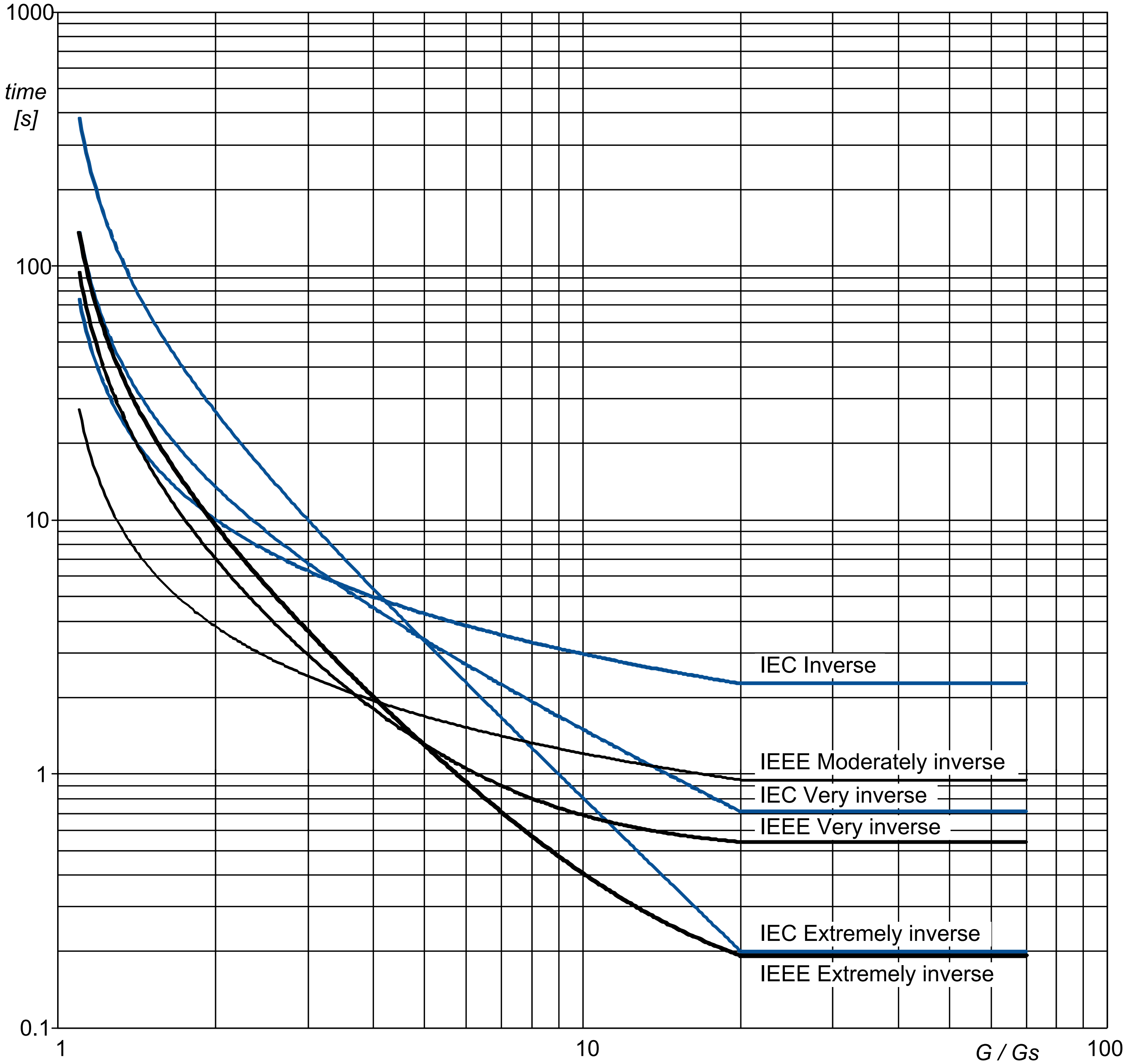
Standard inverse time over-current curves

The controller includes these standard inverse time over-current curves, in accordance with IEC 60255-151.

Table 3.1 Parameters for the inverse time over-current curves

Curve name	k	c	alpha (α, or a)
IEC inverse	0.14 s	0 s	0.02
IEC very inverse	13.5 s	0 s	1
IEC extremely inverse	80 s	0 s	2
IEEE moderately inverse	0.0515 s	0.114 s	0.02
IEEE very inverse	19.61 s	0.491 s	2
IEEE extremely inverse	28.2 s	0.1217 s	2
Custom characteristic	Customisable	Customisable	Customisable

Standard curve shapes for inverse time over-current, with time multiplier setting (TMS) = 1



Definite time characteristic

G_D is the point where the alarm shifts from an inverse curve to a definite time characteristic, as the following graph shows. That is, after this point, the curve is flat, and a current increase does not have any effect on the alarm response time. In IEC 60255-151, this point is defined as $G_D = 20 \times G_S$.

The current measurement range (see the data sheet) can limit the controller's ability to follow the characteristic at higher currents. See the * on the simplified representation diagram above.

In this controller, the maximum current measurement is 20 A. If the rated secondary current of the current measurement transformer is **1 A** (that is, the current transformer rating is -/1 A), then $\mathbf{G_D = 20 \times I_{CT\ primary}}$ for this protection. However, if the rated secondary current of the current transformer is **5 A** (that is, -/5 A), then $\mathbf{G_D = 4 \times I_{CT\ primary}}$.

Influence of the CT primary current rating on G_D example

A current transformer has a primary rating of 500 A and a secondary rating of 5 A. The nominal current of the system is 350 A, and the three-phase inverse time over-current alarm *Limit* is 100 %.

G_D of the inverse time over-current characteristic graph according to IEC 60255-151 is 7000 A.

- $G_D = 20 \times G_S = 20 \times (I_{nom} \times (\text{Limit} / 100)) = 20 \times (350 \times (1 / 1)) = 7000$ A

However, the highest G_D value where measurements can be made is 2000 A.

- Because the secondary current rating is 5 A, the formula to calculate the measurable G_D is $G_D = 4 \times I_{CT\ primary}$.
- $G_D = 4 \times I_{CT\ primary} = 4 \times 500 = 2000$ A

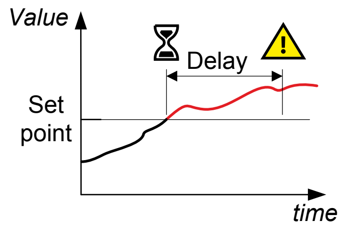
If the time performance at higher currents of the inverse time over-current protection is important, DEIF recommends using a current transformer that is rated for a 1 A secondary current (that is, -/1 A).

3.5.13 Negative sequence over-current (ANSI 46)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Negative sequence current	I_2>	46	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the current state of the negative sequence current part of the current phasors of the A-side. For more information, see Symmetrical components.



Negative sequence current typically occurs due to asymmetrical faults, unbalanced loads, or broken conductors.

Negative sequence current in the stator of a synchronous generator induces a double frequency current in the rotor. This increases the risk of overheating the generator.

`[A-side] > Current protections > Negative sequence current`

Parameter	Range
`Set point`	1.0 to 100.0 % of nominal current
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

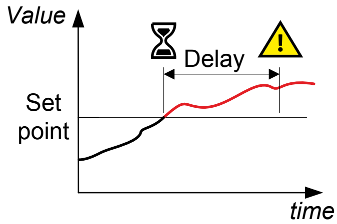
3.5.14 Zero sequence over-current (ANSI $51I_0$)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Zero sequence current	I_0>	$51I_0$	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the current state of the zero sequence current part of the current phasors of the A-side. For more information, see Symmetrical components.

Zero sequence current typically occurs due to earth faults in earthed power systems, or unbalanced loads in four-wire systems (that is, systems with a distributed neutral).



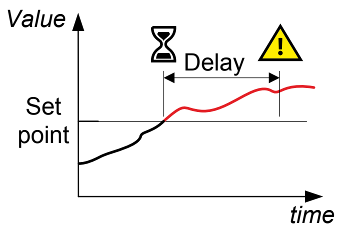
`[A-side] > Current protections > Zero sequence current`

Parameter	Range
`Set point`	0.0 to 100.0 % of nominal current
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

3.5.15 [A-side] over-frequency (ANSI 81O)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Over-frequency	f>	81O	< 100 ms

The alarm response is based on the lowest fundamental frequency (based on phase voltage), from the A-side. This ensures that the alarm only activates when all of the phase frequencies are above the set point.



`[A-side] > Frequency protections > Over-frequency #*`

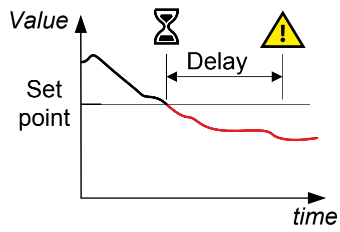
Parameter	Range
`Set point`	100.0 to 120.0 % of nominal frequency
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 to 3.

3.5.16 [A-side] under-frequency (ANSI 81U)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Under-frequency	f<	81U	< 100 ms

The alarm response is based on the highest fundamental frequency (based on phase voltage), from the A-side. This ensures that the alarm only activates when all of the phase frequencies are below the set point.



[A-side] > Frequency protections > Under-frequency #*

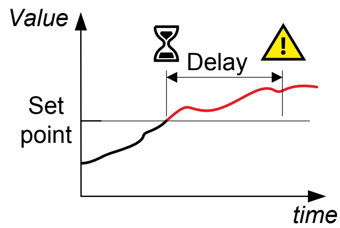
Parameter	Range
`Set point`	80.0 to 100.0 % of nominal frequency
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 to 3.

3.5.17 Overload (power export) (ANSI 32)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Overload	P>	32	< 100 ms

The alarm response is based on the total active power from the A-side, as measured by the controller.



[A-side] > Power protections > Overload* #**

Parameter	Range
`Set point`	0.0 to 200.0 % of nominal power
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

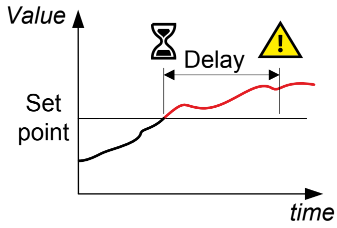
NOTE * For a BUS TIE breaker controller, this is **`Power export`**.

** # is 1 to 5.

3.5.18 Reverse power (power import) (ANSI 32R)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Reverse power	P<	32R	< 100 ms

The alarm response is based on the total active power to the A-side, as measured by the controller.



[A-side] > Power protections > Reverse power* #**

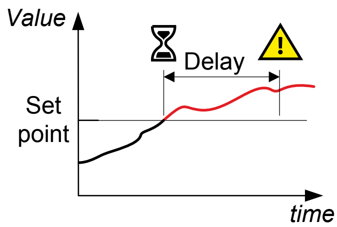
Parameter	Range
`Set point`	0.0 to 200.0 % of nominal power
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * For a BUS TIE breaker controller, this is **Power import**.
** # is 1 or 2.

3.5.19 Reactive power export (ANSI 40O)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Reactive power export (over-excitation)	Q>	40O	< 100 ms

The alarm response is based on the total reactive power (Q) from the A-side, as measured and calculated by the controller.



[A-side] > Reactive power protections > Reactive power export #*

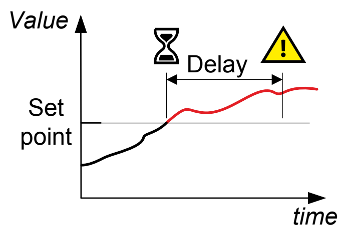
Parameter	Range
`Set point`	0.0 to 300.0 % of nominal reactive power
`Reset hysteresis`	0.0 to 20.0 %

NOTE * # is 1 or 2.

3.5.20 Reactive power import (ANSI 40U)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Reactive power import (loss of excitation/under-excitation)	Q<	40U	< 100 ms

The alarm response is based on the total reactive power (Q) to the A-side, as measured and calculated by the controller.



`[A-side] > Reactive power protections > Reactive power import #*`

Parameter	Range
`Set point`	0.0 to 300.0 % of nominal reactive power (Q)
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 or 2.

3.5.21 Active synchroniser (ANSI 25A)

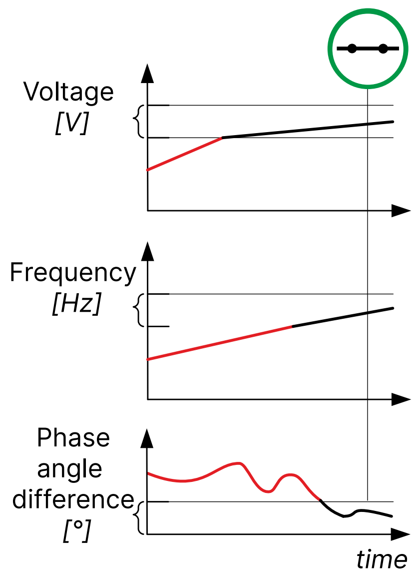
Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Active synchroniser (including blackout close)	-	25A	-

For all breakers, the active synchroniser ensures that the voltages, frequencies, and phase are within the allowed limits before the controller closes the breaker.

The active synchroniser can allow blackout close. That is, if the configured conditions are met and equipment is trying to close a breaker to a busbar that does not have voltage, the breaker can be allowed to close without synchronisation.

The synchronisation is based on the frequency difference, the voltage difference, and the phase across the breaker, as measured by the controller.

The active synchroniser on does not have an alarm or inhibits. However, if the controller cannot synchronise within the time allowed, there will be a sync failure alarm.



The active synchroniser is based on the parameters under:

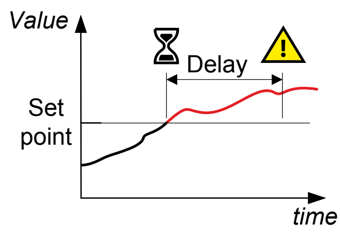
`Breakers > [Breaker] configuration > Synchronisation setting`

3.6 B-side AC protections

3.6.1 [B-side] over-voltage (ANSI 59)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Over-voltage	U>	59	< 50 ms

The alarm response is based on the highest phase-to-phase voltage, or the highest phase-to-neutral voltage, from the B-side, as measured by the controller.



`[B-side] > Voltage protections > Over-voltage #*`

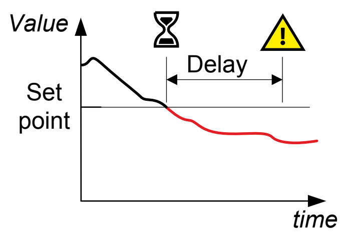
Parameter	Range
`AC setup`	Phase-phase, Phase-neutral
`Set point`	90.0 to 120.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 to 3.

3.6.2 [B-side] under-voltage (ANSI 27)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Under-voltage	U<	27	< 50 ms

The alarm response is based on the lowest phase-to-phase voltage, or the lowest phase-to-neutral voltage, from the B-side, as measured by the controller.



`[B-side] > Voltage protections > Under-voltage #*`

Parameter	Range
`AC setup`	Phase-phase, Phase-neutral
`Set point`	10.0 to 100.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

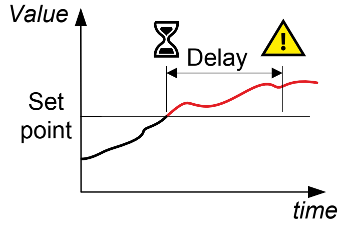
NOTE * # is 1 to 4.

3.6.3 [B-side] voltage unbalance (ANSI 47)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Voltage unbalance (voltage asymmetry)	UUB>	47	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The method is based on the ANSI C84.1-2016 calculation method to determine voltage unbalance. The alarm response is based on the highest difference between any of the three B-side phase-to-phase voltage or phase-to-neutral true RMS values and the average voltage, as measured by the controller.



If phase-to-phase voltages are used, the controller calculates the average phase-to-phase voltage. The controller then calculates the difference between each phase-to-phase voltage and the average voltage. Finally, the controller divides the maximum difference by the average voltage to get the voltage unbalance. See the example.

`[B-side] > Voltage protections > Voltage unbalance`

Parameter	Range
`AC setup`	Phase-phase, Phase-neutral
`Set point`	0.0 to 50.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

B-side voltage unbalance example

The B-side has a nominal voltage of 230 V. The L1-L2 voltage is 235 V, the L2-L3 voltage is 225 V, and the L3-L1 voltage is 210 V.

The average voltage is 223.3 V. The difference between the phase-to-phase voltage and the average is 12.7 V for L1-L2, 2.7 V for L2-L3 and 13.3 V for L3-L1.

The B-side voltage unbalance is 13.3 V / 223.3 V = 0.06 = 6 %

3.6.4 [B-side] positive sequence under-voltage (ANSI 27D)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Positive sequence under-voltage	U_1<	27D	< 60 ms

The alarm response is based on the voltage state on the positive sequence voltage part of the voltage phasors of the B-side. The positive sequence represents the symmetrical part of the system. For more information, see Symmetrical components.

The positive sequence under-voltage alarm protects, for example, generators from running at a voltage that is too low.

`[B-side] > Voltage protections > Positive sequence under-voltage`

Parameter	Range
`Set point`	10.0 to 110.0 %
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.02 s to 1 h

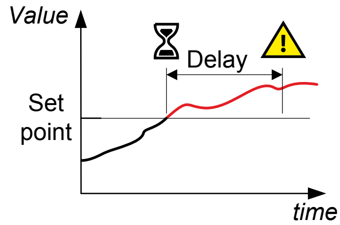
3.6.5 [B-side] negative sequence over-voltage (ANSI 47)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Negative sequence voltage	U_2>	47	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the voltage state of the negative sequence voltage part of the voltage phasors of the B-side. For more information, see Symmetrical components.

Negative sequence voltage typically occurs due to unbalanced loads, or a broken conductor. The negative sequence over-voltage protection protects against unbalanced voltage conditions.



`[B-side] > Voltage protections > Negative sequence voltage`

Parameter	Range
`Set point`	1.0 to 100.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

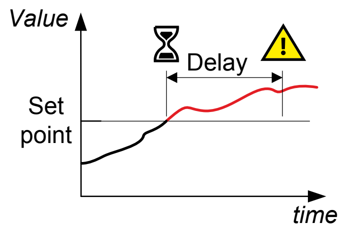
3.6.6 [B-side] zero sequence over-voltage (ANSI 59U_0)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Zero sequence voltage	U_0	59U_0	< 200 ms *

NOTE * This operate time includes the minimum user-defined delay of 100 ms.

The alarm response is based on the voltage state of the zero sequence voltage part of the voltage phasors of the B-side. For more information, see Symmetrical components.

Zero sequence voltage typically occurs due to earth faults or unbalanced loads. The detection of any zero sequence voltage depends on the controller measuring relative to earth or neutral. That is, the controller's neutral voltage terminal (N) must be connected to earth or neutral.



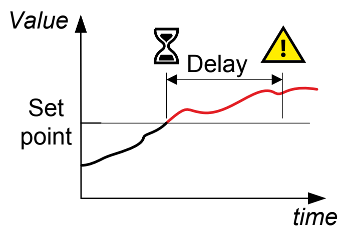
`[B-side] > Voltage protections > Zero sequence voltage`

Parameter	Range
`Set point`	0.0 to 100.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.10 s to 1 h

3.6.7 [B-side] over-frequency (ANSI 81O)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Over-frequency	f>	81O	< 50 ms

The alarm response is based on the lowest fundamental frequency (based on phase voltage), from the B-side. This ensures that the alarm only activates when all of the phase frequencies are above the set point.



`[B-side] > Frequency protections > Over-frequency #*`

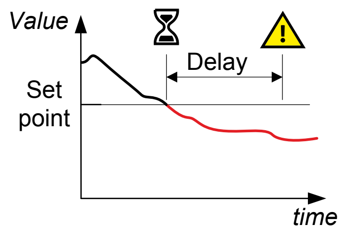
Parameter	Range
`Set point`	100.0 to 130.0 % of nominal frequency
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 to 3.

3.6.8 [B-side] under-frequency (ANSI 81U)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Under-frequency	f<	81U	< 50 ms

The alarm response is based on the highest fundamental frequency (based on phase voltage), from the B-side. This ensures that the alarm only activates when all of the phase frequencies are below the set point.



`[B-side] > Frequency protections > Under-frequency #*`

Parameter	Range
`Set point`	80.0 to 100.0 % of nominal frequency
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 to 4.

3.7 A-side or B-side AC protections

3.7.1 Vector shift (ANSI 78)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Vector shift	dφ/dt	78	< 40 ms

Vector shifts arise when a mains failure occurs while a generator is running parallel with the mains.

Vector shifts can occur because the stator magnetic field lags behind the rotor magnetic field. When a mains failure occurs, the phase angle between the stator and rotor magnetic fields changes. This change in the phase angle, is also known as a vector shift.

The alarm response is based on the change in the phase angle that occurred due to the mains failure. The alarm response can be based on the change in an individual phase, or on the change in all the phases.

In grids where fast automatic reconnection attempts are expected, this protection opens the breaker to prevent damaging failures.

Fast changes in frequency can also activate this alarm. Too sensitive configuration can lead to too many unwanted detections of vector shift.

Figure 3.1 Vector shift causes the instantaneous phase angle change (Δφ)

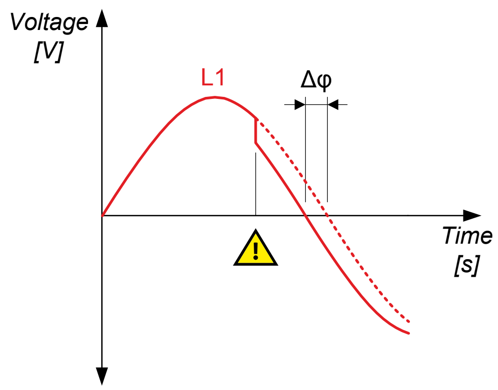


Figure 3.2 Vector shift in phase L1 only

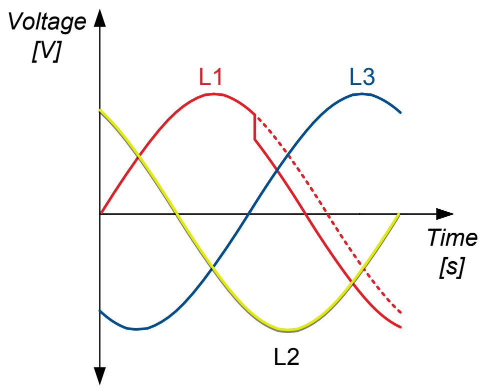
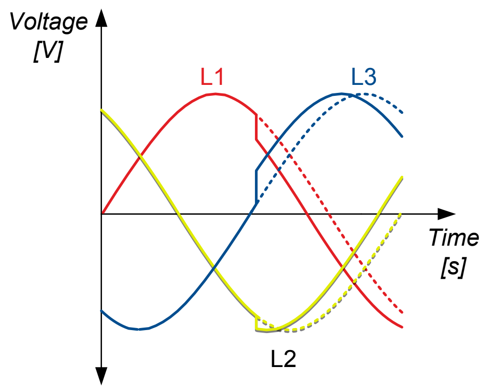


Figure 3.3 Vector shift in all phases



`[B-side] > Additional protections > Vector shift`

Parameter	Range
`AC setup`	[B-side], [A-side]
`Vector shift select`	Individual phases, All phases
`Set point`	1 to 90°

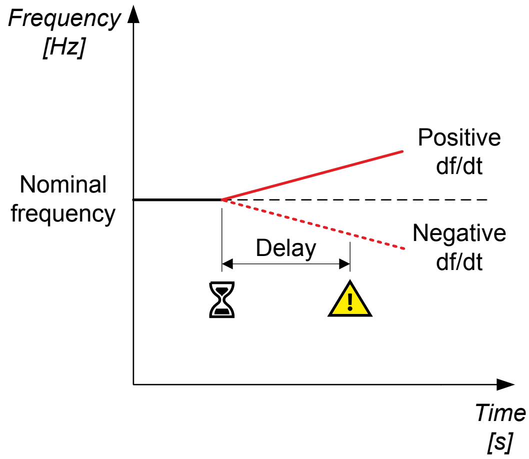
3.7.2 Rate of change of frequency (ANSI 81R)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
ROCOF (df/dt)	df/dt	81R	< 200 ms (12 half periods)

When a mains failure occurs, the measured frequency can change within a short period of time. This is because the generators can be either instantly overloaded or instantly de-loaded. In grids where fast automatic reconnection attempts are expected, this protection opens the breaker to prevent damaging failures.

If the generator overloads instantly, then it slows down. The generator frequency greatly decreases in a short amount of time. Similarly, if the generator de-loads instantly, it speeds up. The generator frequency increases greatly in a short amount of time.

The alarm response is based on the rate of change of the measured frequency. The rate of change in frequency is based on the zero crossings. A new ROCOF value is calculated for each crossing (up and down), based on values from a configurable number of half periods (*Measurement half period*) preceding this. The ROCOF protection compares this resulting value to the set points (*Positive df/dt set point* and *Negative df/dt set point*). The protection allows the user to configure a *Delay*.



[B-side] > Additional protections > ROCOF (df/dt)

Parameter	Range
AC setup	[B-side], [A-side]
Measurement half period	8 to 20 half periods
Positive df/dt set point	0.200 to 10.000 Hz/s
Negative df/dt set point	-10.000 to -0.200 Hz/s
Delay	0.0 to 0.5 s

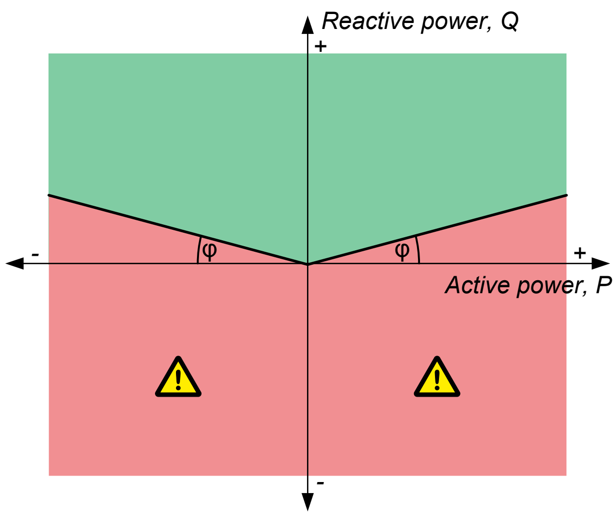
3.7.3 Low voltage low reactive power

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Low voltage low reactive power	V< Q <	27Q	< 250 ms

The low voltage low reactive power protection (also called QU-protection) is activated when all of the following conditions are met within the delay:

- One voltage measurement is below the *Set point*.
- The feed-in current must be greater than the *V< and Q< I min* set point.
- The angle value is greater than the *V< and Q< angle min* set point.

The alarm response is based on the direction of the reactive power (Q) from the A-side, all the phase currents, and the voltage as measured and calculated by the controller.



[A-side] > Additional protections > V< and Q< # *

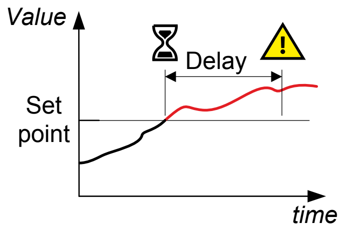
Parameter	Range
`AC setup`	• Phase-phase [B-side] • Phase-neutral [B-side] • Phase-phase [A-side] • Phase-neutral [A-side]
`I min`	0.0 to 100.0 %
`Angle min`	0.00 to 10.00°
`Set point`	0.0 to 100.0 % of nominal reactive power
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 120.10 s

NOTE * # is 1 or 2.

3.7.4 Average over-voltage (ANSI 59AVG)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Average over-voltage		59AVG	-

The alarm response is based on the highest average phase-to-phase voltage, or the highest average phase-to-neutral voltage, from the B-side or A-side, averaged during the calculation time.



The average voltage calculation is based on the power quality approach in EN 61000-4-30. The root mean squared (RMS) voltage is measured and aggregated for 10 periods at 50 Hz nominal frequency (this is 12 periods at 60 Hz). This result is then aggregated 15 times (that is, for a 3-second average). Finally, the 3-second averages are aggregated over the aggregate time.

For this protection, the average voltage is measured and calculated over a minimum of 30 seconds, and updated every 3 seconds.

[A-side] > Additional protections > Average over-voltage # *

Parameter	Range
`AC setup`	• Phase-phase [B-side] • Phase-neutral [B-side] • Phase-phase [A-side] • Phase-neutral [A-side]
`V> aggregate time`	30 s to 15 min**
`Set point`	90.0 to 120.0 % of nominal voltage
`Reset hysteresis`	0.0 to 20.0 %
`Delay`	0.00 s to 1 h

NOTE * # is 1 or 2.
** The selected value is rounded down to the nearest multiple of 3 seconds. For example, if the *V> aggregate time* is set to 38 seconds, the controller uses an aggregate time of 36 seconds.

The calculations are reset if the parameters are changed, or if there is any gap in the measurement.

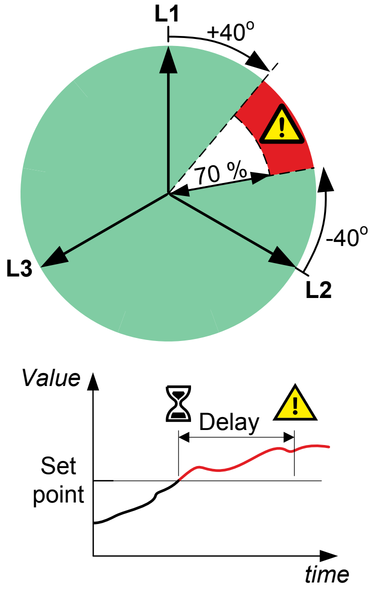
3.8 Other AC protections

3.8.1 Phase sequence error

The controller continuously checks the L1 and L2 line voltage phasors on either side of the breaker against the orientation defined in the controller (see AC configuration). If the voltage is more than the detection voltage, and the phase differs from expected by more than 40°, the alarm is activated. This means that the alarm will also detect if the phase rotation is different from the direction of rotation defined in the controller.

There are two alarms for each controller. These alarms correspond to the controller's AC measurements. There is one alarm for the voltage from the [A-side], and another alarm for the voltage on the [B-side].

The alarm action is *Trip [Breaker]* and cannot be changed.



`[A-side] > AC setup > Phase sequence error`

Parameter	Range
`Detection voltage` *	30 to 90 % of nominal A-side voltage
`Delay`	1 to 10 s

NOTE * The alarm is inhibited if the voltage is below the set point.

`[B-side] > AC setup > Phase sequence error`

Parameter	Range
`Detection voltage` *	30 to 90 % of nominal B-side voltage
`Delay`	1 to 10 s

NOTE * The alarm is inhibited if the voltage is below this set point.

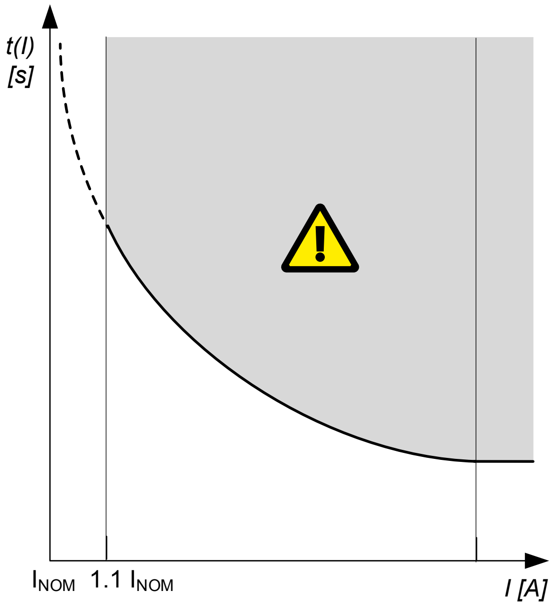
3.8.2 Earth inverse time over-current (ANSI 51G)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Earth inverse time over-current		51G	-

The alarm response is based on the earth current, as measured by the 4th current measurement filtered to attenuate the third harmonic (at least 18 dB; a 128 tap FIR low pass filter is applied). The A-side frequency, as measured by the controller (f), is used as the cutoff frequency. The filter has 0 dB attenuation at f0, and 33 dB attenuation at 3 × f0.

The alarm response time depends on an approximated integral of the current measurement over time. The integral is only updated when the measurement is above the activation threshold.

Note: The diagram on the right is a simplified representation of this alarm. The diagram does not show the integral over time.



Wiring

You must wire the 4th current measurement on MIO2.1 (terminals 70,71) to measure the earth current.

More information
See **I4 current** in the **Installation instructions** for an example of how to wire the earth current measurement.

The *Earth inverse time over-current* and *Neutral inverse time over-current* alarms each require the 4th current measurement. You therefore cannot use both of these protections at the same time.

`Local > 4th current input > Earth inverse time over-current`

Parameter	Range
`Curve`	See below
`Limit` (the set point, also known as LIM)	2.0 to 200.0 % of nominal current (4th current input)
`Time multiplier setting` (TMS)	0.01 to 100.00
`Threshold`	1.000 to 1.300
`k` *	0.001 s to 2 min
`c` *	0 s to 1 min
`alpha (α, or a)` *	0.001 to 1

NOTE * Only used if custom curve is selected.

More information
See Inverse time over-current (ANSI 51) for the calculation method, the standard curves, and information about the definite time characteristic.

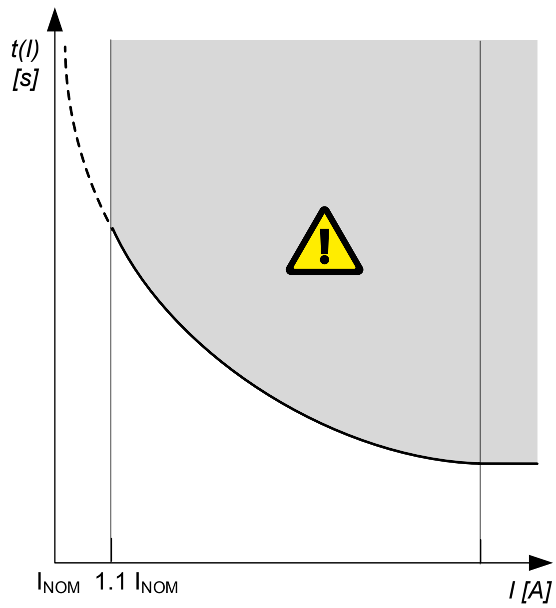
3.8.3 Neutral inverse time over-current (ANSI 51N)

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Neutral inverse time over-current		51N	-

The alarm response is based on the RMS neutral current, as measured by the 4th current measurement.

The alarm response time depends on an approximated integral of the current measurement over time. The integral is only updated when the measurement is above the activation threshold.

Note: The diagram on the right is a simplified representation of this alarm. The diagram does not show the integral over time.



Wiring

You must wire the 4th current measurement on MIO2.1 (terminals 70,71) to measure the ground current.

More information
See **I4 current** in the **Installation instructions** for an example of how to wire the neutral current measurement.

The *Earth inverse time over-current* and *Neutral inverse time over-current* alarms each require the 4th current measurement. You therefore cannot use both of these protections at the same time.

`Local > 4th current input > Neutral inverse time over-current`

Parameter	Range
`Curve`	See below
`Limit` (the set point, also known as LIM)	2.0 to 200.0 % of nominal current (4th current input)
`Time multiplier setting` (TMS)	0.01 to 100.00
`Threshold`	1.000 to 1.300
`k` *	0.001 s to 2 min
`c` *	0 s to 1 min
`alpha (α, or a)` *	0.001 to 1

NOTE * Only used if custom curve is selected.

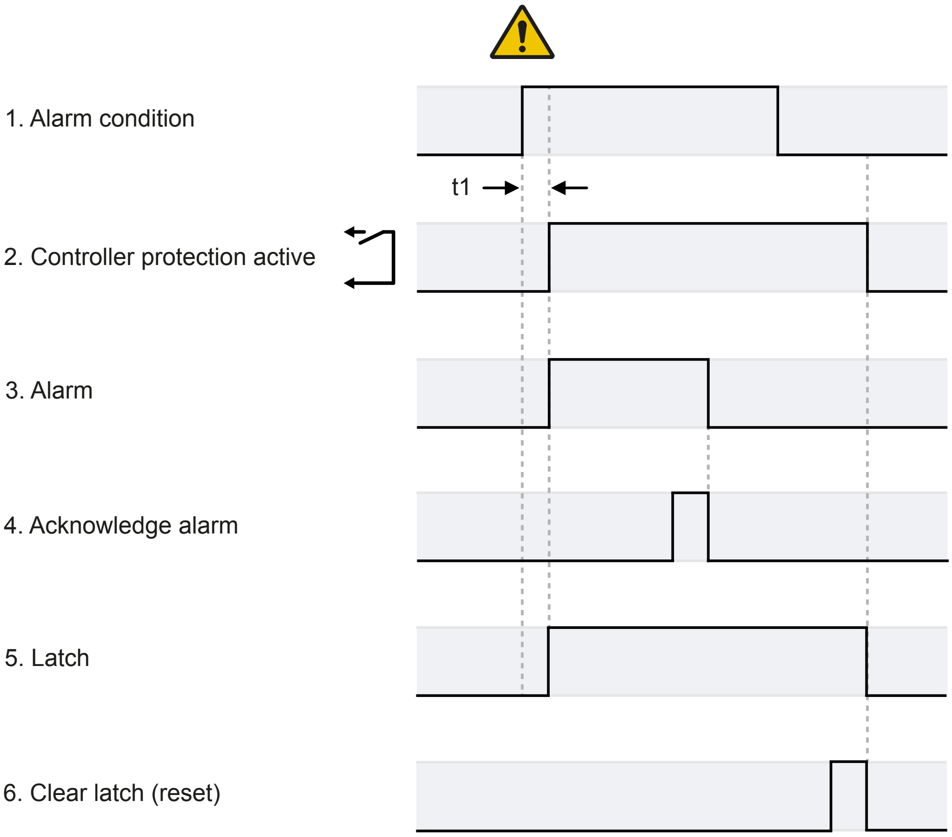
More information
See Inverse time over-current (ANSI 51) for the calculation method, the standard curves, and information about the definite time characteristic.

3.8.4 Lockout relay (ANSI 86)

The lockout relay ensures that the alarm action continues for an alarm, until the lockout relay is reset. The controller can function as a lockout relay for alarm conditions which have the *Latch* parameter enabled. The protection is in effect until the alarm condition is cleared, the alarm acknowledged and the latch is reset.

The lockout relay applies to all latched alarms, and does not activate a specific alarm or have any inhibits.

Protection	IEC symbol (IEC60617)	ANSI (IEEE C37.2)	Operate time
Lockout relay		86	Dependent on protection



1. **Alarm condition**
   - When an alarm condition occurs, an alarm-dependent delay timer activates.
   - If the alarm condition occurs for longer than the delay timer (t1), the protection activates.
2. **Controller protection active**
   - If a latch is enabled for the protection, the latch activates when the controller protection activates.
   - The protection will remain active until the latch is reset, even if the alarm condition clears.
3. **Alarm**
   - The alarm output, for example, an alarm horn, remains active until the alarm is acknowledged.
   - When the alarm is acknowledged, the protection remains active if a latch is enabled.
4. **Acknowledge alarm**
   - The alarm can be acknowledged while the alarm condition is still active, or when the alarm condition has cleared.
   - If a latch is active and the alarm is acknowledged after the alarm condition has cleared, the protection will remain active.
5. **Latch**
   - If a latch is enabled for the alarm, the alarm latch will activate when the controller protection activates.
   - While the latch is active, the alarm protection will also be active.
6. **Clear latch (reset)**
   - The alarm latch can only be removed once the alarm condition is no longer active and the alarm is acknowledged.
   - The protection will remain active until the latch is cleared.

For most alarms, a latch can be *Enabled* as a parameter under `[Alarm location] > [Alarm] > Latch`

`[Alarm location]` is the location of the alarm parameters, for example, `Busbar > Voltage protections`.

`[Alarm]` is the alarm name.

NOTICE

Not powered controller opens digital outputs

If the controller is not powered, the controller opens the digital outputs.

NOTICE

Latched alarms do not trip breaker again if breaker manually operated

Alarms that are latched do not trip the breaker again if the breaker is closed manually by the operator.

Optional: Configuring an external lockout relay

An external lockout relay with manual reset functionality can be connected to a digital output. The digital output activates if a specific alarm condition is triggered by the controller. For example: Under `Configure > Input/output`, a digital output can be configured to activate if *Any latched alarm* is present. When the digital output is activated, the lockout relay connected to it is also activated. If the alarm condition is cleared on the controller, an operator must manually reset the lockout relay.

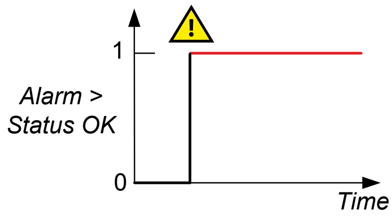
When the controller is connected to an external lockout relay, the controller interfaces with the lockout relay. When the controller interfaces with an external lockout relay, the controller is not seen as the lockout relay for the system.

4. Alarms and protections

4.1 General system alarms

4.1.1 System not OK

This alarm communicates that there is a problem with one of the hardware modules in the controller.



The system is okay if all of the following conditions are met:

- All the modules in the rack are sending an OK signal.
- All the modules in the rack have a software version that is compatible with the controller application software.
- All the modules required for a specific controller type are present in the rack.
- The alternating current module has received all the required settings (wiring mode, nominal settings, and so on) at start-up.
- The controller software has started and is running OK.

By default, the *Status OK* alarm output is configured to terminals 48 of the MIO2.1. This configuration cannot be removed or changed.

`Local > Monitoring > System not OK`

This alarm is always enabled.

More information

See Alarm status digital outputs for how the *Status OK* alarm is configured.

4.1.2 Critical process error

The alarm communicates that the controller's critical communication and/or processing are disrupted.

The alarm action is *Warning* and the alarm is always enabled. The controller also activates the *System not OK* alarm. The alarm parameters are not visible.

It is unlikely that customers will see this alarm. If you do see this alarm take the following actions:

1. Restart the controller.
2. If restarting does not help, update the controller software to the latest version.
3. Contact DEIF.

4.1.3 Configuration update delayed

The controller activates this alarm if an operator and/or external equipment is changing the controller configuration too quickly. For example, a programming error on a PLC can create a storm of Modbus changes.

To protect the controller's internal memory, the excess configuration changes are not stored immediately. The delay can be up to 10 minutes. If the controller loses power during this time, the changes may be lost.

The alarm is always enabled. The alarm action is *Warning*. The alarm is automatically acknowledged when the configuration changes are stored. The alarm parameters are not visible.

4.1.4 Fieldbus connection missing

This alarm is for the internal communication between the controller and its extension units. If there is a redundancy connection, this alarm communicates that an Ethernet connection is missing or broken.

The alarm is always enabled, and the alarm action is *Warning*. The alarm parameters are not visible.

4.1.5 Fieldbus conflict

This alarm is for the internal communication between the controller and its extension units. If there is a hardware change or hardware failure, this alarm communicates that the hardware configuration does not match the previous hardware configuration. Use `Configure > Fieldbus configuration` in PICUS to correct the hardware configuration.

The alarm is always enabled, and the alarm action is *Block*. The alarm parameters are not visible.

4.1.6 Priority error

Controller types: This alarm is present in all controllers.

This alarm communicates that a number of controllers cannot synchronise the priorities in the network.

This alarm activates when one of the following conditions are present:
- There is an error in the system.
- The wrong controller types are present in the system.
- The wrong controller IDs are present in the system.
- The single line application drawings for all the controllers in the system are not the same.

The alarm action is *Warning*, and the alarm is always enabled. You cannot see the alarm parameters.

4.1.7 Controller ID not configured

This alarm communicates that the user has never configured the *Controller ID*.

The alarm is always enabled and the action is *Warning*. The alarm parameters are not visible.

4.1.8 Trip AVR output not configured

This alarm communicates that there is an alarm configured that has a *Trip AVR* alarm action, but the *Trip AVR* output is not configured.

The alarm is always enabled and the action is *Warning*. The alarm parameters are not visible.

The *Trip AVR* digital output can be configured under `Generator > AVR > Trip AVR` on the Input/output page. Alternatively the output can be configured using Modbus.

4.1.9 NTP server not connected

The alarms *NTP server 1 not connected*, *NTP server 2 not connected*, or *No NTP server(s) connected* are activated when the NTP server(s) are configured, but the controller did not connect to the server(s) within 10 minutes after the configuration is written to the controller. These alarms are triggered if the controller network cannot access the NTP server(s), or if the NTP server(s) are not set up correctly.

Configure the parameters for these alarms under `Communication > NTP`. The alarm action is always *Warning* and cannot be changed.

4.1.10 NTP server no response

The alarms *NTP server 1 no response*, *NTP server 2 no response*, or *No NTP server time synchronisation* are activated when the controller was successfully connected to NTP server(s), but the server(s) did not respond to the controller for up to 22 minutes.

Configure the parameters for these alarms under `Communication > NTP`. The alarm action is *Warning* and cannot be changed.

4.1.11 Live voltage detected

This alarm informs the operator that live power was detected during emulation.

The controller activates this alarm if `Test functions > Emulation > Emulation active` is *Enabled* and live power is detected.

The alarm is always enabled. You cannot see or change the alarm parameters.

Parameter	Default
`Delay`	1 s
`Action`	Trip generator breaker and shutdown engine
`Latch`	Enabled

4.2 Custom input alarms

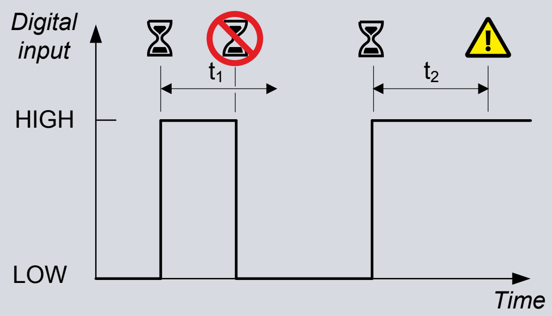
4.2.1 Digital input (DI) alarms

You can configure custom alarms for any of the controller digital inputs (DI). When the digital input (DI) is triggered the alarm becomes active in the system and the controller does the associated alarm action.

HIGH input trigger example

Select *High* for the alarm trigger level.

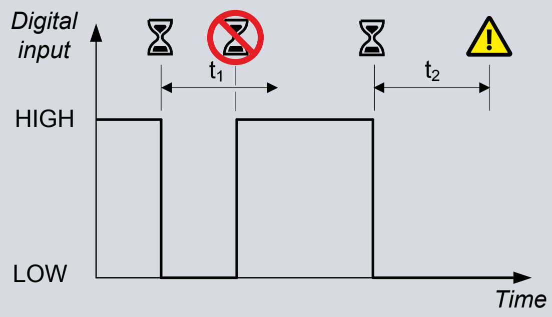
By default, a digital input (DI) is normally low, and the alarm is activated if the digital input is high for longer than the *Time delay*.



LOW input trigger example

Alternatively, configure the digital input (DI) so that the alarm is activated if the digital input is low for longer than the *Time delay*.

Select *Low* for the alarm trigger level.



`[Hardware module] > DI > Alarms`

Parameter	Range	Notes
`Name`	Text	Name for the alarm
`Trigger level`	Low, High	Whether the alarm is triggered at **High** or **Low**.
`Delay`	0 s to 1 h	

4.2.2 Analogue input (AI) alarms

You can configure custom alarms for the controller analogue inputs (AI). When the analogue input alarm set point is exceeded for longer than the delay time, then the alarm becomes active in the system and the controller does the associated alarm action.

Configure the analogue input (AI) sensor setup (including the scale) before creating an alarm for the input. The configuration of the analogue input determines the configuration of the alarm. For example, the analogue input can be configured as a 0 to 20 mA current input that corresponds to a percentage. The analogue input alarm is then configured for a certain percentage set point.

More information
See Analogue input characteristics and configuration for how to configure sensor failure alarms.

`[Hardware module] > AI > Alarms`

Parameter	Range	Notes
`Name`	Text	Name for the alarm
`Trigger level`	Low, High	Whether the alarm is triggered at **High** or **Low**.
`Delay`	0 s to 1 h	
`Set point`	Varies	Depends upon selected input scale unit
`Reset hysteresis`	Varies	Depends upon selected input scale unit

Low oil pressure analogue input alarm example

Configure the analogue input for the oil pressure sensor under **[Hardware module] > AI > Sensor setup**. In this example, the sensor provides a 4 to 20 mA signal, which corresponds linearly to 0 to 10 bar.

Configure the sensor as follows:
Sensor = *0 to 25 mA*
Units = *bar*
Select an unused *Custom input scale #*.
Input (mA), Minimum = *4*, Maximum = *20*
Output (bar), Minimum = *0*, Maximum = *10*
Create two points for the curve: *4 mA and 0 bar*; and *20 mA and 10 bar*.

Configure the alarm as follows:
Name = *Low oil pressure*
Trigger level = *Low*
Enable = *Enabled*
Delay = *0.1 seconds*
Set point = *1 bar*
Action = *Trip generator breaker and shutdown engine*
Inhibit = *Engine not running*

If the engine is running, but the oil pressure falls below 1 bar (this corresponds to an analogue input of less than 5.6 mA) for more than 0.1 seconds, then the alarm is activated. The controller trips the breaker and shuts down the engine.

4.3 General hardware module alarms

4.3.1 Software mismatch on hardware module(s)

This alarm is activated if any of the hardware modules in the controller have a software version installed that differs from the expected version. The alarm action is *Warning*. The alarm parameters are not visible.

NOTE This alarm is only activated if you install a replacement hardware module in the controller. The new module can have different software to the rest of the controller. Reinstall or update the controller firmware to fix the problem. This alarm activates the *System not OK* alarm.

4.3.2 Required IO card(s) not found

This alarm communicates that some of the default hardware modules for the controller type were not found. The alarm action is *Warning*. The controller also activates the *System not OK* alarm. The alarm parameters are not visible.

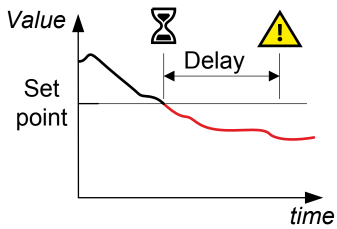
If one or more default controller hardware modules are missing, then this alarm is activated on start-up.

4.4 Controller

4.4.1 PCM2.1 supply voltage low alarm

This default alarm is for power supply voltage protection.

The alarm is based on the power supply voltage measured by the controller. The alarm is activated when the power supply voltage is less than the set point for the delay time.



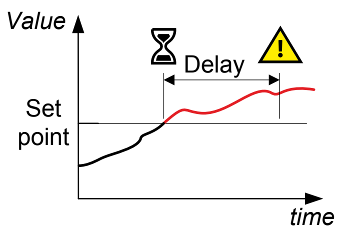
`Hardware > PCM2.1 > Low voltage alarm`

Parameter	Range
`Set point`	8.0 to 32.0 V DC
`Delay`	0 s to 1 h

4.4.2 PCM2.1 supply voltage high alarm

This default alarm is for power supply voltage protection.

The alarm is based on the power supply voltage measured by the controller. The alarm is activated when the power supply voltage exceeds the set point for the delay time.



`Hardware > PCM2.1 > High voltage alarm`

Parameter	Range
`Set point`	12.0 to 36.0 V DC
`Delay`	0 s to 1 h

4.4.3 Controller temperature too high

This is a built-in alarm for the controller internal temperature, as measured on the controller. The alarm is triggered when the controller internal temperature is higher than 80 °C (176 °F). The alarm action is *Warning*. The alarm parameters are not visible.

If the controller operates at internal temperatures higher than 80 °C (176 °F), the performance and the lifetime of the controller is significantly reduced.

4.4.4 Clock battery failure alarm

The *Clock battery failure* alarm is activated when the battery in controller needs to be replaced. The alarm action is *Warning*. The alarm parameters are not visible.

4.4.5 Primary or Secondary CAN missing ID # alarms

This alarm communicates that the CAN ID # is not configured or missing. Where # is the ID number 1 to 40.

The alarm action is *Warning*. You cannot see or change the alarm parameters.

4.4.6 Duplicated CAN IDs alarm

This alarm communicates that there is one or more duplicated CAN IDs used in the system.

The alarm action is *Warning*. You cannot see or change the alarm parameters.

4.4.7 Application internal CAN protocol conflict

The alarm communicates that the controller has a different network protocol from the rest of the controllers in the CAN system.

The alarm can for example activate when a controller with a newer software version than the other controllers is added to the network. This includes different DEIF products in the same system.

The alarm action is *Warning*. You cannot see or change the alarm parameters.

To deactivate this alarm, update all the controllers in the system to the latest software.

4.5 Measurement Input Output module MIO2.1

4.5.1 Relay # wire break alarms

These alarms are for MIO2.1 configured digital output channels. The wire break monitoring is only active when the digital output is open.

`Hardware > MIO2.1 > MIO2.1 relay # wire break` *

Parameter	Range
`Delay`	0 s to 1 h
`Enable`	Not enabled, Enabled
`Action`	Warning

NOTE * # is 9 to 16.

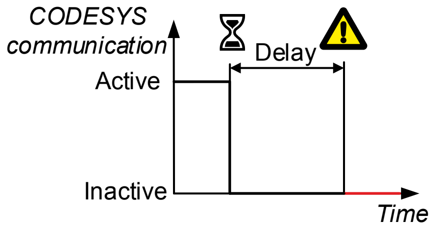
4.6 CODESYS alarms

4.6.1 CODESYS application not OK

This alarm alerts the operator that there is a communication problem between CODESYS and the controller.

If communication between CODESYS and the controller was active and became inactive, the delay timer starts. If the communication does not become active within the delay period, the alarm is triggered.

Controller types: This alarm is present in all controllers that have CODESYS installed.



`CODESYS > Monitoring > Application not OK`

Parameter	Range	Default
`Startup time`	0 to 600 s	60 s
`Delay`	0 to 300 s	1 s
`Enable`	Not enabled, Enabled	Not enabled
`Action`		Warning

4.6.2 CODESYS configuration conflict

This alarm alerts the operator that the same I/O is configured on the controller and on CODESYS.

If an I/O is configured on both CODESYS and the controller at the same time, this alarm is triggered.

To clear the alarm, delete the I/O from either the controller or CODESYS, then do a warm reset of CODESYS.

Controller types: This alarm is present in all controllers that have CODESYS installed.

More information
See the **Multi-line 300 CODESYS guidelines** for more warm reset information.

`CODESYS > Monitoring > I/O config conflict`

This alarm is always enabled.

Parameter	Range	Default
`Action`		Warning

5. Breakers, synchronisation and de-loading

5.1 About

5.1.1 How it works

A number of power sources can supply power to the same busbar. To connect to a live busbar, these power sources must be synchronised in order to safely connect them. Synchronisation consists of matching the voltage, frequency and phases on both sides of the breaker that must be closed.

The **SINGLE genset** and **GENSET** controllers can adjust the frequency and phase of the genset(s) by regulating their governors.

The **SINGLE genset** and **GENSET** controllers can adjust the voltage of the genset(s) by regulating their AVRs.

The **MAINS** and **BUS TIE breaker** controllers can use power management to regulate the gensets for synchronisation.

Each controller type monitors the voltage, frequency and phase across its breaker. If the measurements are within the configured limits, the controller can activate the `Breakers > [Breaker] > Controls > [*B] close` output.

More information

See Regulation for information on the regulation of the gensets.
See Power management for information on the automatic actions to optimise the power supply.
See **each controller type** for information on each controller's breaker sequences.

5.1.2 Regulation required for synchronisation

For synchronisation, the controller must be able to adjust the genset frequency (by regulating the genset governor) and voltage (by regulating the genset AVR).

It does not matter whether the energy sources are already connected to the busbar. The power management only regulates the gensets to synchronise.

The power management regulates the gensets to synchronise the power sources. The controller measures the conditions across its breaker(s). When the synchronisation is within the configured limits, the controller activates the `Breakers > [Breaker] > Controls > Close` output.

SINGLE genset controller

In AUTO and MANUAL mode, when a **SINGLE genset** controller gets a *Close generator breaker* command, the controller ignores the selected regulator mode and external set points. The controller automatically uses the voltage and frequency regulation parameters to synchronise the genset to the busbar. For static synchronisation, the controller also uses the phase regulation parameters.

When a **SINGLE genset** with mains breaker controller gets a *Close mains breaker* command, the controller automatically uses the voltage and frequency parameters to synchronise the genset to the mains. For static synchronisation, the controller also uses the phase regulation parameters.

If the controller is in NO REG mode, the controller does not regulate the genset. The operator can however manually synchronise the genset.

GENSET controller

In AUTO and MANUAL mode, when a **GENSET** controller gets a *Close breaker* command, the controller ignores the selected regulator mode and external set points. The controller automatically uses the voltage and frequency regulation parameters to synchronise the genset to the busbar. For static synchronisation, the controller also uses the phase regulation parameters.

If the controller is in NO REG mode, the controller does not regulate the genset. The operator can however manually synchronise the genset.

MAINS and BUS TIE breaker controllers

MAINS and **BUS TIE breaker** controllers do not regulate.

When one of these controllers gets a *Close breaker* command, it broadcasts over the network the voltage and frequency that it requires to synchronise. In response, the **GENSET** controller(s) in the same section then regulate according to the set point.

5.1.3 Regulation required for de-loading

If possible, the breakers are de-loaded before they are opened, to reduce wear. A breaker is de-loaded by reducing the flow of power through the breaker to the configured level. In AUTO and MANUAL mode, the power management de-loads a breaker by regulating and/or starting the appropriate genset(s) to take the load off that breaker.

Regulation

For de-loading, the controller must be able to adjust the genset frequency (by regulating the genset governor).

De-loading uses the same principles as synchronisation. For synchronisation, the power management adjusts the genset speed(s) so that the frequencies on either side of the breaker match. For de-loading, the power management adjusts the genset speed(s) to minimise the flow of power through the breaker.

The power management can only regulate the voltage and frequency of the gensets, by using the **GENSET** controllers. Where the power management must de-load assets that are not regulated, the power management therefore regulates the gensets to de-load to the unregulated assets.

Controlled stop

If a running genset has a *Controlled stop* alarm action, the power management will start the next genset, synchronise it with the busbar, and close its breaker. The power management will then de-load and open the genset breaker, and stop the genset that had the *Controlled stop* alarm action.

NOTE *Controlled stop* does **not** ensure that the genset stops. *Controlled stop* tries to stop the genset, but will not stop a genset that cannot be de-loaded.

Regardless of the type of regulation, when the de-loading requirements are met (within the time available for de-loading), the controller automatically opens the breaker.

5.2 Synchronisation in each controller mode

5.2.1 Synchronisation in AUTO mode

In AUTO mode, the power management automatically does the regulation required for synchronisation. When the power sources are synchronised, the controller automatically closes the breaker.

5.2.2 Synchronisation in MANUAL mode

In MANUAL mode, the controller must receive an external signal to synchronise and close the breaker. The power management then automatically regulates the gensets as required for synchronisation. When the power sources are synchronised, the controller automatically activates the output to close the breaker.

Synchronisation in MANUAL mode example

The operator presses **Close breaker** CLOSE on the display unit.

5.2.3 Synchronisation in NO REG mode

In NO REG mode, the operator can do the synchronisation manually.

Regardless of the regulation, if the synchronisation requirements are met (within the time available for synchronisation), the controller automatically closes the breaker.

Manual regulation in NO REG mode using controller inputs

The switchboard manual regulation buttons can be connected to digital inputs on the controller, and configured with the following functions:

- `Regulators > GOV > Manual > Manual GOV increase`
- `Regulators > GOV > Manual > Manual GOV decrease`
- `Regulators > AVR > Manual > Manual AVR increase`
- `Regulators > AVR > Manual > Manual AVR decrease`

During manual regulation, when the operator presses the buttons, the controller adjusts the governor and/or AVR output.

During manual regulation to synchronise, the controller status text may be *Manual regulation* rather than *Synchronising [*B]*. However, if the breaker close command is still active and the synchronisation requirements are met, the controller automatically closes the breaker.

5.3 Configuring breakers

5.3.1 Breaker commands

Digital inputs (optional)

The following inputs are not part of the breaker configuration and are optional. They can be used for commands to the controller.

Function	I/O	Type	Details
`Breakers > [Breaker] > Command > [*B] open`	Digital input	Pulse	This input has the same effect as pressing the *Breaker open* button on the display unit.
`Breakers > [Breaker] > Command > [*B] close`	Digital input	Pulse	This input has the same effect as pressing the *Breaker close* button on the display unit.
`Breakers > [Breaker] > Command > Block [*B] close`	Digital input	Continuous	While this input is active, the controller cannot close the breaker.

5.3.2 Pulse breaker

A pulse breaker closes or opens in response to a pulse from the controller.

Wiring examples

More information
See **Breaker wiring** in the **Installation instructions** for an example of pulse breaker wiring.

Inputs and outputs

Function	I/O	Type	Details
`Breakers > [Breaker] > Controls > [*B] close`	Digital output	Pulse	The controller activates the *[*B] close* output to close the breaker.
`Breakers > [Breaker] > Controls > [*B] open`	Digital output	Pulse	The controller activates the *[*B] open* output to open the breaker.

Function	I/O	Type	Details
`Breakers > [Breaker] > Feedback > [*B] open`	Digital input	Continuous	Wire this feedback from the breaker, to inform the controller when the breaker is open.
`Breakers > [Breaker] > Feedback > [*B] closed`	Digital input	Continuous	Wire this feedback from the breaker, to inform the controller when the breaker is closed.
`Breakers > [Breaker] > Feedback > [*B] short circuit`	Digital input	Continuous	Optional: Wire this feedback from the breaker, to inform the controller if a short circuit occurs.

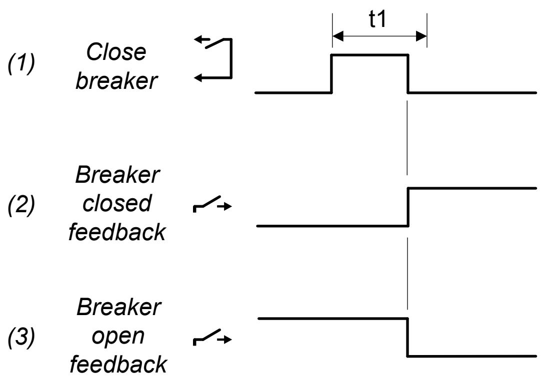
Parameters

`Breakers > [Breaker] configuration > Configuration`

Parameter	Range	Notes
`Pulse time ON`	0.0 to 60.0 s	The length of the breaker close pulse (that is, the maximum amount of time that the `Breakers > [Breaker] > Control > [*B] close` output is activated). If the controller receives breaker closed feedback within this time, the controller stops activating the breaker close output.
`Open point (de-loading)`	1.0 to 20.0 % of nominal power	The breaker is de-loaded when the power flowing through the breaker is less than this set point. The nominal power is the nominal power of the source.
`Delay after Hz/V OK before close`	0.0 to 30.0 s	After the voltage and frequency are okay, the controller delays breaker closing while this timer runs.

Sequence diagram

Table 5.1 Closing a pulse breaker

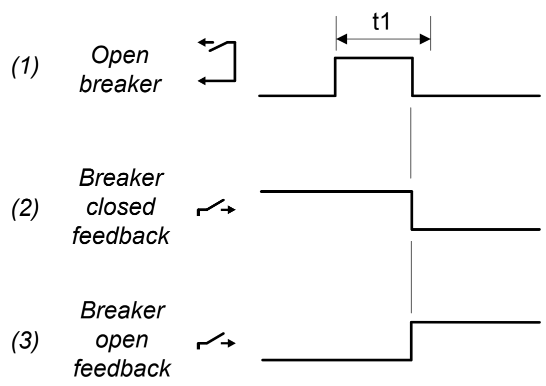


t1 Pulse on (`Parameters > Breakers > [Breaker] > Pulse time ON`)

To close a pulse breaker:

1. **Close breaker**: `Breakers > [Breaker] > Control > [*B] close` (digital output). The controller activates this output until there is breaker closed feedback, or for the *Pulse time ON*.
2. **Breaker closed feedback**: `Breakers > [Breaker] > Feedback > [*B] closed` (digital input). This input is activated when the breaker is closed.
3. **Breaker open feedback**: `Breakers > [Breaker] > Feedback > [*B] open` (digital input). This input is deactivated when the breaker is closed.

Table 5.2 Opening a pulse breaker

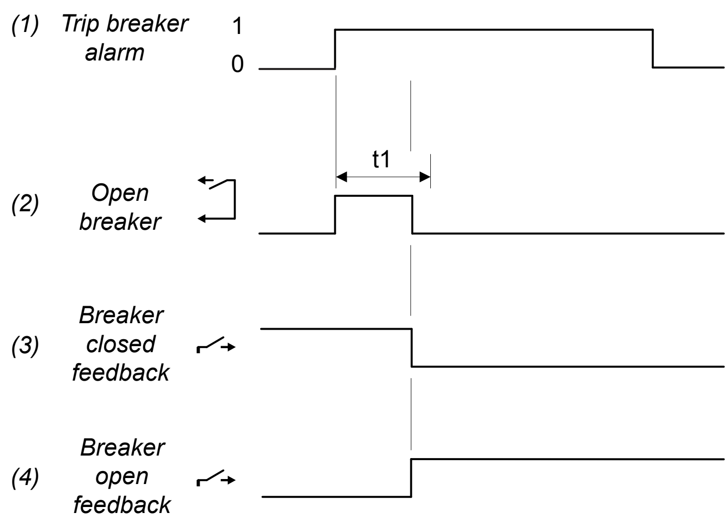


t1 Pulse on (`Parameters > Breakers > [Breaker] > Pulse time ON`)

To open a pulse breaker:

1. **Open breaker**: `Breakers > [Breaker] > Control > [*B] open` (digital output). The controller activates this output until there is breaker open feedback, or for the *Pulse time ON*.
2. **Breaker closed feedback**: `Breakers > [Breaker] > Feedback > [*B] closed` (digital input). This input is deactivated when the breaker is opened.
3. **Breaker open feedback**: `Breakers > [Breaker] > Feedback > [*B] open` (digital input). This input is activated when the breaker is opened.

Table 5.3 Trip a pulse breaker



t1 Pulse on (`Parameters > Breakers > [Breaker] > Pulse time ON`)

To trip a pulse breaker:

1. **Trip breaker alarm**
2. **Open breaker**: `Breakers > [Breaker] > Control > [*B] open` (digital output). The controller activates this output until there is breaker open feedback, or for the *Pulse time ON*.
3. **Breaker closed feedback**: `Breakers > [Breaker] > Feedback > [*B] closed` (digital input). This input is deactivated when the breaker is opened.
4. **Breaker open feedback**: `Breakers > [Breaker] > Feedback > [*B] open` (digital input). This input is activated when the breaker is opened.

5.3.3 Breaker state outputs

Digital outputs (optional)

The outputs are not part of the breaker configuration and are optional.

Function	I/O	Type	Details
`Breakers > [Breaker] > State > [*B] is open`	Digital output	Continuous	Activated when the breaker is open.
`Breakers > [Breaker] > State > [*B] is closed`	Digital output	Continuous	Activated when the breaker is closed.
`Breakers > [Breaker] > State > [*B] is synchronising`	Digital output	Continuous	Activated when the system is synchronising the breaker.
`Breakers > [Breaker] > State > [*B] is de-loading`	Digital output	Continuous	Activated when the system is de-loading the breaker.

Application

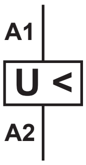
A digital output with a breaker state may be wired to a switchboard light, to help the operator.

For example, for a **MAINS** controller, a digital output may have the `Mains breaker > State > MB is deloading` function. A switchboard light is lit when the controller system is de-loading the shaft generator breaker.

5.3.4 Breaker under-voltage coil configuration

You can configure a breaker to use an under-voltage coil. The controller can then know that the breaker is open when there is a low voltage. This can be used in cases where there is no redundant breaker feedback connected and a blackout occurs.

Use PICUS to configure the under-voltage coil setting on the breaker.



More information
See the **PICUS manual** for how to configure the breaker for an under-voltage coil.

5.4 Synchronisation functions

5.4.1 Dynamic synchronisation

During dynamic synchronisation, the synchronising genset can run at a slightly different speed to the genset(s) on the busbar. This speed difference is called the *slip frequency*. Dynamic synchronisation is recommended where fast synchronisation is required, and where the synchronising genset is able to take load when the breaker closes.

The synchronising genset is typically run with a positive slip frequency. That is, the synchronising genset runs at a slightly higher speed than the genset(s) on the busbar. This is to ensure that the synchronising genset starts to deliver power immediately after synchronisation, and thereby avoid a reverse power situation.

This type of synchronisation is relatively fast because of the minimum and maximum frequency differences. Synchronisation is possible while the controller is still regulating the frequency towards the set point. The frequency does not have to be the same as the busbar frequency. As long as the frequency difference is within the limits and the phases are matched, the controller can send the close breaker signal.

NOTE Dynamic synchronisation is recommended where fast synchronisation is required, and where the incoming gensets are able to take load when the breaker closes.

Digital input

If required, assign a digital input to select dynamic synchronisation.

Function	I/O	Type	Details
`Breakers > [Breaker] > Command > [*B] dynamic synchronisation`	Digital input	Continuous	**Activated**: The controller uses dynamic synchronisation. **Deactivated**: The controller uses the synchronisation defined in the *Sync. type* parameter.

Parameters

`Breakers > [Breaker] configuration > Synchronisation setting`

Name	Range	Notes
`Sync. type`	Dynamic, Static, Automatic *	*Dynamic or Automatic ** must be selected.
`Delta frequency min.`	-2.0 to 2.0 Hz	For synchronisation: Add *Delta frequency min.* to the busbar frequency, for the **minimum** frequency of the synchronising generator. If this value is too low, there can be reverse power when the breaker closes.
`Delta frequency max.`	-2.0 to 2.0 Hz	For synchronisation: Add *Delta frequency max.* to the busbar frequency, for the **maximum** frequency of the synchronising generator. *Delta frequency max.* must always be higher than *Delta frequency min.*
`Delta voltage min.`	2.0 to 10.0 % of nominal voltage	The maximum that the voltage of the synchronising generator may be below the voltage of the busbar for the breaker to close.
`Delta voltage max.`	2.0 to 10.0 % of nominal voltage	The maximum that the voltage of the synchronising generator may be above the voltage of the busbar for the breaker to close.
`Breaker close time`	40 to 300 ms	The time between when the close breaker signal is sent and when the breaker actually closes.

NOTE * Automatic is only available on **MAINS** and **BUS TIE breaker** controllers. The controller checks the information for the busbar section connected to the breaker. If the section can be regulated, the controller uses dynamic synchronisation. Otherwise the controller uses static synchronisation. See Mains breaker synchronisation and Bus tie breaker synchronisation for more details.

Frequency window example

Busbar frequency: **50.1 Hz**
Delta frequency min.: **-0.1 Hz**
Delta frequency max.: **0.3 Hz**

The generator frequency must be between **50.0 Hz** and **50.4 Hz** for synchronisation.

Slip frequency

The slip frequency target is calculated as follows:

Slip frequency = (*Delta frequency min.* + *Delta frequency max.*)/2

Slip frequency example

Delta frequency min.: **-0.1 Hz**
Delta frequency max.: **0.3 Hz**

The slip frequency is **0.1 Hz**.

When the dynamic synchronisation starts, the frequency control function regulates the synchronising genset frequency towards the following set point:

$$f_{set\ point} = f_{busbar} + \text{Slip frequency}$$

Slip frequency bad example

Delta frequency min.: **-0.3 Hz**
Delta frequency max.: **0.3 Hz**

The slip frequency is **0.0 Hz**. There is a risk that there will be a long synchronisation time, because there is no change in the phase difference.

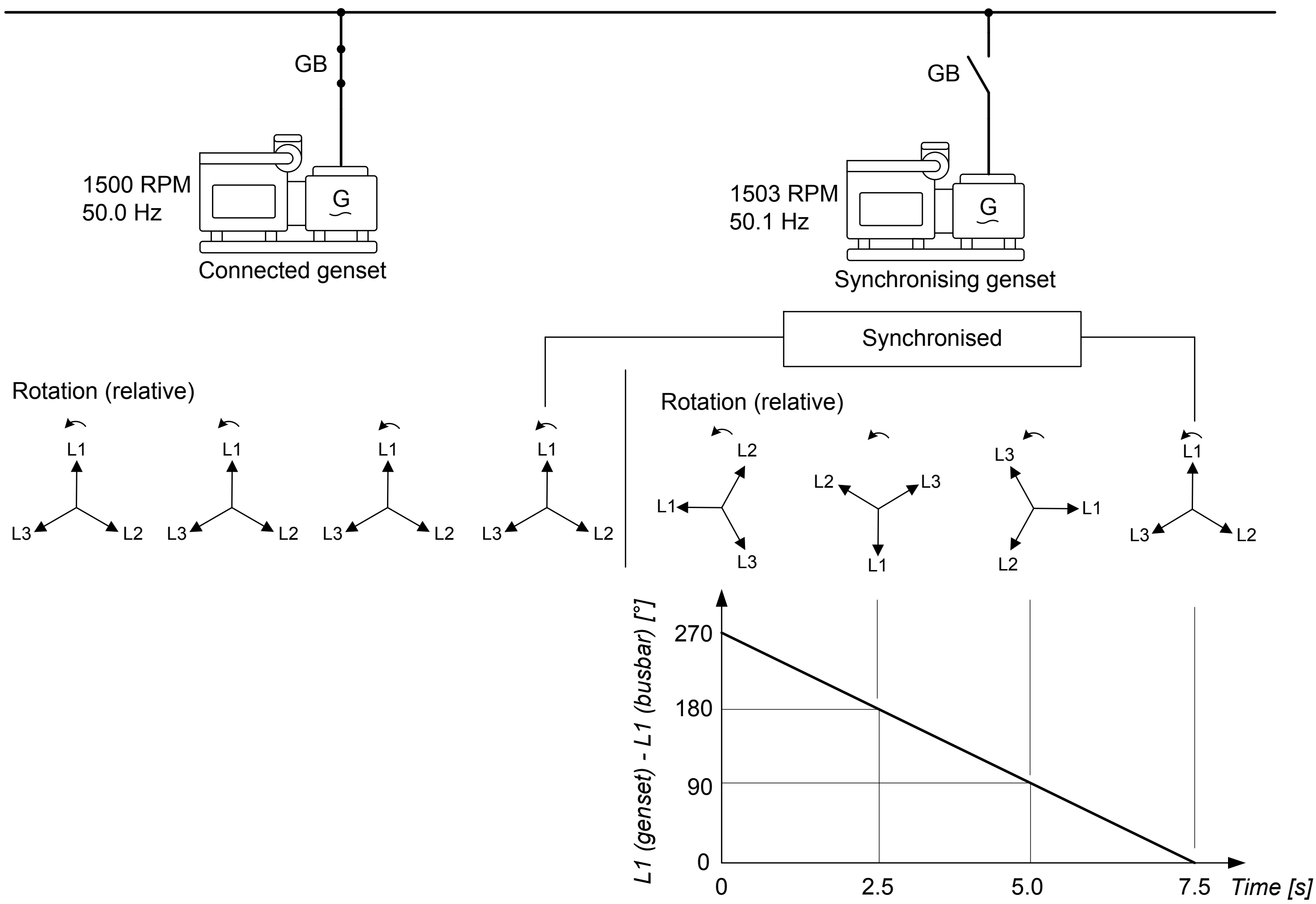
Speed up for slip frequency under 0.3 Hz

If the slip frequency is under 0.3 Hz, the controller automatically changes the slip frequency target until the phase difference is 30 degrees. This cannot be configured or disabled.

Dynamic synchronisation principle

The dynamic synchronisation principle is shown in the following example.

Figure 5.1 Dynamic synchronisation principle, with phasor diagrams



The power sources are the connected gensets and the synchronising genset. Synchronisation minimises the phase difference between the power sources.

In this example, the synchronising genset is running at 1503 RPM (about 50.1 Hz). The connected genset is running at 1500 RPM (50.0 Hz). This gives the synchronising genset a positive slip frequency of 50.1 Hz - 50.0 Hz = 0.1 Hz. If the slip frequency is less than *Delta frequency max.*, and more than *Delta frequency min.*, then the controller can close the breaker when the power sources are synchronised (subject to the voltages also being within the required limits).

In the example above, the difference in the phase between the synchronising genset and the busbar gets smaller and smaller. When the difference in the phases is near zero, the controller will send the breaker close signal based on the

Breaker closing time (this is not shown in the example). In this way, the breaker physically closes when the genset and the busbar phases are exactly aligned.

When the generator is running with a positive slip frequency of 0.1 Hz relative to the busbar, the phases of the two systems will be aligned every 10 seconds:

$$T_{sync} = 1 / (f_{sync\ genset} - f_{busbar}) = 1 / (50.1\ Hz - 50.0\ Hz) = 10\ s$$

The phases for both three-phase systems rotate. However, in this example, the phasors for the busbar are shown as stationary to simplify the explanation. This is because we are only interested in the phase difference.

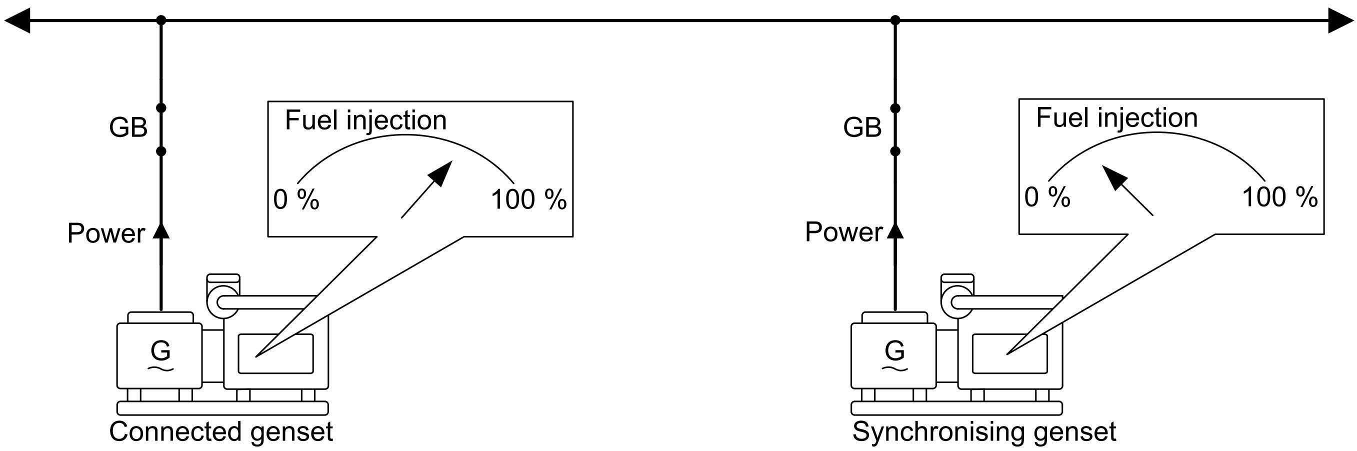
Load distribution after synchronisation

When the breaker closes, the synchronising genset will take some of the load if it had a positive slip frequency. A negative slip frequency will lead to reverse power in the synchronising genset.

The proportion of the load that the synchronising genset takes depends on the frequency difference, and the prime mover characteristics.

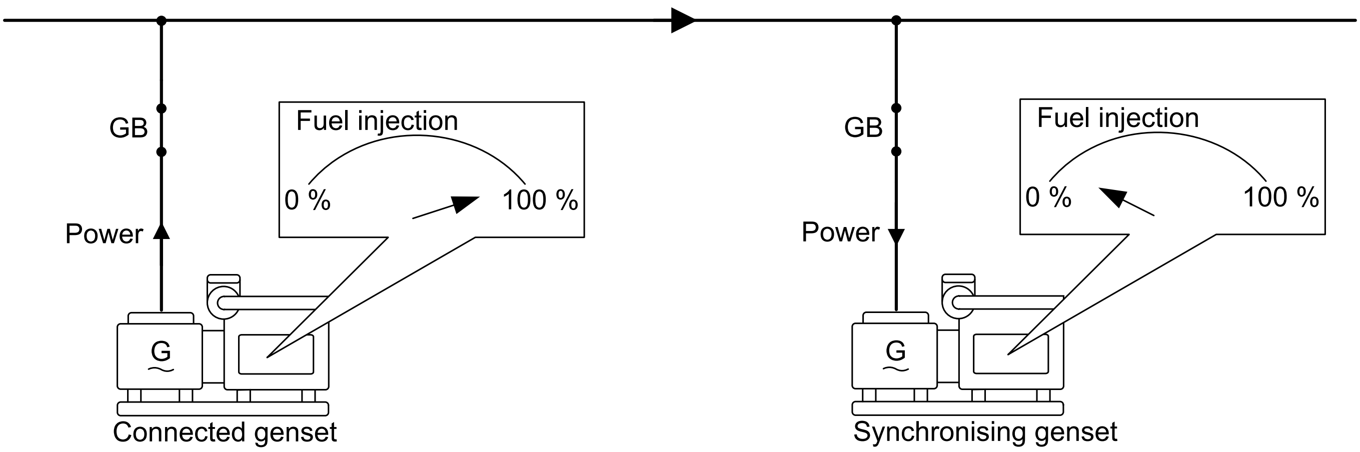
The following example shows that at a given *positive* slip frequency, the synchronising genset will *export* power to the load after the breaker closes.

Figure 5.2 Example of load distribution after synchronisation with a positive slip frequency



The following example shows that at a given *negative* slip frequency, the synchronising genset will *receive* power from the connected genset when the breaker closes. This can cause a reverse power trip.

Figure 5.3 Example of load distribution after synchronisation with a negative slip frequency



NOTE To avoid trips caused by reverse power, configure the synchronisation parameters for a positive slip frequency.

Close breaker signal

The controller always calculates when to send the close breaker signal to get the best possible synchronisation of the power sources. The close breaker signal is sent just before the power sources are synchronised. The close breaker signal is timed so that the breaker is closed when the difference in the phases of the L1 phasors is zero.

The timing of the close breaker signal depends on the *Breaker closing time* and the slip frequency.

For example, if the response time of the circuit breaker (t_{CB}) is 250 ms, and the slip frequency (f_{slip}) is 0.1 Hz:

$$\text{degrees}_{CLOSE} = 360 \text{ degrees} \times t_{CB} \times f_{slip} = 360 \text{ degrees} \times 0.25 \text{ s} \times 0.1 \text{ Hz} = 9 \text{ degrees}$$

In this example, the controller activates the close breaker output 9 degrees before the phases are aligned.

5.4.2 Static synchronisation

During static synchronisation, the synchronising genset runs very close to the same speed as the generator on the busbar. The aim is to let the gensets run at exactly the same speed, with the phases of the A-side and the B-side matching exactly. Static synchronisation is most suited to systems with a very stable frequency.

Static synchronisation is recommended where a slip frequency is not acceptable.

Static synchronisation should only be used with an analogue output (that is, not relay outputs).

Static synchronisation application example

Use static synchronisation during commissioning, to synchronise the genset to the busbar while the breaker closing is disabled. The commissioning engineer can then measure the voltages across the breaker, as a safety check.

Inputs and outputs

This function uses the controller AC measurements, regulators, and breaker configuration.

Digital input

You can use a parameter to configure the synchronisation type as *Static synchronisation*. If you need to change the synchronisation type, you can assign a digital input to select static synchronisation.

Function	I/O	Type	Details
`Breakers > [Breaker] > Command > [*B] static synchronisation`	Digital input	Continuous	**Activated**: The controller uses static synchronisation. **Deactivated**: The controller uses the synchronisation defined in the *Sync. type* parameter.

Static synchronisation digital input examples

A system has several bus tie breakers and a ring busbar. The bus tie breakers are configured for dynamic synchronisation. However, to close the last breaker in the ring, the controller must use static synchronisation.

A system has two connections to the same mains supply. The mains breakers are configured for dynamic synchronisation. To connect the second mains breaker, the controller must use static synchronisation.

For both of these examples, you do not need the digital input if you configure the *Sync. type* as *Automatic*.

Parameters

`Breakers > [Breaker] configuration > Synchronisation setting`

Name	Range	Notes
`Sync. type`	• Dynamic • Static	*Static* must be selected. To see the static synchronisation parameters, write the change to the controller, and refresh.
`Delta frequency min.`	-2.0 to 2.0 Hz	For synchronisation: Add *Delta frequency min.* to the B-side frequency, for the **minimum** frequency of the synchronising generator. This value must be negative for static synchronisation.
`Delta frequency max.`	-2.0 to 2.0 Hz	For synchronisation: Add *Delta frequency max.* to the B-side frequency, for the **maximum** frequency of the synchronising generator. *Delta frequency max.* must always be higher than *Delta frequency min.*
`Delta voltage min.`	2.0 to 10.0 % of nominal voltage	The maximum that the voltage of the synchronising generator may be below the voltage of the busbar for the breaker to close.
`Delta voltage max.`	2.0 to 10.0 % of nominal voltage	The maximum that the voltage of the synchronising generator may be above the voltage of the busbar for the breaker to close.
`Breaker close time`	40 to 300 ms	The time between when the close breaker signal is sent and when the breaker actually closes. This is not used for static synchronisation.
`Phase window`	0.0 to 45.0°	The maximum phase difference allowed for synchronisation.
Minimum time in phase window	0.1 s to 15 min	To close the breaker, the measurements must show that the controller will be able to keep the phase difference within the phase window for this minimum time.

Frequency window example

Busbar frequency: **50.1 Hz**
Delta frequency min.: **-0.1 Hz**
Delta frequency max.: **0.3 Hz**

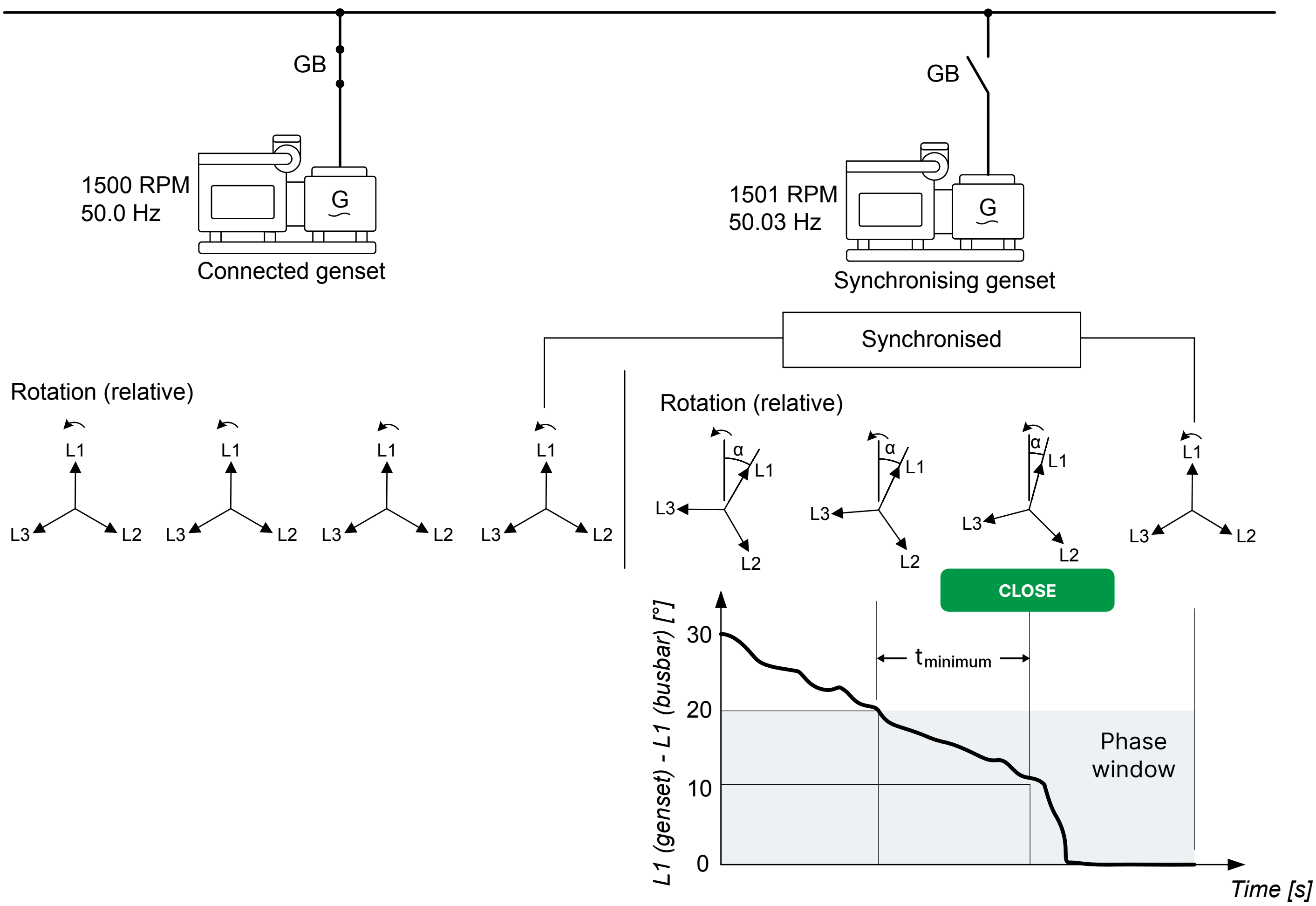
The generator frequency must be between **50.0 Hz** and **50.4 Hz** for synchronisation.

NOTE For static synchronisation, on average, the frequencies need to be nearly identical.

Static synchronisation principle, with phasor diagrams

The static synchronisation principle is shown below. Phase regulation for synchronisation reduces the phase difference to meet the static synchronisation requirements.

Figure 5.4 Static synchronisation principle



Phase regulation for synchronisation

When static synchronisation is started, if the frequency difference is outside the frequency window, the frequency regulation regulates the synchronising genset frequency towards the busbar frequency.

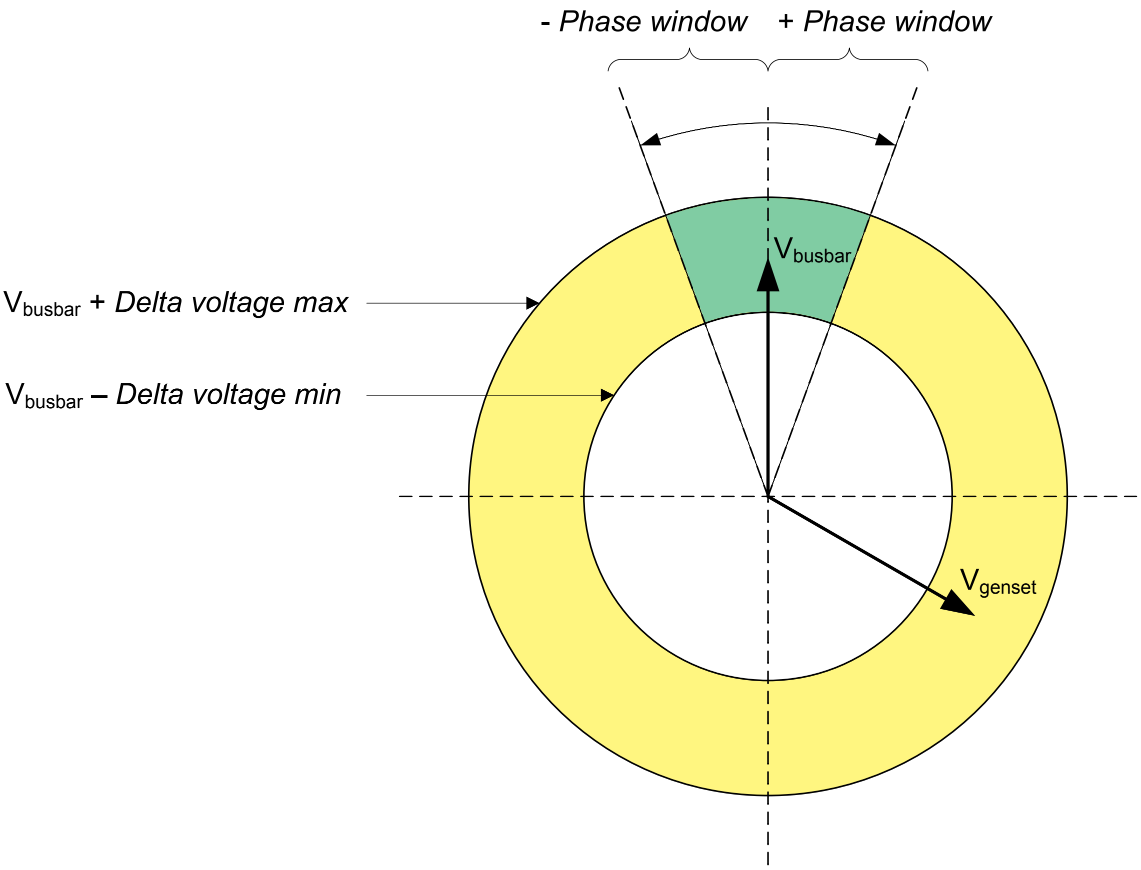
When the genset-busbar difference is 200 mHz, the phase synchronisation function takes over. The phase regulator for synchronisation aims to minimise the angle between the synchronising genset and the busbar.

Close breaker signal

The output `Breaker > [Breaker] > Control > [*B] Close` is activated when the phase difference between the synchronising generator and the busbar is kept within the *Phase window* while the *Minimum time in phase window* timer runs. The voltage differences must also be within the configured range (*Delta voltage min.* and *Delta voltage max.*). This is shown in the following drawing. In addition, the frequency differences must be within the configured range (*Delta frequency min.* and *Delta frequency max.*).

The response time of the breaker is not relevant when using static synchronisation.

Figure 5.5 Voltage and phase difference for static synchronisation



Load distribution after synchronisation

The difference between the frequencies of A-side and B-side is low. The load distribution therefore does not change much when the breaker closes.

5.4.3 Regulator parameters for synchronisation

During synchronisation the controller regulates the governor to change the frequency or phase. These settings are only used during synchronisation, and can be configured to optimise the synchronisation speed for the system.

If the controller can regulate the AVR, it also regulates the voltage. Note that there are no special parameters for voltage regulation for synchronisation.

Analogue synchronisation parameters

`Regulators > GOV analogue configuration > Frequency synchronisation`

Parameter	Range	Notes
`Kp`	0.00 to 60.00	The PID gain for the regulator.
`Ti`	0.00 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0.00 to 2.00 s	The PID control derivative.

`Regulators > GOV analogue configuration > Phase synchronisation`

The phase synchronisation parameters are only used when static synchronisation is selected.

Parameter	Range	Notes
`Kp`	0.00 to 60.00	The PID gain for the regulator.
`Ti`	0.00 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0.00 to 2.00 s	The PID control derivative.

Relay synchronisation parameters

`Regulators > GOV relay configuration > Frequency synchronisation`

Parameter	Range	Notes
`Kp`	0 to 100	The gain for the regulator.

`Regulators > GOV relay configuration > Phase synchronisation`

Note: When static synchronisation is required, DEIF does not recommend using digital outputs to regulate the governor. The phase synchronisation parameter is only used when static synchronisation is selected.

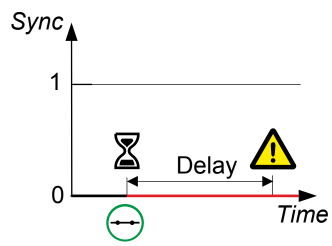
Parameter	Range	Notes
`Kp`	0 to 100	The gain for the regulator.

5.5 Synchronisation and breaker alarms

5.5.1 Breaker synchronisation failure

This alarm alerts the operator about a breaker synchronisation failure.

The alarm is based on the synchronisation of the A-side to the B-side, as measured by the controller. The alarm is activated if the controller has not been able to synchronise within the delay time.



`Breakers > [Breaker] monitoring > Synchronisation failure`

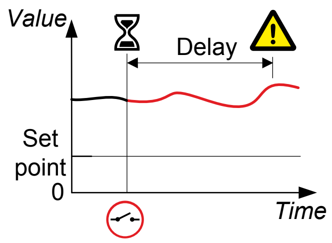
Parameter	Range
`Delay`	30.0 s to 5 min

5.5.2 De-load failure

This alarm alerts the operator to breaker de-load failure.

The alarm is based on the load across the breaker, as measured by the controller. When the controller internal set point has ramped down to the breaker open point, the timer starts. The controller activates the alarm if the load across the breaker is not reduced to the *Open point (de-loading)* within the delay time.

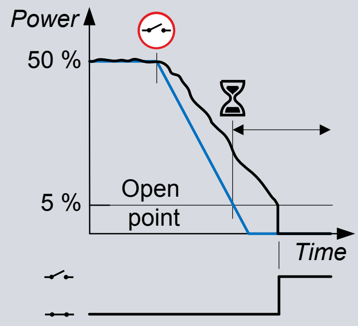
The *Open point (de-loading)* is configured under **Breakers > [Breaker] configuration > Configuration**.



Parameter	Range
Delay	0.0 s to 1 h

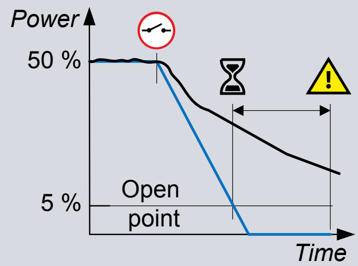
Effect of de-load ramp example

The genset is running at 50 % of nominal power. The breaker open point is 5 % of nominal power. The graph shows the power set point in blue, and the genset power in black. The breaker opens in time, and there is no de-load error.



Effect of slow de-loading example

The genset is running at 50 % of nominal power. The breaker open point is 5 % of nominal power. The graph shows the power set point in blue, and the genset power in black. The de-loading is a lot slower than the power set point ramp down. The breaker does not open in time, and there is a de-load error alarm.



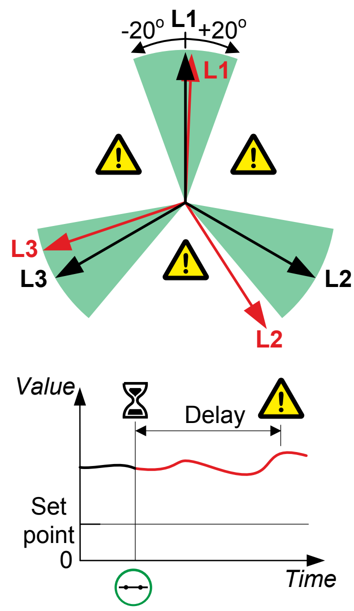
More information
See Regulation for more information about de-loading.

5.5.3 Vector mismatch

This alarm alerts the operator to a vector mismatch during synchronisation.

The alarm is based on the difference between the phases on either side of the breaker, as measured by the controller. The alarm is activated when synchronisation is ON and the difference in the phases is more than the set point.

On the diagram to the right, the phasor diagram for the busbar is black, and the mismatch that is allowed by default is green. The phasor diagram for the A-side is red. L2 is outside the allowed window.



`Breakers > [Breaker] monitoring > Vector mismatch`

Parameter	Range
`Set point`	1 to 20°
`Delay`	5.0 s to 1 min*

NOTE * DEIF recommends that this delay is lower than the genset *Breaker synchronisation failure* delay.

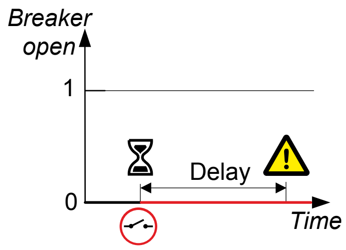
Frequency-based inhibit

The *Vector mismatch* alarm is inhibited outside of the synchronisation window. That is, it is inhibited if the frequency from the A-side is more than the *Delta frequency min.* below the B-side frequency, or the *Delta frequency max.* above the B-side frequency. These parameters are defined under **Synchronisation settings**.

5.5.4 Breaker opening failure

This alarm alerts the operator to a breaker open failure.

The alarm is based on the breaker feedback signal(s) (a digital input, or two digital inputs) to the controller. The alarm timer starts when the controller sends the signal to open the breaker. The alarm is activated if the breaker feedback does not change from closed to open within the delay time.



The alarm is always enabled when at least one breaker feedback is configured. The alarm always has the *Latch enabled*.

If no breaker feedback is configured in the **Input/output** for the breaker, then the alarm parameters are not visible.

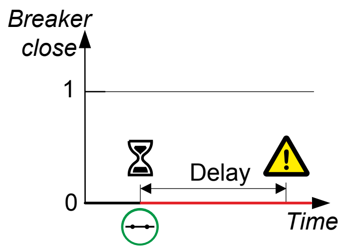
`Breakers > [Breaker] monitoring > Opening failure`

Parameter	Range
`Delay`	0.1 to 60.0 s

5.5.5 Breaker closing failure

This alarm is for breaker closing failure.

The alarm is based on the breaker feedback signal, which is a digital input to the controller. The alarm timer starts when the controller sends the signal to close the breaker. The alarm is activated if the breaker feedback signal does not change from open to closed within the delay time.



This alarm is always enabled when at least one breaker feedback is configured for the breaker. The alarm always has the *Latch enabled*.

If no breaker feedback is configured in the **Input/output** for the breaker, then the alarm parameters are not visible.

`Breakers > [Breaker] monitoring > Closing failure`

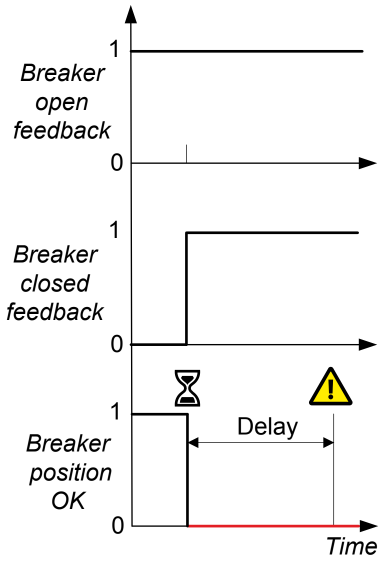
Parameter	Range
`Delay`	0.1 to 60.0 s

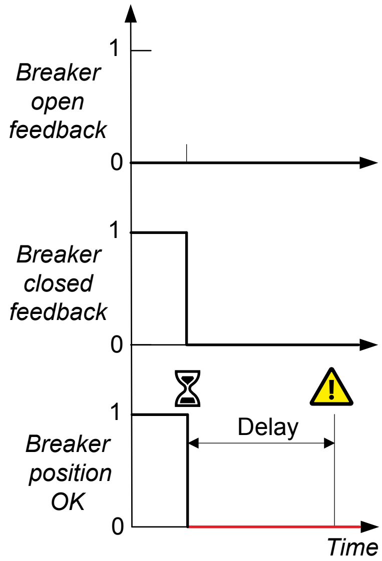
5.5.6 Breaker position failure

This alarm is for breaker position failure. The alarm is present where both open and closed feedback are configured.

The alarm is based on the breaker feedback signals, which are digital inputs to the controller. The alarm is activated if the breaker *Closed* and *Open* feedbacks are both missing for longer than the delay time. The alarm is also activated if the breaker *Closed* and *Open* feedbacks are both present for longer than the delay time.

When both breaker feedback functions are configured for the breaker, the alarm is always *Enabled* and has the *Latch enabled*.





If only one or no breaker feedbacks are configured in the **Input/output** for the breaker, then the alarm parameters are not visible.

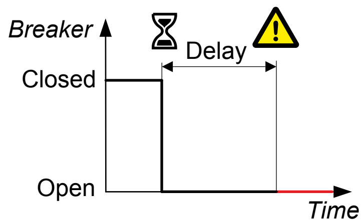
`Breakers > [Breaker] monitoring > Position failure`

Parameter	Range
`Delay`	0.1 to 5.0 s

5.5.7 Breaker trip (external)

This alarm alerts the operator to an externally-initiated breaker trip.

The alarm is activated if the controller did not send an open signal, but the breaker feedback shows that the breaker is open.

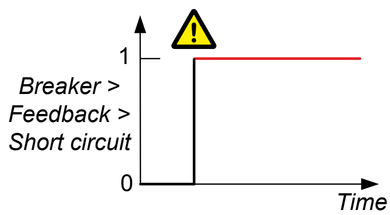


`Breakers > [Breaker] monitoring > Tripped (external)`

The alarm always has the *Latch enabled*. The delay is always 0.1 s.

5.5.8 Breaker short circuit

The alarm response is based on the digital input with the *Breakers > Feedback > [*B] short circuit* function (see below). This digital input is typically wired to the breaker's short circuit feedback output.



Parameter

`Breakers > [Breaker] monitoring > Short circuit`

Digital input

Function	I/O	Type	Details
`Breakers > [Breaker] > Feedback > [*B] short circuit`	Digital input	Continuous	• Required for short circuit detection, when the breaker is tripped independently due to a short circuit. One input is required for each breaker. • The breaker activates this input when it detects a short circuit. The controller then activates the *[Breaker] short circuit* alarm.

5.5.9 Breaker configuration failure

This alarm blocks breaker operation if the breaker is not properly configured. The alarm is activated if a breaker is present on the single-line application drawing, but the **Input/output** functions that are required for the breaker type are not fully configured.

This alarm is always enabled, and has the alarm action *Block* with *Latch enabled*. You cannot see or change the parameters for this alarm.

6. Regulation

6.1 About regulation

6.1.1 How it works

The **SINGLE genset** and **GENSET** controllers can use analogue and/or relay control functions for regulation.

The controller sets the regulation mode according to the system conditions.

All the input and output information in this chapter is written from the DEIF controller point of view, except if clearly stated otherwise.

Overview of analogue control

Analogue control generally achieves finer control results than relay control. Analogue control also allows the controller to use a pulse width modulation (PWM) output, for governors and automatic voltage regulators that support this as an input (as an alternative to an analogue input to the governor or AVR). DEIF recommends that you use the full capability of analogue control in situations which require precision, such as static synchronisation.

Overview of relay control

Relay control is not able to produce the same precision as a well-tuned analogue controller. However, setting up relay control is simpler. To extend the life of relays, the controller has a range around the reference where the controller does not send regulation pulses to the governor or automatic voltage regulator. This range is called the regulation deadband. Analogue regulation does not have a deadband area, which contributes to more accurate regulation of the governor or AVR.

6.1.2 Analogue regulation

More information
See Analogue outputs for how to configure the analogue output(s) and PWM.

Configuring analogue outputs

Assign the analogue output regulation function(s) to the analogue output terminals under `Configure > Input/output`.

- `Regulators > GOV > GOV output [%]`
- `Regulators > AVR > AVR output [%]`

Configure the parameter to *Analogue* (where *[Regulator]* is *Governor* or *AVR*).

`Regulators > [Regulator] general configuration > Regulator output`

Parameter	Range
Output type	• Analogue / ECU (for GOV) • Analogue / DVR (for AVR) • Relay

Configuring pulse width modulation

Some governors require a pulse width modulation (PWM) input. The controller converts the analogue output to a PWM signal for the PWM terminals.

Connect the governor to the controller's PWM terminals.

Assign the `Regulators > GOV > GOV output [%]` function to the PWM terminals.

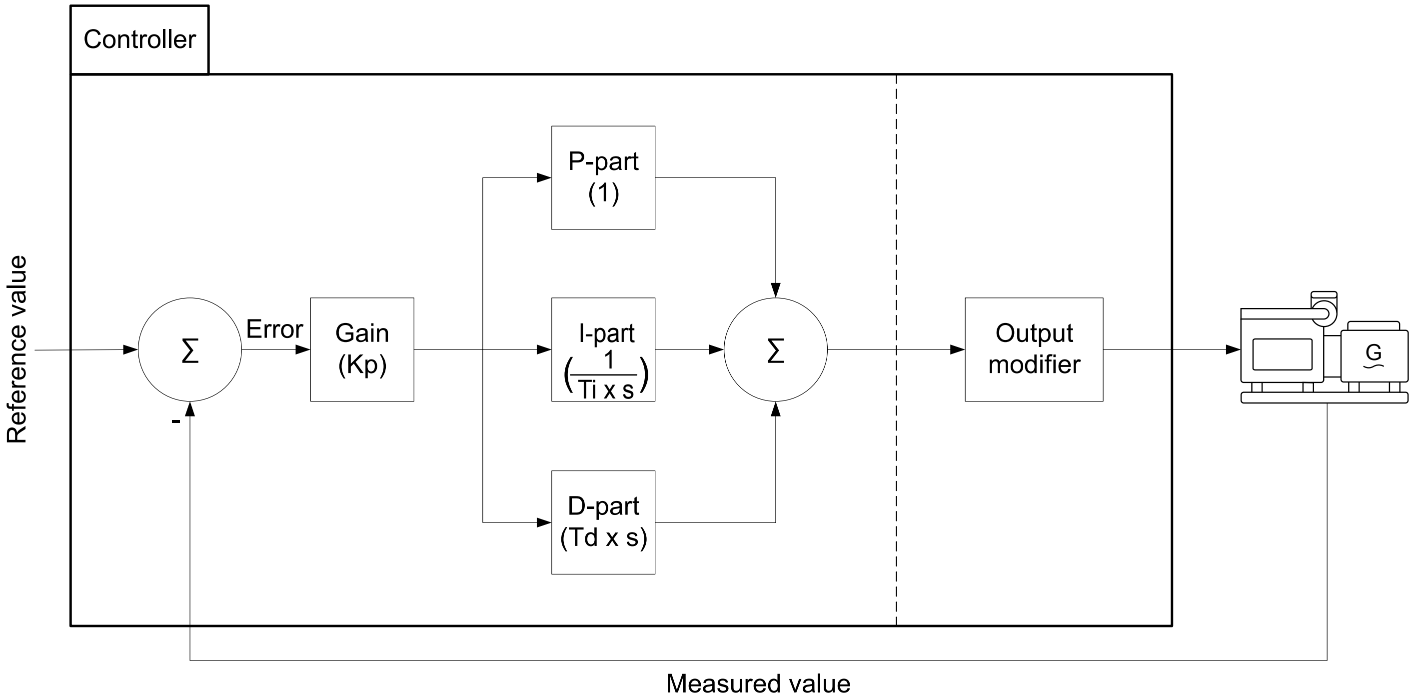
More information
See Pulse width modulation (PWM) output characteristics for the relationship between duty cycles and the PWM output.

Analogue PID controller

A schematic of the analogue PID controller is given below. Analogue control works as follows:

1. The controller measures the operating value(s).
2. The controller deducts the measured value from the reference value to determine the error (also known as the deviation).
3. The error is the input for the PID controller. The controller sends the PID controller output to the output modifier.
4. The output modifier converts the output from the PID controller as required for the governor or AVR.
5. The governor or AVR then regulate the genset fuel or excitation.

Figure 6.1 Simplified overview of the analogue PID controller



PID control

The PID controller consists of three parts.

Part	Contribution (Laplace domain)	Configurable parameters
Proportional part	1	Kp
Integral part	1 / (Ti x s)	Kp, Ti
Derivative part	Td x s	Kp, Td

Gain

The gain (*Kp*) determines the magnitude of the signal.

The same gain (*Kp*) is applied to **each part** of the analogue controller. That is, increasing the gain not only increases the proportional part, but also increases the integral part and the derivative part.

Proportional part

The proportional part contributes the gain × error to the PID output.

Gain (*Kp*) is the only term in the proportional part of the controller. That is, the contribution of the proportional part of the controller is directly proportional to the calculated error. For example, if *Kp* is 15 and the calculated error is +0.02, the proportional contribution is +0.30.

A high *Kp* makes the system respond strongly to the error. However, the response can be too large, and can lead to long settling times. A high *Kp* may make operation unstable.

A low *Kp* makes the system respond more weakly to the error. A low *Kp* can reduce the settling time. However, the response can be too small, and therefore ineffective.

Integral part

The integral part eliminates the steady-state error.

The integral part is determined by:

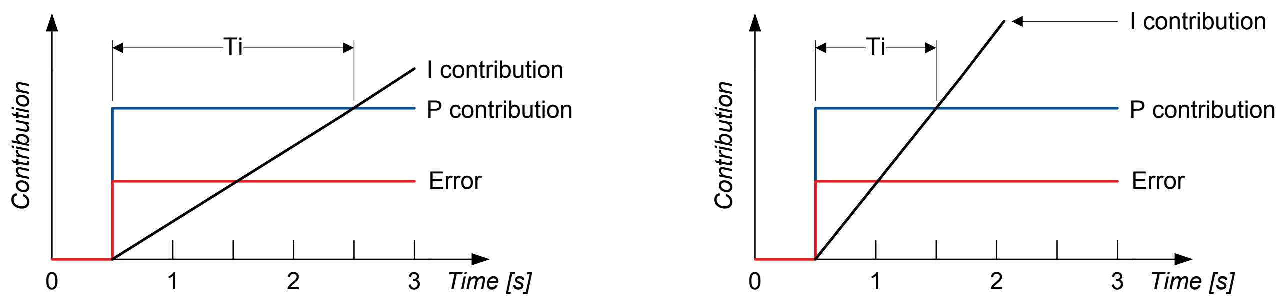
- The gain × error
- The integration time (*Ti*)
- The error history

Ti is the time it takes for the contribution of the integral part to be equal to the contribution of the proportional part. If *Ti* is reduced, the contribution of the integral part is increased.

Do not set *Ti* too low. This can make the operation unstable (the effect is similar to a very high gain).

The figures below show the effect of *Ti* (a constant error is used to simplify the example).

When the system is far away from the reference point the integral part will have a large contribution to the correction. When the system is close to the reference value, the integral part can have a small contribution to the correction.



The integral contribution results from integrating the error.

Set *Ti* to zero to turn off the integral part.

Derivative part

The derivative part stabilises operation, allowing higher gain and lower integral action times. The derivative part can improve the settling time.

The derivative part is determined by:

- The amplified error
- The derivative time (*Td*)
- The current rate of change of the error

The derivative part uses the current rate of change over *Td* to predict the future error. If *Td* is higher than the optimal time, the settling time can be very long. For very high values, the system might not be able to settle at the reference value (the effect is similar to a very high gain).

From experience, the derivative part can improve regulation during load sharing, power regulation and static synchronisation, when the parameter is properly tuned.

Use the derivative part if the situation requires very precise regulation (for example, static synchronisation). If the derivative part is used, it is important to tune it properly.

Set *Td* to zero to turn off the derivative part.

6.1.3 Relay regulation

Relay control uses the *[Regulator] increase* and *[Regulator] decrease* relays to increase or decrease the control signal, based on the output of the controller (where [Regulator] is either GOV, or AVR).

Droop must be enabled on the governor and/or AVR when you use relay regulation. If droop is not enabled on the governor and/or AVR, it is difficult to maintain a stable operation mode.

Configuring digital outputs

To use relay outputs to interface with the governor or AVR, assign the digital output regulation functions under `Configure > Input/output`.

Configure the parameter to *Relay* (where *[Regulator]* is *Governor* or *AVR*).

`Regulators > [Regulator] general configuration > Regulator output`

Parameter	Range
Output type	• Analogue / ECU (for GOV) • Analogue / DVR (for AVR) • Relay

Relay regulation ranges

The controller determines whether the output should be increased or decreased by comparing the measured value to the reference. The controller determines how far the deviation (also known as the error) is from the reference, multiplies it by the gain, and selects the output range. The output can be in one of three ranges, which are summarised in the table below:

Range	Relay position	Notes
Constant range	Closed	See the diagrams below. The measured value is far away from the reference value. The *[Regulator] increase* * or *[Regulator] decrease* * relay is activated for the maximum time allowed by the *Period time*. If the measured value is still far away after the maximum time was reached, then the relay is reactivated after the *Period time* is reached.
Variable range	Intermittent open/close	The measured value is approaching the reference value, but is not in the deadband range yet. The *[Regulator] increase* * or *[Regulator] decrease* * relay pulses. The signal from the relay is thus intermittent. The length of the pulse is dependent on the distance from the reference value, the period time and the controller gain, *Kp*. If the measured value is further away from the reference value, the controller uses a longer pulse. If the measured value is closer to the reference value, the controller uses a shorter pulse. You can define the minimum pulse width. See points 2, 3, 4 and 5 on the figures below.
Deadband range	Open	The measured value is so close to the reference value that it is within the deadband percentage of the reference value. The deadband is specific to the control type that is active, and you can define the deadband value. The *[Regulator] increase* * and *[Regulator] decrease* * relays remain deactivated continuously.

Range	Relay position	Notes
		See point 6 on the figures below.

NOTE * [Regulator] is either GOV, or AVR.

If the output is in either the constant or the variable range, the controller activates the configured relay (governor increase or decrease, or AVR increase or decrease) for the required time. The figures below show how the time decreases from the value set for *Period time* to the value set for *Minimum ON time* as the measured value gets closer to the reference for high *Kp* values and low *Kp* values.

Figure 6.2 Up and down relay on time for different errors (deviations from the reference)

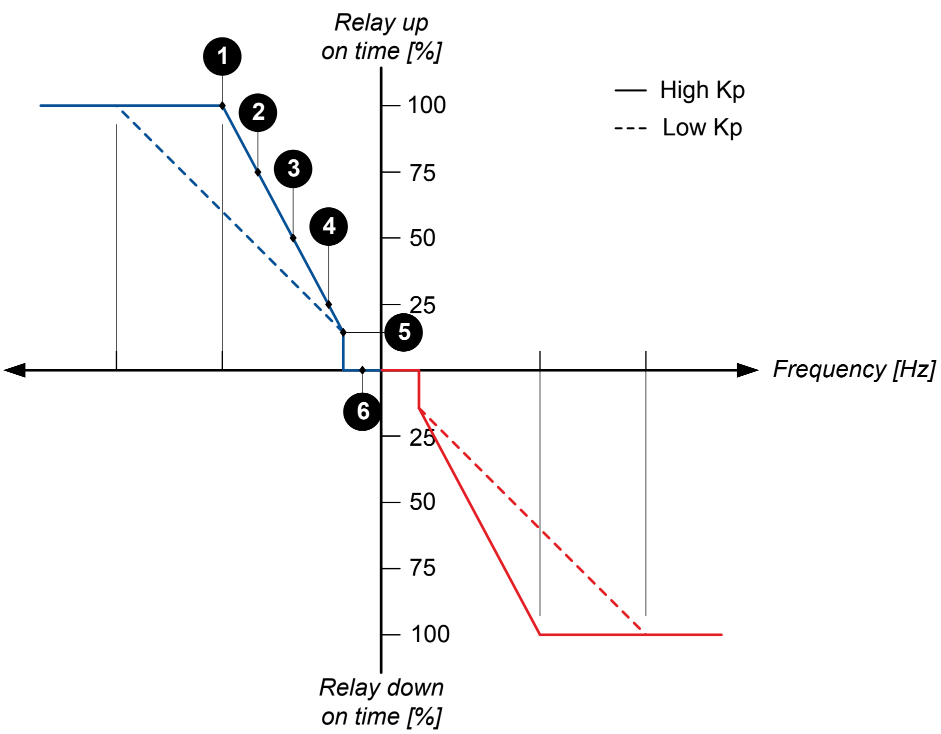
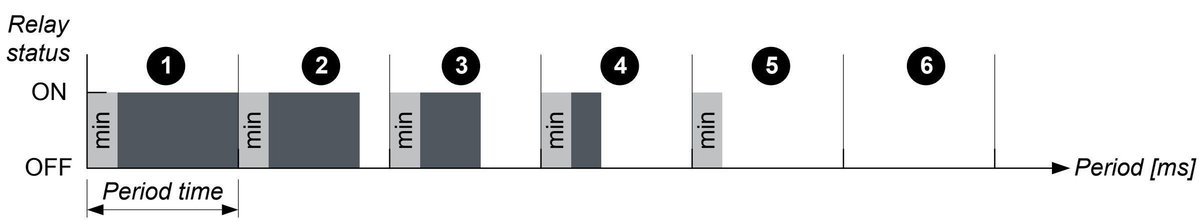


Figure 6.3 Relay action (based on measurements at the end of the period time)



Pulse properties

A relay regulator output has these main properties:

- Period time
- Minimum ON time

The *Period time* defines the time from the start time of one pulse to the start time of the next pulse.

The *Minimum ON time* sets the minimum amount of time a relay is allowed to be closed. This should be similar to the minimum time required for the system to respond to the output signal.

The pulse length is never shorter than the *Minimum ON time*. As *Kp* increases, the variable range decreases. As *Kp* decreases, the variable range increases.

6.1.4 Droop

The droop percentage for a genset governor is a measure of how much the engine speed changes when there is a change in the genset power output. Similarly, for a genset AVR, the droop percentage shows the relationship between the generator voltage and the reactive power output.

Regulation of a genset using frequency droop or voltage droop might be required under certain system conditions. For example, when the controller cannot interface with all the controllers in the system.

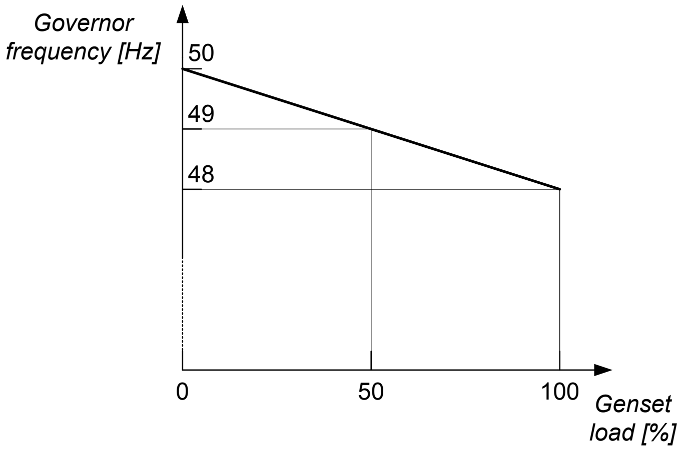
Droop definitions

Droop name	Description
Governor or AVR droop	The droop setting of the governor or AVR. The governor droop and AVR droop is always present when it is activated in the governor or AVR.
Controller droop	The droop setting in the controller. This refers to the *Frequency droop* parameter, the *Voltage droop* parameter, or both parameters. The controller droop setting is only active when the frequency droop and/or voltage droop is the selected regulation mode. When the regulation mode is present, the controller regulates the governor and/or AVR to follow the droop curve, based on the emulated droop from the controller.
Frequency droop	This droop value is related to the engine speed. Since engine speed and the generator frequency are proportional, you can also use the generator frequency to calculate frequency droop (governor droop).
Voltage droop	The droop value that is related to the generator voltage (AVR droop).

When the controller is in *Frequency droop* or *Voltage droop* regulation mode, the regulation of the governor and AVR emulates a situation where the load sharing is controlled by the droop. For example, when there is a higher load, the controller regulates the governor to get a slightly lower frequency. The droop setting in the controller does not change the actual droop in the governor or AVR.

The genset frequency follows the frequency of the busbar when more than one power generating assets or mains is connected to the busbar. The power output is related to the frequency by the droop curve when droop is activated in the governor, or when frequency droop is the active regulation mode in the controller. When the load on the busbar changes (for example, when a load is added or removed), all the gensets that are connected to the busbar that are in droop mode will adjust their power output according to the droop curve at the busbar frequency. If the gensets have the same droop value, then the load is shared equally between the gensets.

Figure 6.4 Example of a frequency droop curve for a genset with 4% frequency droop

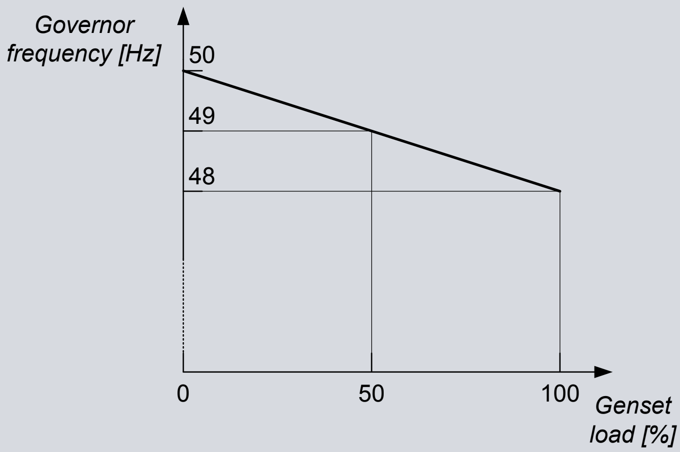


The reactive power output is related to the voltage by the voltage droop curve when droop is activated in the AVR, or when voltage droop is the active regulation mode on the controller. The reactive power load during voltage droop is shared in a similar way as active power is shared during frequency droop.

Gensets with the same droop setting example

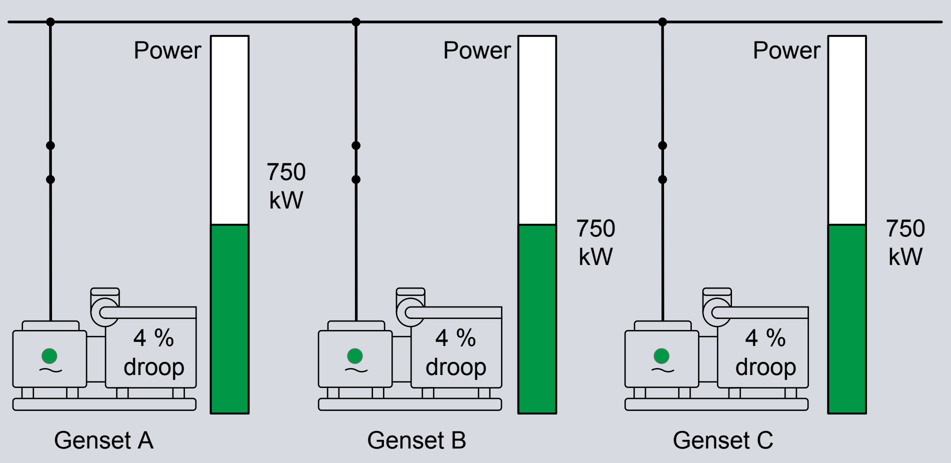
Gensets A, B and C have a nominal power of 1500 kW each and operate at a nominal frequency of 50 Hz. Each genset has a 4 % controller droop. The droop curve for each genset is the same, and is shown in the figure below.

Figure 6.5 Droop curve for gensets A, B and C



All of the gensets are connected to the busbar and are running frequency droop as the active regulation mode. When the load on the busbar increases to 2250 kW, the gensets are able to share the load equally because they have the same droop. The new frequency of the busbar and the gensets is 49 Hz (50 Hz × (1 - 0.04 × 750 kW / 1500 kW) = 49 Hz).

At a total load of 2250 kW, the system runs at 49 Hz. Gensets A, B and C each supply 750 kW (50 % of nominal power).

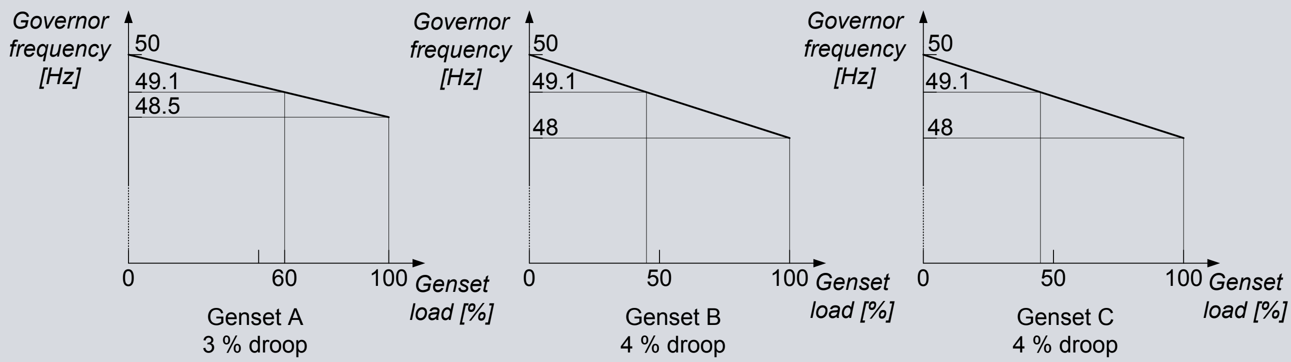


If the gensets that are connected to the same busbar section have different droop settings, the genset(s) with a lower droop will be loaded more. When the droop curve for one or more gensets are different from the other gensets on the busbar, the gensets take a different proportion of the load due to the different droop curves.

Gensets with different droop settings example

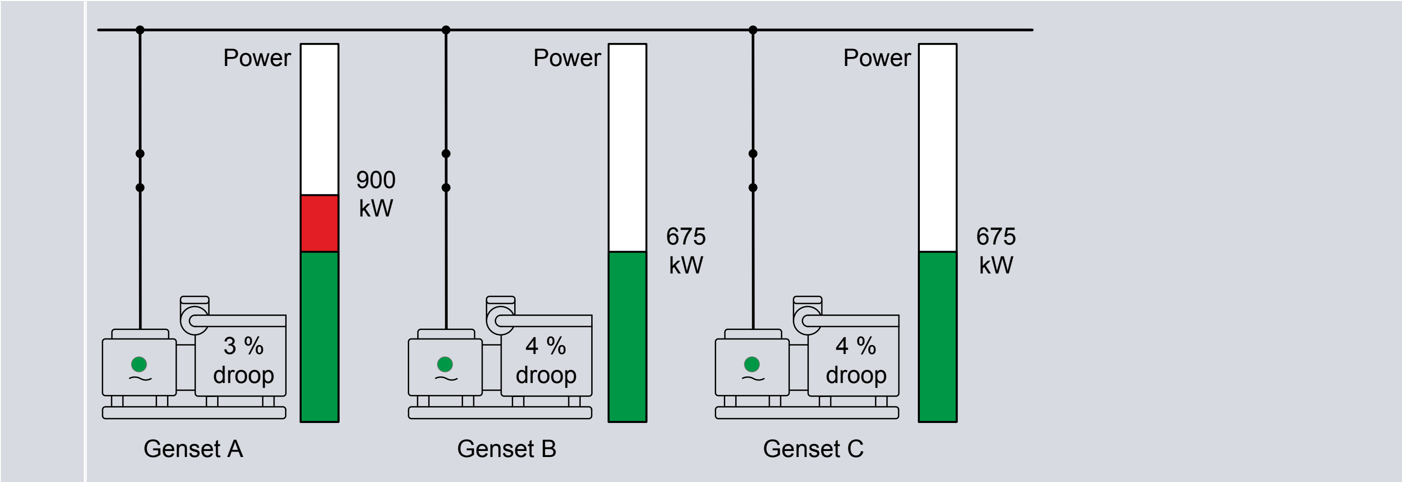
Gensets A, B and C have a nominal power of 1500 kW each and operate at a nominal frequency of 50 Hz. Genset A has a 3 % droop and gensets B and C each have a 4 % droop.

Figure 6.6 Droop curves for gensets A, B and C



All of the gensets are connected to the busbar and are running frequency droop as the active regulation mode. When the load on the busbar increases to 2250 kW, the load is not shared equally between the gensets. The new frequency on the busbar is 49.1 Hz. Because all the generators on the busbar operate at the same frequency, Genset A takes more of the load than gensets B and C.

At a total load of 2250 kW, the system runs at 49.1 Hz. Genset A supplies 900 kW (60 % of nominal power), while Gensets B and C each supply 675 kW (45 % of their nominal power).



More information
See Frequency droop and Voltage droop for information about these regulation modes.

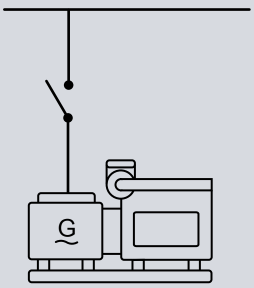
6.1.5 Regulation rules

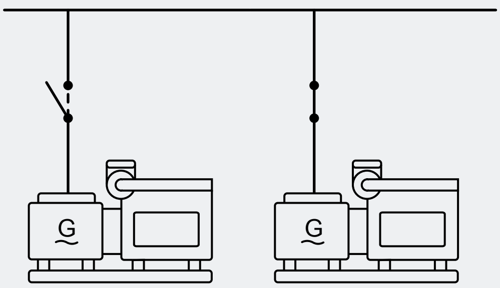
The controller regulates the genset as follows:

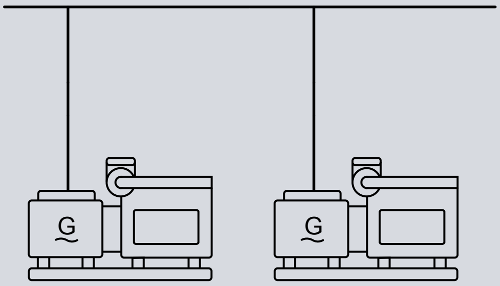
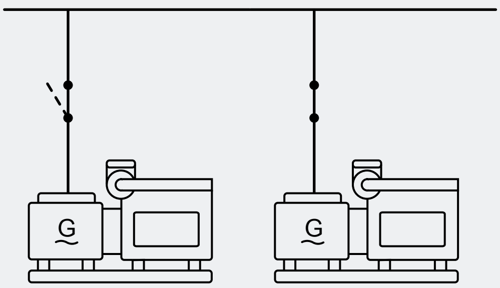
- **Not connected**: According to the selected regulation mode and inputs.
- **Synchronising**: The controller synchronises the genset to the busbar. The regulation mode and other inputs are ignored.
- **Connected**: According to the selected regulation mode and inputs.

During regulation of the system, the guidelines for the controller mode selection should be followed. The suggested regulation mode in the table is always for the asset on the left side of the busbar in the image.

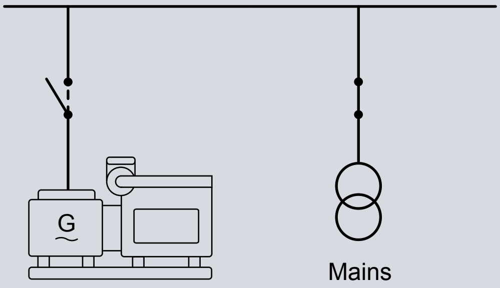
Suggested regulation modes

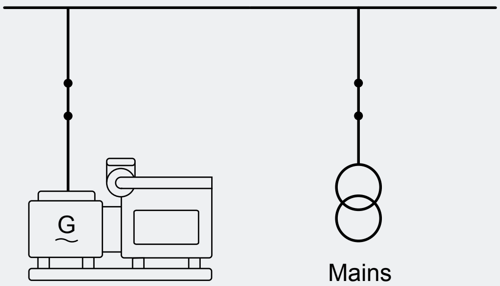
Condition		Suggested governor mode	Suggested AVR mode	Set point source
	The generator breaker is open and the genset is running. This can be a stand-alone genset, or a genset in a system.	• Fixed frequency (Recommended) • Fixed RPM (Recommended for asynchronous gensets) • Power load share • Frequency droop	• Fixed voltage (Recommended) • Reactive power load share • Voltage droop	• Genset nominal frequency • Genset nominal voltage

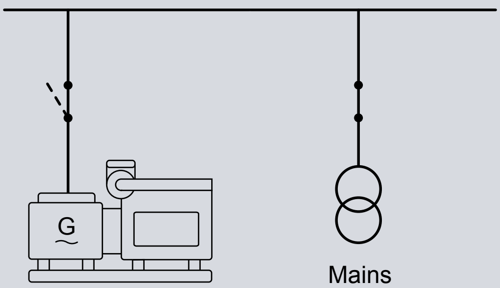
	The generator breaker is open and the **GENSET** controller receives a close breaker command.	• Before sending command to close breaker:
		  ◦ Fixed frequency (Recommended)
		  ◦ Fixed RPM (Recommended for asynchronous gensets)
			• Before sending command to close breaker:
			  ◦ Fixed voltage (Recommended)
			  ◦ Reactive power load share
			  ◦ Voltage droop
			• No mode selection required while synchronising	

Condition		Suggested governor mode	Suggested AVR mode	Set point source
	The controller sends commands to synchronise genset to the busbar frequency and voltage.	◦ Power load share ◦ Frequency droop • No mode selection required while synchronising		
	The genset is connected to the busbar without mains and is producing power. The genset can be one genset connected to the busbar, or a genset running parallel to another power producing component (except mains) on the busbar.	• Power load share (Recommended) • Fixed power • Frequency droop	• Reactive power load share (Recommended) • Fixed reactive power • Fixed cos phi • Voltage droop	• Controller set point • External set point ◦ Modbus ◦ Analogue
	The genset is running parallel to another power producing component on the busbar (except mains). The **GENSET** controller receives a open breaker command. The controller sends	• Before sending command to open breaker: ◦ Power load share (Recommended) ◦ Fixed power ◦ Frequency droop • No mode selection required while de-loading	• Before sending command to open breaker: ◦ Reactive power load share (Recommended) ◦ Fixed reactive power ◦ Fixed cos phi ◦ Voltage droop • No mode selection required while de-loading	

Condition		Suggested governor mode	Suggested AVR mode	Set point source
	commands to de-load the generator breaker.			

	The generator breaker is open and the **GENSET** controller receives a close breaker command.
	
	The controller sends commands to synchronise genset to the busbar frequency and voltage.
		• Before sending command to close breaker:
		  ◦ Fixed frequency (Recommended)
		  ◦ Fixed RPM (Recommended for asynchronous gensets)
		  ◦ Power load share
		  ◦ Frequency droop
		• No mode selection required while synchronising
			• Before sending command to close breaker:
			  ◦ Fixed voltage (Recommended)
			  ◦ Reactive power load share
			  ◦ Voltage droop
			• No mode selection required while synchronising	

	The genset is running parallel to mains and is producing power.
	
	The genset can be part of a system of power producing components on the busbar that are running parallel to mains.
		• Fixed power (Recommended)
		• Frequency droop
			• Fixed reactive power (Recommended)
			• Fixed cos phi (Recommended)
			• Voltage droop
				• Controller set point
				• External set point
				  ◦ Modbus
				  ◦ Analogue

	The genset is running parallel to mains. The **GENSET** controller receives a open breaker command.	• Before sending command to open breaker:
		  ◦ Fixed power (Recommended)
		  ◦ Frequency droop
		• No mode selection required while de-loading
			• Before sending command to open breaker:
			  ◦ Fixed reactive power (Recommended)
			  ◦ Fixed cos phi (Recommended)
			  ◦ Voltage droop	

Condition		Suggested governor mode	Suggested AVR mode	Set point source
	The controller sends commands to de-load the generator breaker.		• No mode selection required while de-loading	

6.2 Governor regulation modes

6.2.1 How it works

The genset regulation system consists of a number of regulation modes for the governor. Each regulator processes the input information and calculates the regulation to reach the required operating value. The resulting value is then modified according to the governor interface, and sent to the governor.

NOTICE

Parameters require input/output configuration

To see the parameters, you must have a governor configured in the controller with *Input/output* (relay output or analogue output).

6.2.2 Frequency regulation

When a genset is running with an open generator breaker, the controller uses frequency regulation to keep the frequency at the nominal set point.

The frequency regulation parameters define the regulation when the controller regulates the frequency.

Analogue governor output: Frequency parameters

`Regulators > GOV analogue configuration > Frequency regulation`

Parameter	Range	Notes
`Kp`	0 to 60	The PID gain for the regulator.
`Ti`	0 s to 1 min	The PID regulator integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0 to 2 s	The PID regulator derivative.

Relay governor output: Frequency parameters

`Regulators > GOV relay configuration > Frequency regulation`

Parameter	Range	Notes
`Kp`	0 to 100	This is the gain for the regulator.
`Deadband`	0.2 to 10.0 %	The deadband for the regulator, as a percentage of the nominal frequency.

6.2.3 Power regulation

The controller uses power regulation when ramping up the power to a genset (increasing the load), or ramping down the power of a genset (decreasing the load).

If multiple gensets are connected to the same busbar section, a **GENSET** controller can regulate the power from its genset. Connected gensets automatically run at the same engine speed. Therefore, decreasing the fuel to one genset automatically increases the active power from the other genset.

More information
See Regulation required for de-loading.

If a single genset is connected to the busbar, changing the governor input only changes the frequency of the genset and not the power.

Analogue governor output power parameters

The power regulation parameters define analogue regulation when the controller regulates the governor to change the genset active power output.

`Regulators > GOV analogue configuration > Power regulation`

Parameter	Range	Notes
`Kp`	0 to 60	The PID gain for the regulator.
`Ti`	0 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0 to 2 s	The PID control derivative time.

Relay governor output power parameters

The power regulation parameters define relay regulation when the controller regulates the governor to change the genset active power output.

`Regulators > GOV relay configuration > Power regulation`

Parameter	Range	Notes
`Kp`	0 to 100	This is the gain for the regulator.
`Deadband`	0.2 to 10.0 %	The deadband for the regulator, as a percentage of the nominal power.

6.2.4 Frequency droop

If a genset is connected to the busbar, with or without other power generating assets connected to the same busbar section, the controller can use frequency droop to regulate the genset frequency/power.

This setting does not provide optimal regulation of the genset, and should only be used if there is a specific design reason for its use.

During frequency droop regulation the controller regulates the governor output to follow the droop setting of the controller.

More information
See Droop for the relationship between the controller droop and the governor droop.

Parameters

Regulators > GOV analogue configuration > Frequency droop

Parameter	Range	Notes
Droop	0.0 to 10.0 %	The droop percentage that the controller is regulating towards. The controller droop does not have to be the same as the genset's governor droop. A high droop setting results in high frequency deviations from nominal frequency. A too low droop setting results in not adding the necessary stability to the system.

Regulators > GOV relay configuration > Frequency droop

Parameter	Range	Notes
Droop	0.0 to 10.0 %	The droop percentage that the controller is regulating towards. The controller droop does not have to be the same as the genset's governor droop. A high droop setting results in high frequency deviations from nominal frequency. A too low droop setting results in not adding the necessary stability to the system.

The droop setting for an analogue regulator is not linked to the droop setting for a relay regulator. This means that if you change from an analogue output to a relay output (or from a relay output to an analogue output), you must check the droop setting and correct it if required.

6.2.5 Power load sharing

Active power (kW) is shared in the system by controlling the fuel supply of the gensets.

During load sharing the controller regulates the governor output to the gensets. The power management calculates the **GENSET** controller load set point and communicates this over the DEIF network. By default, all gensets will share an equal portion of the load. Asymmetric power load sharing is also available. For asymmetric load sharing, some gensets can be prioritised to provide an optimum portion of the load per genset, while the other gensets absorb the varying load in the system.

More information
See Load sharing for information about asymmetric load sharing.

Analogue governor output power load sharing parameters

The power load sharing parameters define analogue regulation when the controller regulates the governor to control the genset active power output for load sharing.

Regulators > GOV analogue configuration > Power load sharing regulation

Parameter	Range	Notes
Kp	0.00 to 60.00	The PID gain for the regulator.
Ti	0.00 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
Td	0.00 to 2.00 s	The PID control derivative.
P weight	0.0 to 100.0 %	If P weight is 100 %, the controller ignores the frequency set point to achieve the power set point. If P weight is 0 %, the controller ignores the power set point, to achieve the frequency set point.

Parameter	Range	Notes
		DEIF recommends that you start with the default value, and then, if necessary, adjust this parameter. If *P weight* is too low, the load sharing will not be effective and the load will float between the controllers. If *P weight* is too high, the frequency regulation will be too slow, for example, when a new heavy consumer connects.

Relay governor output power load sharing parameters

The power load sharing parameters define relay regulation when the controller regulates the governor to control the genset active power output for load sharing.

`Regulators > GOV relay configuration > Power load sharing regulation`

Parameter	Range	Notes
`Kp`	0 to 100	This is the gain for the regulator.
`f deadband`	0.2 to 10.0 %	The frequency deadband for the regulator, as a percentage of nominal frequency. The default deadband is ± 1 %. That is, for a genset with a nominal frequency of 50 Hz, the deadband is 1 Hz. When the controller frequency set point is 50 Hz, the regulator will not control the frequency if it is between 49.5 and 50.5 Hz.
`P weight`	0.0 to 100.0 %	If P weight is 100 %, the controller ignores the frequency set point to achieve the power set point. If P weight is 0 %, the controller ignores the power set point, to achieve the frequency set point. DEIF recommends that you start with the default value, and then, if necessary, adjust this parameter. If *P weight* is too low, the load sharing will not be effective and the load will float between the controllers. If *P weight* is too high, the frequency regulation will be too slow, for example, when a new heavy consumer connects.
`P deadband`	0.2 to 10.0 %	The power deadband for the regulator, as a percentage of nominal power. The default deadband is ± 2 %. That is, for a genset with a nominal power of 100 kW, the deadband is 4 kW. When the controller power set point is 50 kW, the regulator will not control the power if it is between 48 and 52 kW.

6.2.6 Frequency synchronisation

During the synchronisation sequence, the controller uses frequency synchronisation regulation to match the genset frequency to the frequency of the busbar.

More information

See Regulation required for synchronisation and Regulator synchronisation parameters.

6.2.7 Phase synchronisation

For static synchronisation, during the synchronisation sequence, the controller uses phase synchronisation regulation to match the genset phases to the phases of the busbar.

More information

See Regulation required for synchronisation and Regulator synchronisation parameters.

6.3 AVR regulation modes

6.3.1 How it works

The genset regulation system consists of a number of basic control modes for the AVR. Each controller processes the input information and calculates what action the genset should take to reach the required operating value. The calculated value is then modified according to the AVR interface, and sent to the AVR.

NOTICE

Parameters require the output configuration

To see the parameters, you must have an AVR configured in the controller with relay outputs or analogue output.

6.3.2 Voltage regulation

The controller regulates and maintains the genset voltage at its nominal set point by sending a signal to the AVR to adjust the exciter current.

Before the generator breaker is closed, the controller uses voltage regulation to match the genset voltage with the voltage of the other gensets on the busbar. This minimises the circulating current in the system after gensets are connected to the busbar. The controller calculates the necessary values to eliminate the circulating current between the generators before the busbar is connected to a load. Then the controller uses the AVR output to send the adjusted values to the AVR. If a genset is already connected to a load, the controller must match the generator voltages before closing an additional generator breaker.

Analogue AVR output voltage parameters

The voltage regulation parameters define analogue regulation when the controller regulates AVR to change the voltage.

`Regulators > AVR analogue configuration > Voltage regulation`

Parameter	Range	Notes
`Kp`	0.00 to 60.00	The PID gain for the regulator.
`Ti`	0.00 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0.00 to 2.00 s	The PID control derivative.

Relay AVR output voltage parameters

The voltage regulation parameters define relay regulation when the controller regulates the voltage.

`Regulators > AVR relay configuration > Voltage regulation`

Parameter	Range	Notes
`Kp`	0 to 100	This is the gain for the regulator.
`Deadband`	0.0 to 10.0 %	The deadband for the regulator, as a percentage of the nominal voltage.

6.3.3 Reactive power regulation

By controlling the AVR current for the genset, the controller controls the reactive power (kvar) of the genset. The controller sends a signal to the AVR to change the excitation of the generator. This changes the phase angle between the current and the voltage, hereby regulating the reactive power.

If a genset is connected to the busbar along with other power generating assets, the controller can use reactive power regulation to ensure that the genset provides the same amount of reactive power to the busbar.

The controller also uses reactive power regulation when ramping up the reactive power of a genset (increasing the load), and when ramping down the reactive power of a genset (decreasing the load).

If multiple gensets are connected to the same busbar section, the controller can regulate its genset to provide the required amount of reactive power. Connected gensets automatically run at the same engine speed. Therefore, decreasing the excitation in the generator automatically decreases the reactive power that it provides, and increases the load on the other power generating assets. Increasing the excitation in the generator automatically increases the reactive power that the genset provides, and decreases the load on the other power generating assets.

Analogue AVR output reactive power parameters

The reactive power regulation parameters define analogue regulation when the controller regulates the genset reactive power output.

`Regulators > AVR analogue configuration > Reactive power regulation`

Parameter	Range	Notes
`Kp`	0.00 to 60.00	The PID gain for the regulator.
`Ti`	0.00 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0.00 to 2.00 s	The PID control derivative.

Relay AVR output reactive power parameters

The reactive power regulation parameters define relay regulation when the controller regulates the genset reactive power output.

`Regulators > AVR relay configuration > Reactive power regulation`

Parameter	Range	Notes
`Kp`	0 to 100	This is the gain for the regulator.
`Deadband`	0.0 to 10.0 %	The deadband for the regulator, as a percentage of the nominal reactive power.

6.3.4 Voltage droop

If a genset is connected to the busbar, with or without other power generating assets connected to the same busbar section, the controller can use voltage droop to regulate the genset voltage/reactive power.

This setting does not provide optimal regulation of the genset, and should only be used if there is a specific design reason for its use. For example, another genset that cannot communicate with the controller is connected to the same busbar section.

During voltage droop regulation the controller regulates the AVR output to follow the droop setting of the controller.

More information
See Droop for the relationship between the controller droop and the AVR droop.

Parameters

Regulators > AVR analogue configuration > Voltage droop

Parameter	Range	Notes
`Droop`	0.0 to 10.0 %	The droop percentage that the controller emulates. The controller droop does not have to be the same as the genset's AVR droop. A high droop setting results in high voltage/reactive power deviations from nominal voltage. A too low droop setting results in not adding the necessary stability to the system.

Regulators > AVR relay configuration > Voltage droop

Parameter	Range	Notes
`Droop`	0.0 to 10.0 %	The droop percentage that the controller emulates. The controller droop does not have to be the same as the genset's AVR droop. A high droop setting results in high voltage/reactive power deviations from nominal voltage. A too low droop setting results in not adding the necessary stability to the system.

The droop setting for an analogue regulator is not linked to the droop setting for a relay regulator. This means that if you change from an analogue output to a relay output (or from a relay output to an analogue output), you must check the droop setting and correct it if required.

6.3.5 Reactive power load sharing

During reactive power (kvar) load sharing, the controller uses the nominal voltage as a reference to regulate the AVR output to the genset. The nominal voltage reference can be adjusted by contributing a weighted amount of the reactive power set point to the reference value.

Reactive power load sharing can be used in a system where more than one genset is connected to the same busbar section. At least two of these gensets must have reactive power load sharing activated in order to share the load between them.

All gensets on the same busbar section that have reactive power load sharing active, will share an equal percentage of the load.

Analogue AVR output reactive power load sharing parameters

The reactive power load sharing parameters define analogue regulation when the controller regulates the AVR to change the genset reactive power output for load sharing.

Regulators > AVR analogue configuration > Reactive power load sharing regulation

Parameter	Range	Notes
`Kp`	0.00 to 60.00	The PID gain for the regulator.
`Ti`	0.00 s to 1 min	The PID control integral time. To turn off the integral component, set Ti to 0. This might cause unexpected regulator behaviour.
`Td`	0.00 to 2.00 s	The PID control derivative.
`Q weight`	0.00 to 100.00 %	If Q weight is 100 %, the controller uses the reactive power and voltage set points equally during load sharing regulation. If Q weight is 0 %, the controller ignores the reactive power set point during load sharing regulation.

Parameter	Range	Notes
		DEIF recommends that you start with the default value, and then, if necessary, adjust this parameter. If Q weight is too low, the reactive power load sharing will not be effective and the load will float between the controllers. If Q weight is too high, the voltage regulation will be too slow, for example, when a new heavy consumer connects.

Relay AVR output reactive power load sharing parameters

The reactive power load sharing parameters define relay regulation when the controller regulates the AVR to change the genset reactive power output for load sharing.

`Regulators > AVR relay configuration > Reactive power load sharing regulation`

Parameter	Range	Notes
`Kp`	0 to 100	This is the gain for the regulator.
`V deadband`	0.0 to 10.0 %	The voltage deadband for the regulator, as a percentage of the nominal voltage.
`Q deadband`	0.0 to 10.0 %	The reactive power deadband for the regulator, as a percentage of the nominal reactive power.
`Q weight`	0.0 to 100.0 %	If Q weight is 100 %, the controller uses the reactive power and voltage set points equally during load sharing regulation. If Q weight is 0 %, the controller ignores the reactive power set point during load sharing regulation. DEIF recommends that you start with the default value, and then, if necessary, adjust this parameter. If Q weight is too low, the reactive power load sharing will not be effective and the load will float between the controllers. If Q weight is too high, the voltage regulation will be too slow, for example, when a new heavy consumer connects.

6.4 Governor

6.4.1 Governor regulation function

A governor is external equipment used to control the engine speed for the genset. During frequency regulation, when the speed drops below the required speed, the governor increases the fuel supply to the engine which increases the engine speed. Similarly, by decreasing the fuel supply, the engine speed also decreases. The frequency of the genset is directly related to engine speed and the number of poles in the generator.

The governor must allow external adjustment (digital inputs or analogue input), to let the **GENSET** controller bias the governor internal set point.

Parameters for governor general configuration

The governor general configuration settings apply to all the controller's governor regulation outputs (for example, relay, analogue, pulse width modulation, and so on).

Regulator output

If a governor analogue regulation output and both governor relay regulation outputs are configured, then one output must be selected as the output that sends feedback to the governor.

`Regulators > GOV general configuration`

Parameter	Range	Notes
`Regulator output`	• Relay • Analogue / ECU	**Relay:** The controller uses the relay outputs to regulate the governor (only visible if both relays for the governor regulation are configured). **Analogue / ECU**: The controller uses an analogue output or engine interface communication (to the engine control unit) to regulate the governor. This option is only visible if a governor analogue regulator output and/or EIC is configured.

Regulation delay

This parameter sets the time the controller waits before starting to regulate the genset. The delay time starts after the running feedback confirms that the genset is running. It is not desirable to start regulation exactly when running feedback is achieved. Frequency and voltage are still low compared to the nominal value at this point. The regulation delay is intended to delay regulation until the frequency and voltage have stabilised at their preset values. This prevents regulation overshoot at start-up.

`Regulators > GOV general configuration`

Parameter	Range	Notes
`Regulator delay`	0 s to 2.75 h	The controller waits for the amount of time specified by this parameter, before regulating the genset.

Parameters for governor regulation set point

The governor regulation set point settings apply to all the controller's governor regulation outputs (for example, relay, analogue, pulse width modulation, and so on).

`Regulators > GOV regulation set points > Active power ramp configuration`

Parameter	Range	Notes
`Warm up set point`	0.1 to 100.0 % of the genset nominal power	When the genset reaches this power set point, the warm up is completed.
`Island ramping`	Enabled, Not enabled	**Enabled**: The controller uses ramps during island operation.
`Enter operation ramp enable`	Enabled, Not enabled	**Enabled**: The controller uses the enter operation ramp when entering operation.
`Deload ramp enabled`	Enabled, Not enabled	**Enabled**: The controller uses the deload ramp when deloading the breaker.

Active power ramp up

This parameter defines the speed of the ramp up of the genset active power when the genset is connected to a busbar or when the fixed power set point changes. The ramping functionality ramps the regulation set points to follow the configurable curve towards the final set point. This reduces the mechanical strain on the genset when the breaker closes and the genset starts to supply power to the system. Limiting the power ramp up speed also increases the system stability.

The parameter consists of two curves. Each curve can consist of 2 to 10 coordinates for the time and the percentage of the genset nominal power.

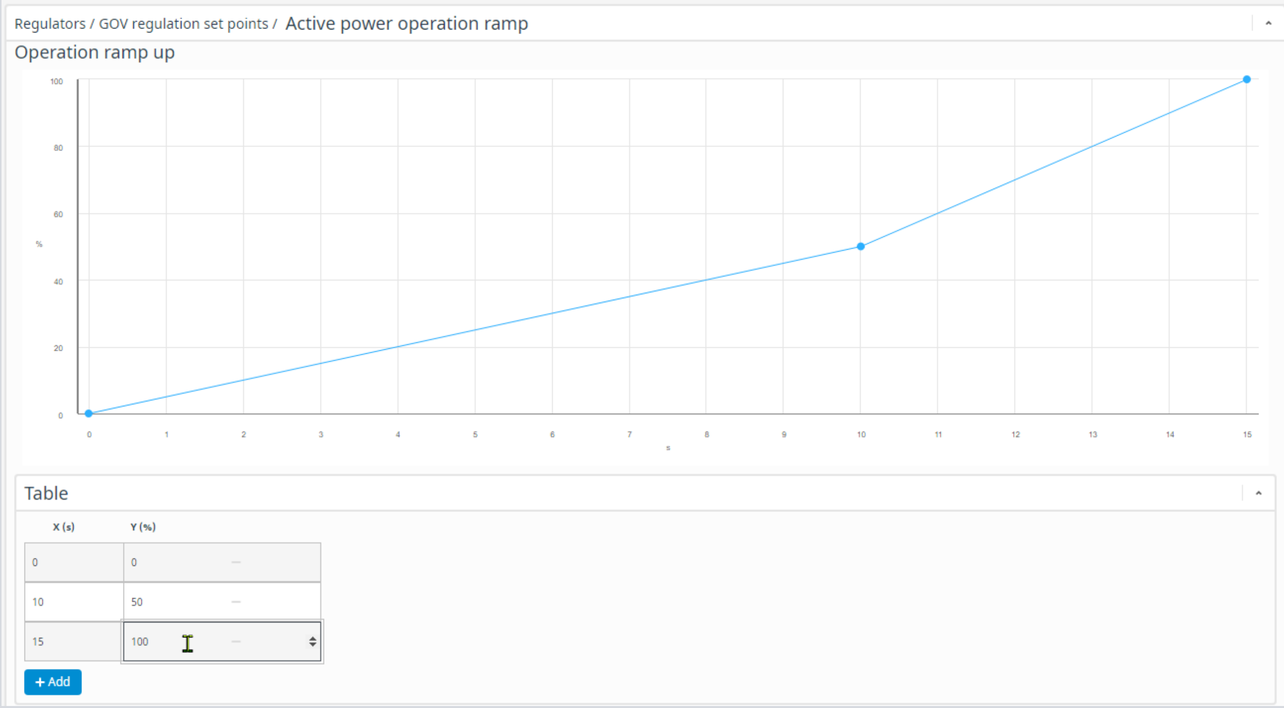
`Regulators > GOV regulation set points > Active power operation ramp > Operation ramp up`

Parameter	Range	Notes
`[s]`	0 to 3600 s	The time coordinate for the active power ramp up curve.
`[%]`	0 to 100 %	The percentage of nominal active power of the genset coordinate for the active power ramp up curve.

Active power ramp up example

You want a 100 kW genset to ramp up to 50 % of its nominal power at 5 %/s, and 10%/s between 50 % and a 100 % of its nominal power. This means that it will take at least 15 seconds to ramp up the genset load from 0 kW to 100 kW.

The coordinates for the primary power ramp up curve are: (0 s; 0 %), (10 s; 50 %) and (15 s; 100 %).



This means that the controller regulates the genset to follow a slope of 5 kW/s for the first 50 % of the genset's nominal power. And the controller regulates the genset to follow a slope of 10 kW/s between 50 % and a 100 % of the genset's nominal power.

If the genset load is 0 kW, and 50 kW is required from the genset, it takes at least 10 seconds to ramp up the genset load.
If the genset load is 0 kW, and 70 kW is required from the genset, it takes at least 12 seconds to ramp up the genset load.

Regulators > GOV regulation set points > Active power enter operation ramp > Enter operation ramp

Parameter	Range	Notes
[s]	0 to 3600 s	The time coordinate for the enter operation active power ramp up curve.
[%]	0 to 100 %	The percentage of nominal active power of the genset coordinate for the enter operation active power ramp up curve.

Active power ramp down

This parameter defines the speed of the ramp down of the genset active power when the fixed power set point changes or when the genset disconnects from the busbar. This reduces the mechanical strain on the genset and breaker when the breaker opens and the genset stops supplying power to the system. Limiting the power ramp down speed also increases the system stability.

The parameter consists of two curves. Each curve can consist of 2 to 10 coordinates for the time and the percentage of the genset nominal power.

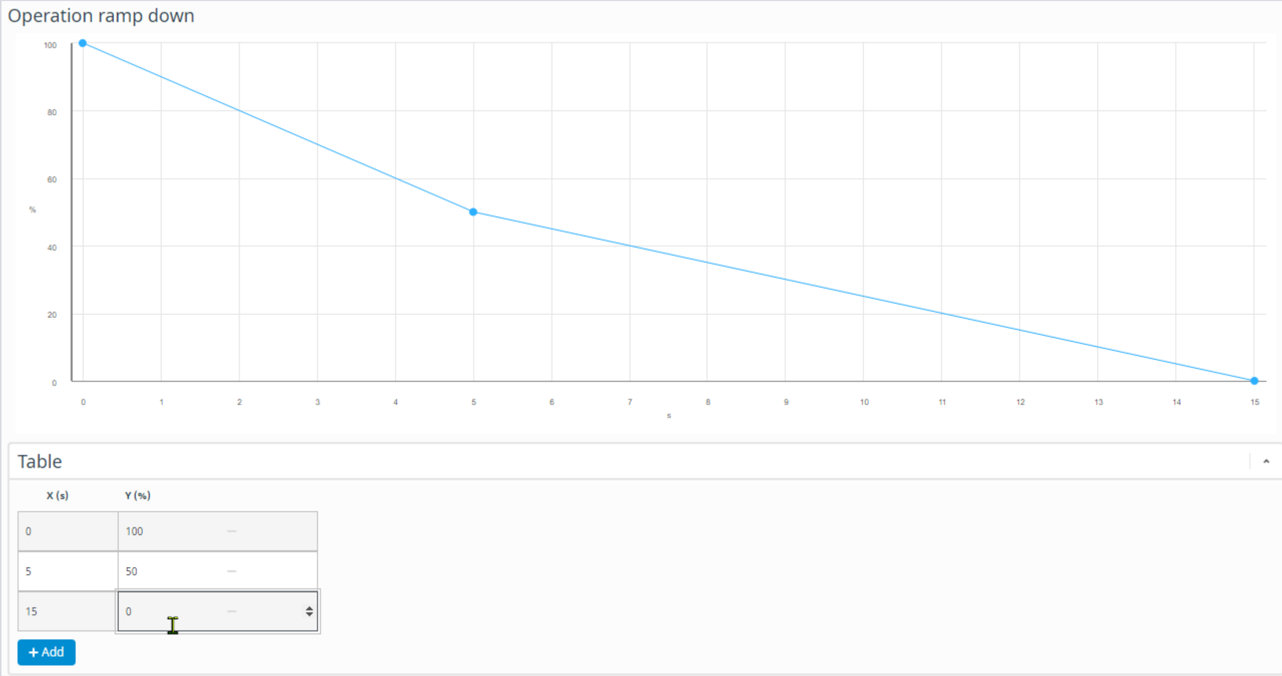
Regulators > GOV regulation set points > Active power operation ramp > Operation ramp down

Parameter	Range	Notes
[s]	0 to 3600 s	The time coordinate for the power ramp down curve.
[%]	0 to 100 %	The percentage of nominal power of the genset coordinate for the power ramp down curve.

Power ramp down example

You want a 100 kW genset to ramp down to 50 % of its nominal power at 10 %/s, and 5%/s between 50 % and a 0 % of its nominal power. This means that it will take at least 15 seconds to ramp down the genset load from 1000 kW to 0 kW.

The coordinates for the primary power ramp up curve are: (0 s; 100 %), (5 s; 50 %) and (15 s; 0 %).



This means that the controller regulates the genset to follow a slope of 10 kW/s between 100 % and 50 % of the genset's nominal power. And the controller regulates the genset to follow a slope of 5 kW/s between 50 % and a 0 % of the genset's nominal power.

If the genset load is 50 kW, and 0 kW is required from the genset, it takes at least 10 seconds to ramp down the genset load.
If the genset load is 70 kW, and 0 kW is required from the genset, it takes at least 12 seconds to ramp down the genset load.

Regulators > GOV regulation set points > Active power deload ramp > Deload ramp

Parameter	Range	Notes
[s]	0 to 3600 s	The time coordinate for the deload power ramp curve.
[%]	0 to 100 %	The percentage of nominal power of the genset coordinate for the deload power ramp curve.

Regulators > GOV regulation set points > Base load

Parameter	Range	Notes
Base load	10 to 120 % of the genset nominal power	The base load set point.
Enable	Enabled, Not enabled	**Enabled**: The generator set runs at a fixed power and does not participate in frequency control. Should the plant power requirement drop, the set point is lowered so the other generator(s) on line produces at least 10 % power.
Return mode	Manual, Auto	When base load ends, the controller runs in the selected mode.

6.4.2 Governor analogue regulation function

You can configure an analogue output on the controller to regulate the governor. You can also set a number of parameters for the governor analogue regulation function.

Outputs

Function	I/O	Units	Details
`Regulators > GOV > GOV output [%]`	Analogue output	-100 to 100 %	The controller adjusts this output to regulate the governor. DEIF recommends that you use the full range of the output, that is from -100 % to 100 %, when you configure the output.
`Regulators > GOV > GOV regulator reference [kW]`	Analogue output	0 to 1000 kW	The controller can output its governor reference set point.

NOTE The setup and parameters for governor regulation using pulse width modulation (PWM) is exactly the same as for an analogue output.

More information
See **Input/Output** in the **PICUS manual** for how to configure an analogue output.

Parameters

To see the governor analogue control parameters, you must assign the function to an analogue output.

When you start and/or run a genset, you might want to adjust the starting point for analogue regulation. This is done by changing the output offset.

`Regulators > GOV analogue configuration > Offset`

Parameter	Range	Notes

`GOV output offset 1`
`GOV output offset 2`
`GOV output offset 3`
`GOV output offset 4`
	-100.0 to 100.0 %	The offset is added to the GOV analogue output. The number of the offset relates to the nominal settings set. If you select *Nominal settings 1*, then the controller uses *GOV output offset 1*. The nominal settings set also determine the values of other nominal settings and engine RPM.
		
		When the genset starts, it starts from the offset value, allowing the genset to reach the set point quickly. Ideally, the governor should be tuned so that if there is no signal, the genset runs at its nominal frequency if there is no load. However, if this is not possible, *GOV output offset* allows you to compensate the output to the governor.
		
		To set this parameter, start with *GOV output offset* = 0 %. Change the offset value in small increments to fine tune the frequency output of the genset. When you reach the desired genset frequency output, the offset is tuned.

6.4.3 Governor relay regulation function

You can configure relay outputs on the controller to regulate the governor. You can also set a number of parameters for the governor relay regulation function.

Digital outputs

Function	I/O	Type	Details
`Regulators > GOV > Controls > GOV increase`	Digital output	Variable-length pulse	The controller activates this output to regulate the governor to increase the engine speed or power.
`Regulators > GOV > Controls > GOV decrease`	Digital output	Variable-length pulse	The controller activates this output to regulate the governor to decrease the engine speed or power.

Parameters

These parameters are only visible, if you assign the functions to digital outputs.

`Regulators > GOV relay configuration > Automatic configuration`

Parameter	Range	Notes
`Period time`	250 ms to 32.5 s	You can make the governor response faster by decreasing the *Period time*. However, if the rest of the system is slow anyway, you can reduce the wear on the relays by increasing the *Period time*. Although a relay controller is capable of fast responses, the *Period time* should be similar to the response of the system to extend the relay life.
`Minimum ON time`	10 ms to 6.5 s	The Minimum ON time must be long enough to ensure that the governor can detect the shortest pulse that the controller sends to it. You can increase the Minimum ON time to force a slow system to respond more to the controller's regulation. If the controller needs to increase the governor output, the GOV increase digital output is activated for at least the Minimum ON time. While the controller is increasing the governor output, the GOV decrease digital output is not activated. If the controller needs to decrease the governor output, the GOV decrease digital output is activated for at least the Minimum ON time. While the controller is decreasing the governor output, the GOV increase digital output is not activated.

`Regulators > GOV relay configuration > Manual configuration`

Parameter	Range	Notes
`Period time`	0.1 to 10.0 s	You can set the *Period time* manually for the governor response.

6.5 Automatic voltage regulator

6.5.1 AVR regulator

An AVR is used to control the excitation of the genset. When the current to the exciter is increased, the magnetic field of the exciter also increases. During voltage regulation, this increases the voltage output from the genset. Similarly, by decreasing the current to the exciter, the voltage output from the genset is decreased. Reactive power is adjusted to increase or decrease voltage.

The AVR must allow external adjustment (digital inputs or analogue input), to let the genset controller bias the AVR internal set point.

The sections below describe the common input parameters for the automatic voltage regulator (AVR).

Parameters

The `AVR general configuration` and `AVR regulation set points` settings apply to all the controller's AVR regulation outputs (for example, relay or analogue).

To see these parameters, you must configure an AVR output function.

If an AVR analogue regulation output and both AVR relay regulation outputs are configured, then one output must be selected as the output that sends feedback to the AVR.

`Regulators > AVR general configuration > Regulator output`

Parameter	Range	Notes
`Regulator output`	• Relay • Analogue / Digital AVR	**Relay:** The controller uses the relay outputs to regulate the AVR (only visible if both relays for the AVR regulator are configured). **Analogue / Digital AVR**: The controller uses an analogue output or digital AVR to regulate the AVR (only visible if an analogue AVR regulator output is configured).

The ramp up curve defines the speed of the ramp up of the genset reactive power when the genset is connected to a busbar or when the fixed reactive power set point changes. The ramping functionality ramps the regulation set points to follow the configurable curve towards the final set point. This reduces the mechanical strain on the genset when the breaker closes and the genset starts to supply power to the system. Limiting the power ramp up speed also increases the system stability.

The curve can consist of 2 to 10 coordinates for the time and the percentage of the genset nominal reactive power.

`Regulators > AVR regulation set points > Reactive power operation ramp > Operation ramp up`

Parameter	Range	Notes
`[s]`	0.0 to 1 h	The time coordinate for the reactive power ramp up curve.
`[%]`	-100 to 100 %	The percentage of nominal reactive power of the genset coordinate for the reactive power ramp up curve.

Reactive power ramp up using reactive power curve example

You want a 100 kvar genset to ramp up to 50 % of its nominal reactive power at 5 %/s, and 10%/s between 50 % and a 100 % of its nominal reactive power. This means that it will take at least 15 seconds to ramp up the genset reactive power from 0 kvar to 100 kvar.

The coordinates for the primary power ramp up curve are: (0 s; 0 %), (10 s; 50 %) and (15 s; 100 %).

This means that the controller regulates the genset to ensure that the reactive power ramp up does not exceed 5 kvar/s for the first 50 % of the genset's nominal reactive power. And the controller regulates the genset to ensure that the reactive power ramp up does not exceed 10 kvar/s between 50 % and a 100 % of the genset's nominal reactive power.

If the genset reactive power is 0 kvar, and 50 kvar is required from the genset, it takes at least 10 seconds to ramp up the genset reactive power.
If the genset reactive power is 0 kvar, and 70 kvar is required from the genset, it takes at least 12 seconds to ramp up the genset reactive power.

The ramp down curve defines the speed of the ramp down of the genset active power when the fixed power set point changes or when the genset disconnects from the busbar. This reduces the mechanical strain on the genset and breaker when the breaker opens and the genset stops supplying power to the system. Limiting the power ramp down speed also increases the system stability.

The curve can consist of 2 to 10 coordinates for the time and the percentage of the genset nominal reactive power.

Regulators > AVR regulation set points > Reactive power operation ramp > Operation ramp down

Parameter	Range	Notes
[s]	0 to 3600 s	The time coordinate for the reactive power ramp down curve.
[%]	-100 to 100 %	The percentage of nominal reactive power of the genset coordinate for the reactive power ramp down curve.

Reactive power ramp down example

You want a 100 kvar genset to ramp down to 50 % of its nominal reactive power at 10 %/s, and 5 %/s between 50 % and a 0 % of its nominal reactive power. This means that it will take at least 15 seconds to ramp down the genset reactive power from 100 kvar to 0 kvar.

The coordinates for the power ramp up curve are: (0 s; 100 %), (5 s; 50 %) and (15 s; 0 %).

This means that the controller regulates the genset to ensure that the reactive power ramp down does not exceed 10 kvar/s between 100 % and 50 % of the genset's nominal reactive power. And the controller regulates the genset to ensure that the reactive power ramp down does not exceed 5 kvar/s between 50 % and a 0 % of the genset's nominal reactive power.

If the genset reactive power is 50 kvar, and 0 kvar is required from the genset, it takes at least 10 seconds to ramp down the genset reactive power.
If the genset reactive power is 70 kvar, and 0 kvar is required from the genset, it takes at least 12 seconds to ramp down the genset reactive power.

6.5.2 AVR analogue regulation function

You can configure an analogue output on the controller to regulate the AVR. You can also set a number of parameters for the AVR analogue regulation function.

Inputs and outputs

Function	I/O	Type	Details
Regulators > AVR > AVR output [%]	Analogue output	-	The controller adjusts this output to regulate the AVR.
Regulators > AVR > AVR regulator reference [kvar]	Analogue output	-	The controller can output its reactive power reference set point.
Regulators > AVR > Cos phi reference []	Analogue output	-	The controller can output its cos phi reference set point.

NOTE The setup and parameters for AVR regulation using pulse width modulation (PWM) is exactly the same as for an analogue output.

Parameters

To see the AVR analogue control parameters, you must assign the `Regulators > AVR > AVR output [%]` function to an analogue output (that is, AO or PWM).

When you start and/or run a genset, you might want to adjust the starting point for analogue regulation. This is done by changing the output offset.

`Regulators > AVR analogue configuration > Offset`

Parameter	Range	Notes

`AVR output offset 1`
`AVR output offset 2`
`AVR output offset 3`
`AVR output offset 4`
	-100.0 to 100.0 %	The offset is added to the AVR analogue output. The number of the offset relates to the nominal settings set. If you select *Nominal settings 1*, then the controller uses *AVR output offset 1*. The nominal settings set also determine the values of other nominal settings and engine RPM.
		
		When the genset is started, it will start from the offset value, allowing the genset to reach the set point quickly. Ideally, the AVR should be tuned so that if there is no signal, the genset runs at its nominal voltage if there is no load. However, if this is not possible, AVR output offset allows you to compensate the output to the AVR.
		
		To set this parameter, start with *AVR output offset* = 0 %. Change the offset value in small increments to fine tune the voltage output of the genset. When you reach the desired genset voltage output, the offset is tuned.

6.5.3 AVR relay regulation parameters

You can configure relay outputs on the controller to regulate the AVR. You can also set a number of parameters for the AVR relay regulation function.

Digital outputs

Function	I/O	Type	Details
`Regulators > AVR > Controls > AVR increase`	Digital output	Variable-length pulse	The controller activates this output to send a signal to the AVR to increase the voltage or reactive power.
`Regulators > AVR > Controls > AVR decrease`	Digital output	Variable-length pulse	The controller activates this output to send a signal to the AVR to decrease the voltage or reactive power.

Parameters

These parameters adjust the controller's relay control output. To see these parameters, you must assign the functions to digital outputs.

`Regulators > AVR relay configuration > Automatic configuration`

Parameter	Range	Notes
`Period time`	50 ms to 15 s	You can make the AVR response faster by decreasing the *Period time*. However, if the rest of the system is slow anyway, then decreasing the *Period time* will provide no additional benefits. Although a relay controller is capable of fast responses, it is recommended to set the *Period time* to be similar to the response of the system.
`Minimum ON time`	10 ms to 3 s	The *Minimum ON time* must be long enough to ensure that the AVR can detect the shortest pulse that the controller sends to it. You can increase the *Minimum ON time* to force a slow system to respond to the controller's regulation. If the controller needs to increase the AVR output, the AVR increase digital output is activated for at least the Minimum ON time. While the controller is increasing the AVR output, the AVR decrease digital output is not activated. If the controller needs to decrease the AVR output, the AVR decrease digital output is activated for at least the Minimum ON time. While the controller is decreasing the AVR output, the AVR increase digital output is not activated.

`Regulators > AVR relay configuration > Manual configuration`

Parameter	Range	Notes
`Period time`	0.1 to 10.0 s	You can set the *Period time* manually for the AVR response.

6.6 Configuration alarms

6.6.1 GOV relay setup incomplete

The alarm is based on the **Input/output** configuration of the controller. The controller activates the alarm when only one of the following digital outputs is configured:

- `Regulators > GOV > Control > GOV increase`
- `Regulators > GOV > Control > GOV decrease`

The alarm action is *Warning* and the alarm remains active until the configuration is corrected.

The alarm is always enabled. The alarm parameters are not visible.

6.6.2 AVR relay setup incomplete

The alarm is based on the **Input/output** configuration of the controller. The controller activates the alarm when only one of the following digital outputs are configured:

- `Regulators > AVR > Control > AVR increase`
- `Regulators > AVR > Control > AVR decrease`

The alarm action is *Warning* and the alarm remains active until the configuration is corrected.

The alarm is always enabled. The alarm parameters are not visible.

6.6.3 GOV output selection failure

The controller activates the alarm if an output, either relay or analogue, was selected as the regulation output, but the selected output is then removed from the **Input/output** configuration.

The alarm remains active until either:

- The deleted output is added to the **Input/output** configuration
- The correct manual output is selected under `Regulators > GOV general configuration > Regulator output > Output type`

The alarm is always enabled. You cannot see or change the alarm parameters.

6.6.4 AVR output selection failure

The controller activates the alarm if an output, either relay or analogue, was selected as the regulation output, but the selected output is then removed from the **Input/output** configuration.

The alarm remains active until either:

- The deleted output is added to the **Input/output** configuration
- The correct manual output is selected under `Regulators > AVR: common settings > Regulator output > Output type`

The alarm is always enabled. You cannot see or change the alarm parameters.

6.7 Regulation alarms

6.7.1 GOV regulation error

This alarm shows when there is an error with the governor controlled regulation.

The alarm is based on the difference between the measured value and the required set point, as a percentage of the set point. The larger the set point, the more the measured value is allowed to differ from the set point.

The alarm activates if the measured value is outside of the permitted range for longer than the delay.

This alarm is not activated when the genset frequency swings in and out of the permitted range above and below the set point. This is because this alarm only activates when the measured value is constantly above the upper limit, or constantly below the lower limit for the entire delay period.

Parameters

Do not set the alarm set point lower than the deadband percentage for relay regulation. Doing so might activate the alarm in an area where regulation is not possible.

`Regulators > GOV monitoring > Regulation error`

Parameter	Range
`Set point` (absolute value)	1.0 to 100.0 % regulation deviation
`Delay`	10.0 s to 1 h

Alarm deviation examples

1. The controller is trying to control the genset to run at 50 Hz, and the measured frequency is 49.5 Hz.
   - The deviation from the set point is |(49.5 Hz - 50 Hz)| / 50 Hz =0.01 = 1 %.
   - The deviation is less than the alarm set point, and the alarm is not activated.
2. The controller is trying to control the genset to run at 60 Hz and the measured speed is 62 Hz.
   - The deviation from the set point is |(62 Hz - 60 Hz)| / 60 Hz = 0.03 = 3.3 %.
   - The deviation is less than the alarm set point, and the alarm is not activated.
3. The controller is controlling 1500 kW genset, and is running fixed power regulation with a set point of 1000 kW. The measured power is 600 kW.
   - The deviation from the set point is |(600 kW - 1000 kW)| / 1000 kW = 0.4 = 40 %
   - The deviation is more than the alarm set point. If the measured power is stays below 700 kW for longer than the delay, then the alarm activates.

6.7.2 AVR regulation error

This alarm shows when there is an error with the AVR controlled regulation.

The alarm is based on the difference between the measured value and the required set point, as a percentage of the set point. The larger the set point, the more the measured value is allowed to differ from the set point.

The alarm activates if the measured value is outside of the permitted range for longer than the delay.

This alarm is not activated when the genset voltage swings in and out of the permitted range above and below the set point. This is because this alarm only activates when the measured value is constantly above the upper limit, or constantly below the lower limit for the entire delay period.

Parameters

Do not set the alarm set point lower than the deadband percentage for relay regulation. Doing so might activate the alarm in an area where regulation is not possible.

`Regulators > AVR monitoring > Regulation error`

Parameter	Range
`Set point` (absolute value)	1.0 to 100.0 % regulation deviation
`Delay`	10.0 s to 1 h

Alarm deviation examples

1. The controller is running fixed voltage regulation with a set point of 400 V, and the measured voltage is 250 V.
   - The deviation from the set point is $|(250\ V - 400\ V)|$ / 400 V × 100 = 38 %.
   - The deviation is more than the alarm set point. If the measured power is stays below 280 V for longer than the delay, then the alarm activates.
2. The controller is running fixed reactive power regulation with a set point of 0 % of nominal reactive power, and the measured value is 2 % of nominal reactive power.
   - The deviation from the set point is 2 %.
   - The deviation is less than the alarm set point, and the alarm is not activated.
3. The controller is running fixed cos phi regulation with a set point of 0.9 I, and the measured value is 0.95 C.
   - The deviation from the set point is $|(0.95\ C - 0.9\ I)|$ / 0.9 I × 100 = 17 %.
   - The deviation is less than the alarm set point, and the alarm is not activated.

7. Power management

7.1 Power management principles

7.1.1 How it works

Power Management makes sure that the required power is available. The power management system makes sure the system runs as efficiently as possible, and responds appropriately to changes. This requires the controllers to share information and work together.

Power management scope

The functions of the power management:

- Takes action to prevent blackouts
- Restores power after a blackout
- Calculates the available power in the system
- Automatically starts and stops gensets based on the load
- Shares the load between the generators
- Manages the genset priority
- Loads and de-loads generators
- Handles the mains connection
- Handles the bus tie breaker
- Handles storage controllers *
- Handles solar controllers *

NOTE * Contact DEIF for availability.

Control and modes

The power management functions best when all the controllers are in AUTO mode. MANUAL mode allows operator or external system (for example, a PLC) commands. Controllers should not normally be in MANUAL mode.

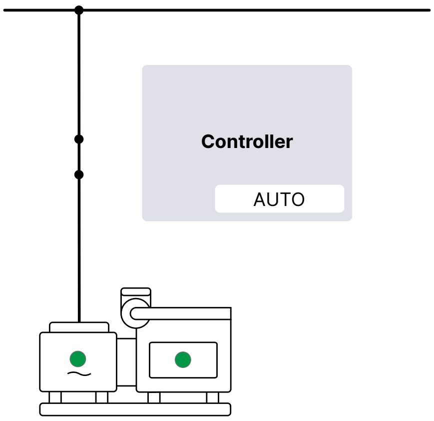
More information
See Control and modes in **System principles** for general mode information.

You can configure that a mode change applies to only the local controller, or for all controllers in the same section.

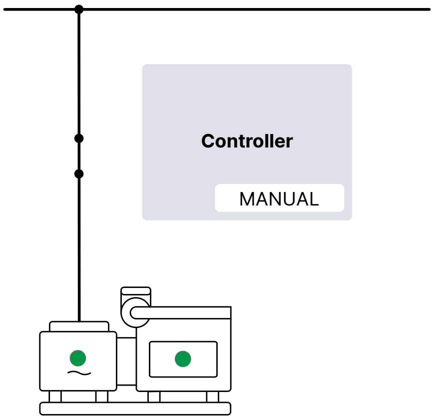
More information
See Mode change in section for how to configure this setting.

Power management and controller modes

AUTO The power is managed when there is at least one controller in AUTO mode, and where power sources are either connected or ready to start. If there are not enough power sources in AUTO mode to supply the load, the power management is limited.



MANUAL The power cannot be managed automatically if all the controllers are in MANUAL mode. The controllers can share the load and restore power after a blackout. However, there is no automatic genset start or stop. The power management does not include the available power from connected controllers in MANUAL mode in the available power calculations.



Power availability

The controllers share information across the DEIF network, so that each controller can calculate the available power for the section.

The available power is used to determine when to start and stop gensets. Note that the mains connection(s) and set points affect the available power.

More information
See Power calculations for more information.

Efficient operation

The power management can be configured to maximise the system's fuel efficiency.

Multi-master control

The power management calculations are all done by each controller, for true multi-master control. This means that if a controller fails, the system can continue to function (as far as possible).

Protections

Most power management failures activate the standard controller alarms. Only the alarms that are specific to power management are described in this chapter.

Power management communication

Each controller calculates:

- Nominal power = ∑ Nominal power for connected power sources in the section
- Consumed power = ∑ Actual power from the connected power sources in the section
- Available power = Nominal power - Consumed power
- Genset priority order
- Genset start

Power management features	
Plant modes	• Automatic mains failure • Fixed power • Peak shaving • Load take-over • Mains power export
Genset modes	• Power management • Island mode
Power management operation	CAN bus-based power management: • Control up to 32 generator, mains and/or tie breakers ◦ Up to 32 GENSET and/or MAINS controllers • Up to 8 bus tie breakers on the generator bus or load bus
Load control	Load control between controllers up to 32 assets. Load control between iE 250 and other DEIF controllers up to 16 gensets. Genset controllers can do asymmetrical load sharing. Genset controllers can synchronise/de-load Mains and BTB controllers. Automatic detection of load sharing busbar sections (including for a ring busbar).
Priority selection	• Set the first priority • Relative, absolute, and manual * • Running hours • Fuel optimisation
Additional features	Generator load-dependent start and stop Asymmetrical generator load sharing N + X Safety stop of generator

NOTE * Contact DEIF for availability.

7.1.2 Power management with other controllers

You can use these controllers in a power management system with an iE 250 controller:

- **AGC-4 Mk II**
  - Each AGC-4 Mk II controller must have option G5.
  - For more information, see the **AGC-4 Mk II Designer's handbook**.
- **AGC-4**
  - The predecessor of AGC-4 Mk II.
  - Each AGC-4 controller must have option G4, G5 or G8.
  - AGC-4 software version 4.81.2 or later is compatible with iE 250.
- **AGC 150 Generator, Mains and BTB**
  - For more information, see the **AGC 150 Generator Mains BTB Designer's handbook**.

7.1.3 Creating the power management application

Power management requires a single-line application drawing.

More information
See Single-line application drawing, and the **PICUS manual** for how to configure and write the single-line application drawing. See Change controller type if you need to change the controller type.

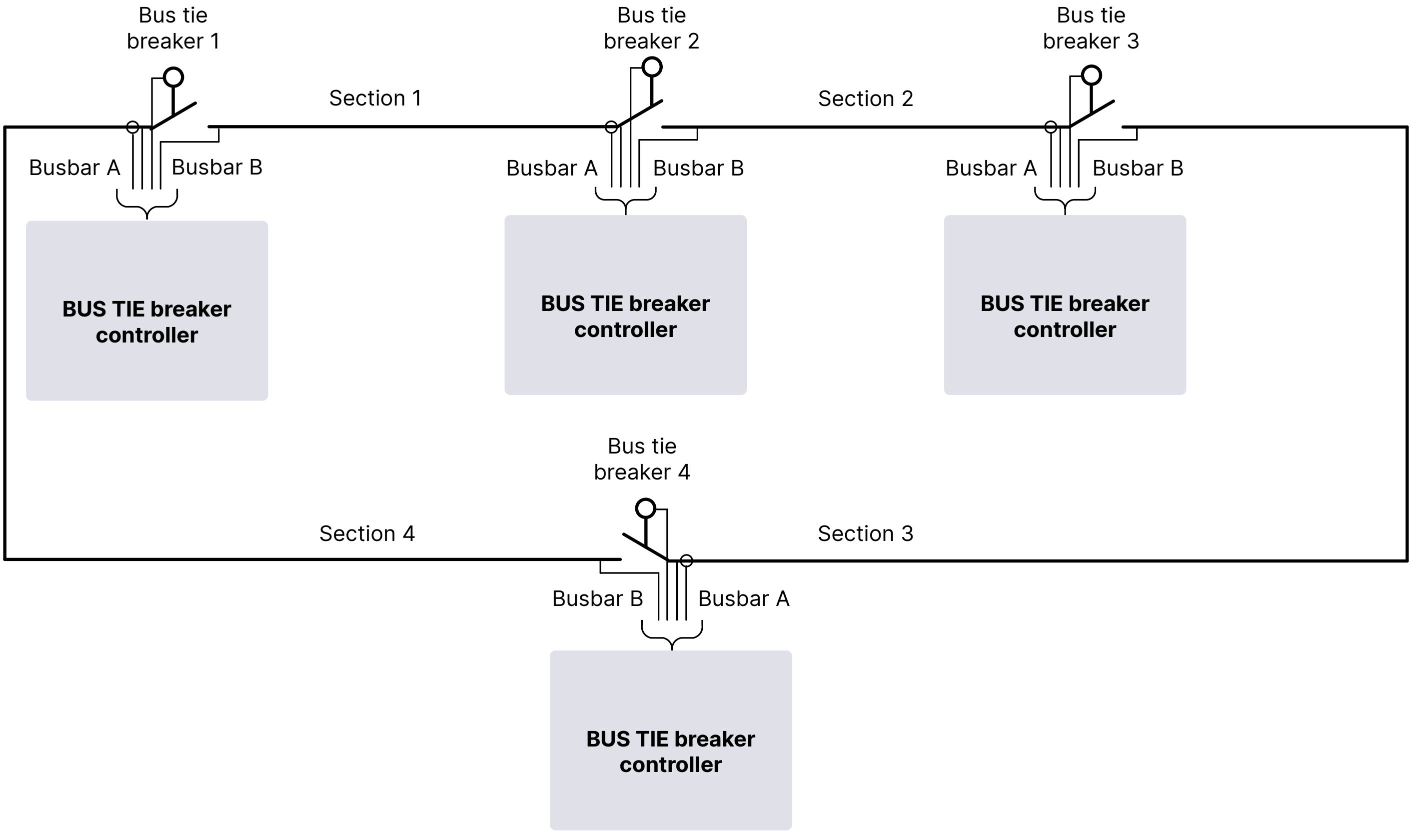
7.1.4 Busbar sections

There can be bus tie breakers in the single-line application drawing. When all the bus tie breakers are closed, the plant effectively has a single busbar. However, when one or more bus tie breakers are open, the power management has to manage busbar sections.

The power management manages the power for the busbar sections, according to a set of power management rules. The busbar sections are dynamic (that is, the busbar sections change whenever bus tie breakers are opened or closed).

Each **BUS TIE breaker** controller can create a new busbar section, as shown in the example below.

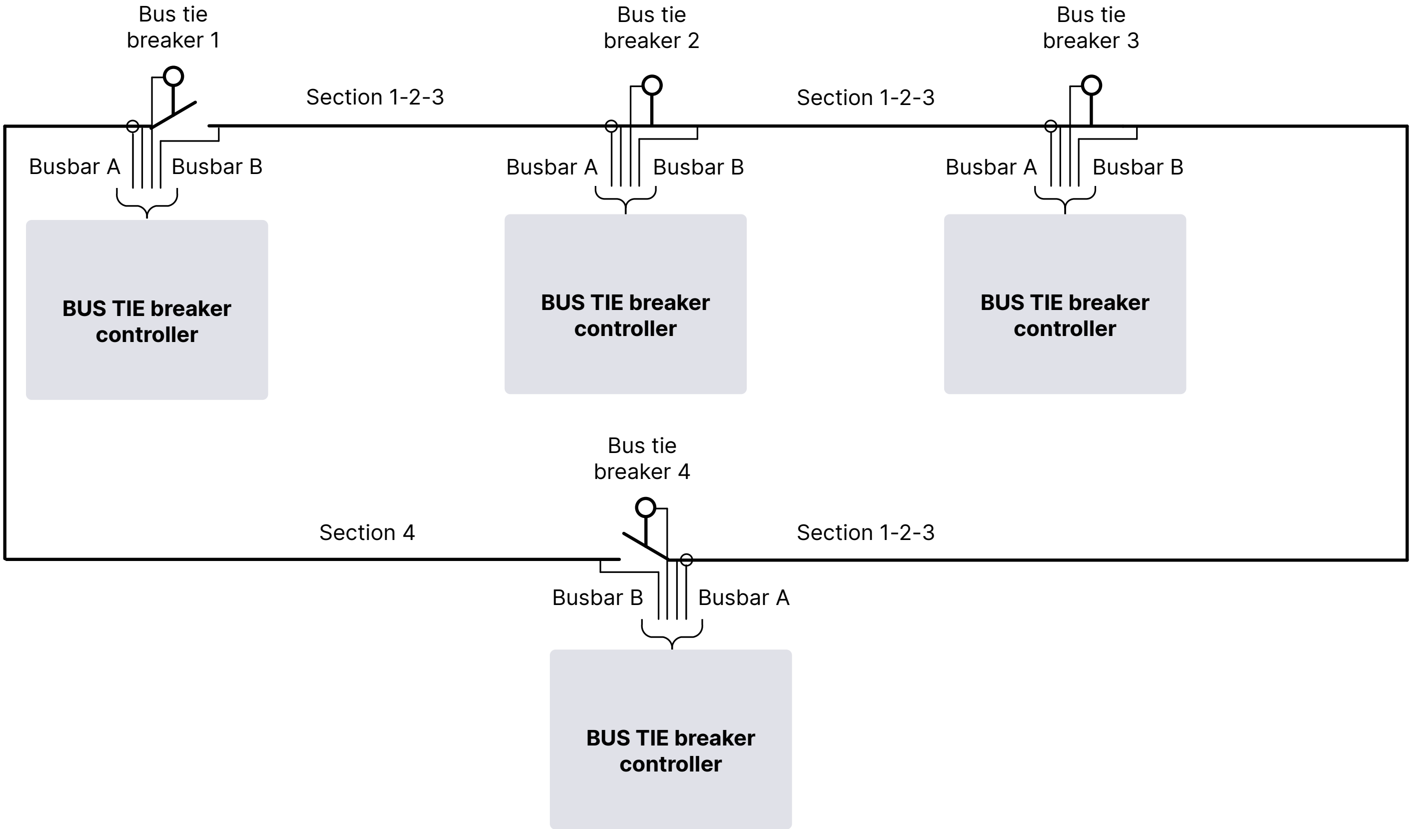
Example of busbar sections created by bus tie breakers



When the breaker(s) are open, each busbar section is independent from the other section(s). The controllers in the section manage the power independently for that section.

If the breaker(s) are closed, then the connected busbar sections together form one busbar section, as shown in the example below. The controllers in the connected busbar section manage the power for the combined busbar section.

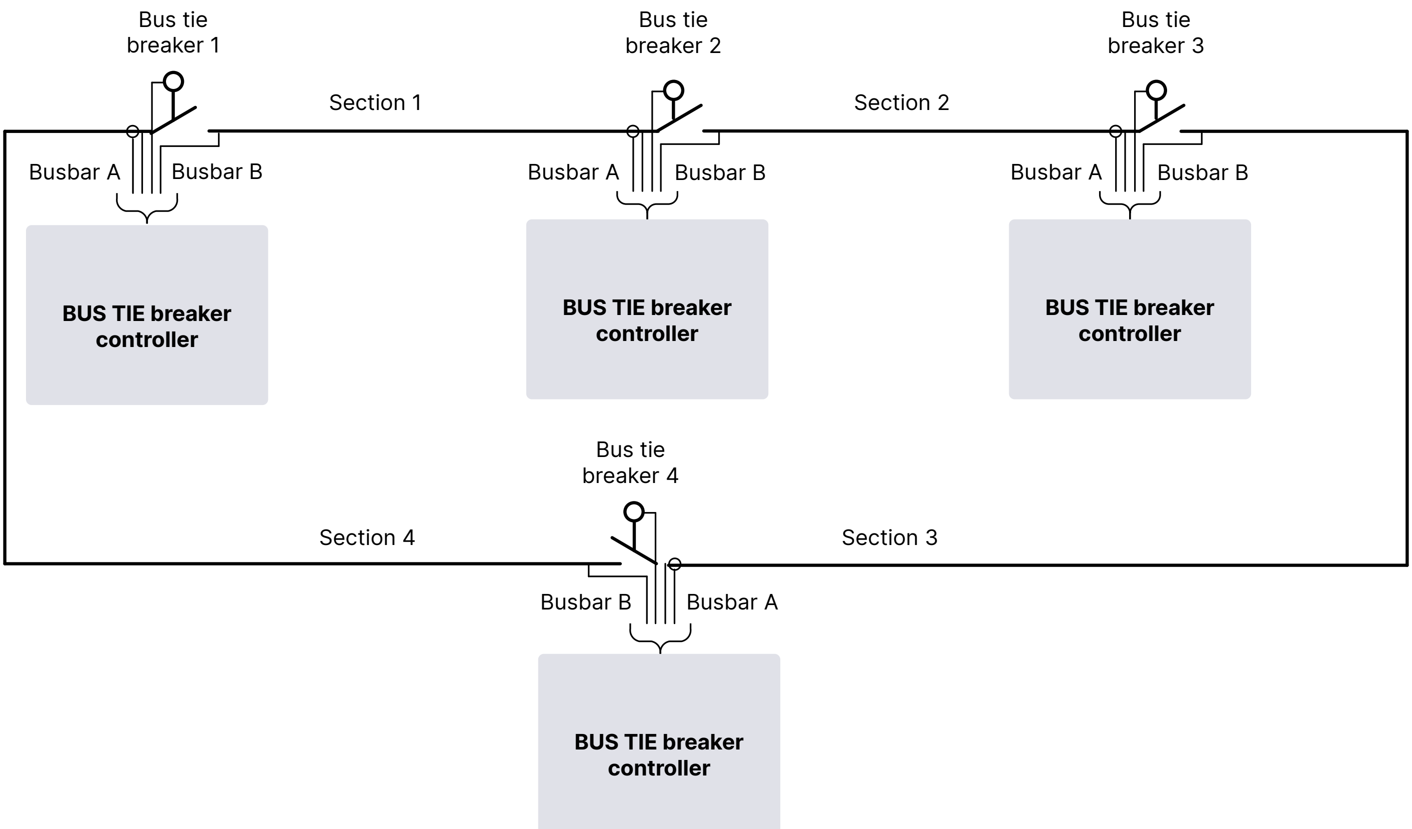
Example of busbar sections created by closing two bus tie breakers



NOTE The busbar sections are numbered here to make it easier to understand sections. However, busbar section numbers are not used in PICUS.

7.1.5 Ring busbar connection

BUS TIE breaker controllers can be installed in system with a ring busbar.



NOTE A ring busbar connection is only allowed if there are at least two bus tie breakers in the single-line application drawing. These bus tie breakers can be controlled by **BUS TIE breaker** controllers and/or externally controlled.

Parameters

`System power management > Bus tie breaker > Closed ring`

Parameter	Range	Default	Comment
`Ring close allowed`	• Not enabled • Enabled	Not enabled	**Not enabled** • The power management does not allow the last open bus tie breaker to close to create a ring busbar. If the operator presses the close button, then an info message appears on the display unit. **Enabled** • The power management allows the last open bus tie breaker to close to create a ring busbar.

If all the bus tie breakers in a ring are closed, and the operator presses the open button for a **BUS TIE breaker** controller, then that bus tie breaker opens without de-loading.

7.1.6 Managing section settings

Different power management settings can be created for each section while the bus tie breaker(s) are open. However, the power management settings for the section that is created when the bus tie breaker(s) are closed can then be inconsistent. It is therefore necessary to ensure that if all the bus tie breaker(s) are closed, all of the controllers in the application have the same power management settings. Use the `Store common settings` function used during commissioning, and whenever the power management strategy for the application is changed.

This topic explains:

- Power management static and dynamic sections.
- Power management common settings.
- How to use the `Store common settings` parameter to avoid inconsistent power management settings.

Static and dynamic sections

A **static section** is the smallest busbar section that the application can be divided into. By definition, there are no BTBs inside a static section.

A **dynamic section** is a continuous busbar section. This can be separated from the rest of the application by open BTB(s). There are no open BTBs inside a dynamic section. There may closed BTB(s) within the dynamic section. You can think of a dynamic section as two or more static sections, with the bus tie breakers between the static sections closed.

Common settings

Common settings refers to the power management settings that must be the same for all the controllers in a section. These include the load-dependent start-stop settings, and the mains controller plant mode.

The section settings handling follows these principles:

- In a static section, every change to the common settings automatically changes and stores the common settings in all the controllers in the section.
- When a BTB closes and a dynamic section is formed, the power management ensures that all the controllers have the same common settings. The user can also change parameters to make changes to the common settings. However, these common settings are not stored.
- You can use the parameter `Store common settings` to force the power management to store the dynamic system's common settings in each controller.
- When a BTB opens and a static section is formed, all of the controllers in the static section return to their stored common settings.

Storing the common settings

During commissioning, or when the system power management parameters are changed, close all the bus tie breakers, so that the application is one dynamic section. Select the `Store common settings` parameter to force the controller to write the common settings to all the controllers in the dynamic section.

Once the common settings are stored, make sure that you change the parameter back to **Not selected**. If you do not change the parameter to **Not selected**, this may lead to unintended changes to the parameters when a bus tie breaker opens or closes, since this would change the dynamic section(s).

`System power management > Store common settings > Settings`

Name	Range	Details
`Store common settings`	Not selected, Selected	**Selected**: When the parameter change is written, the common settings parameters are written to all the controllers in the dynamic section. **Not selected**: No action.

7.1.7 Local parameters

Local parameters only apply to one controller. Configure them under `Local power management`. These parameters are not automatically shared with other controllers in the system.

7.1.8 Mode changes and sections

You can configure the mode change to apply to only the local controller or to all controllers in the same section.

NOTE This function also applies to applications without BTBs.

Parameters

`Local power management > Mode > Update`

Parameter	Range	Default	Notes
`Selection`	• Local update • Update all	Local update	Decides how change mode should be applied within the section. **Local update** • Only the local controller changes mode. **Update all** • All controllers in the section change mode.

NOTE Joining or splitting sections does not cause any mode changes.

7.1.9 System power management

System power management parameters apply to the whole application, and are configured under `System power management`. When you write changes in these parameters, the system power management parameters are automatically updated in **all** the controllers in the system.

7.1.10 Parallel operation

In general, parallel operation is when two or more power sources supply power to the same busbar. The frequency and voltage of the power sources must be synchronised in order for the breakers to close for parallel operation.

Some power sources are not allowed to connect to the same busbar at the same time (that is, they are not allowed to be parallel). Others are only allowed to connect simultaneously for a limited time. The short-time parallel parameters are used to limit the time that power sources are connected to the same busbar.

Rules for parallel operation

- Gensets can run in parallel with each other indefinitely.
- Use parameters to define the rules for parallel operation with mains.
- Multiple mains can run in parallel with each other if multiple mains are enabled.

More information
See **Short-time parallel** in **Genset controller** for parameters to limit the time that the genset is parallel to the mains. See **Multiple mains** in **Mains controller** for a parameter for multiple mains in parallel.

7.1.11 Auto start/stop

For safety, the power management can only start and stop gensets/mains remotely when auto start/stop is activated. Note that in local operation, even if auto start/stop is not activated, the operator can start/stop the assets from the display.

Digital input*

Function	I/O	Type	Details
`System power management > Automatic start > Auto start/stop`	Digital input	Continuous	When this input is activated, the power management can remotely start/stop the genset/mains.

NOTE * Alternatively, use Modbus to activate this digital input function.

7.1.12 Manage missing controllers

For various reasons, communication may be lost with one or more of the controllers in the section. To protect the section, by default the power management automatically changes the remaining controllers to manual control. However, parameters are available so that you can configure a different response if one or more controllers are missing. You can set the minimum number of missing controllers before the mode is changed under `System > Monitoring > Missing controllers`.

NOTICE

Missing controllers

If controllers are missing, then the power management cannot know their operating information, including the breaker positions. Evaluate the risks before configuring these parameters.

Parameters

`System > Monitoring`

Parameter	Range	Notes
`Mode while controller missing`	• MANUAL • Manual/Auto mode • No mode change	If the minimum number of controllers are missing: **MANUAL** • No regulation is activated. This allows regulation by the operator. **Manual/Auto mode** • The power management changes the mode of the remaining controllers to manual mode. **No mode change** • The power management does not change the mode of the remaining controllers.

7.2 Power management modes

7.2.1 Plant/genset mode

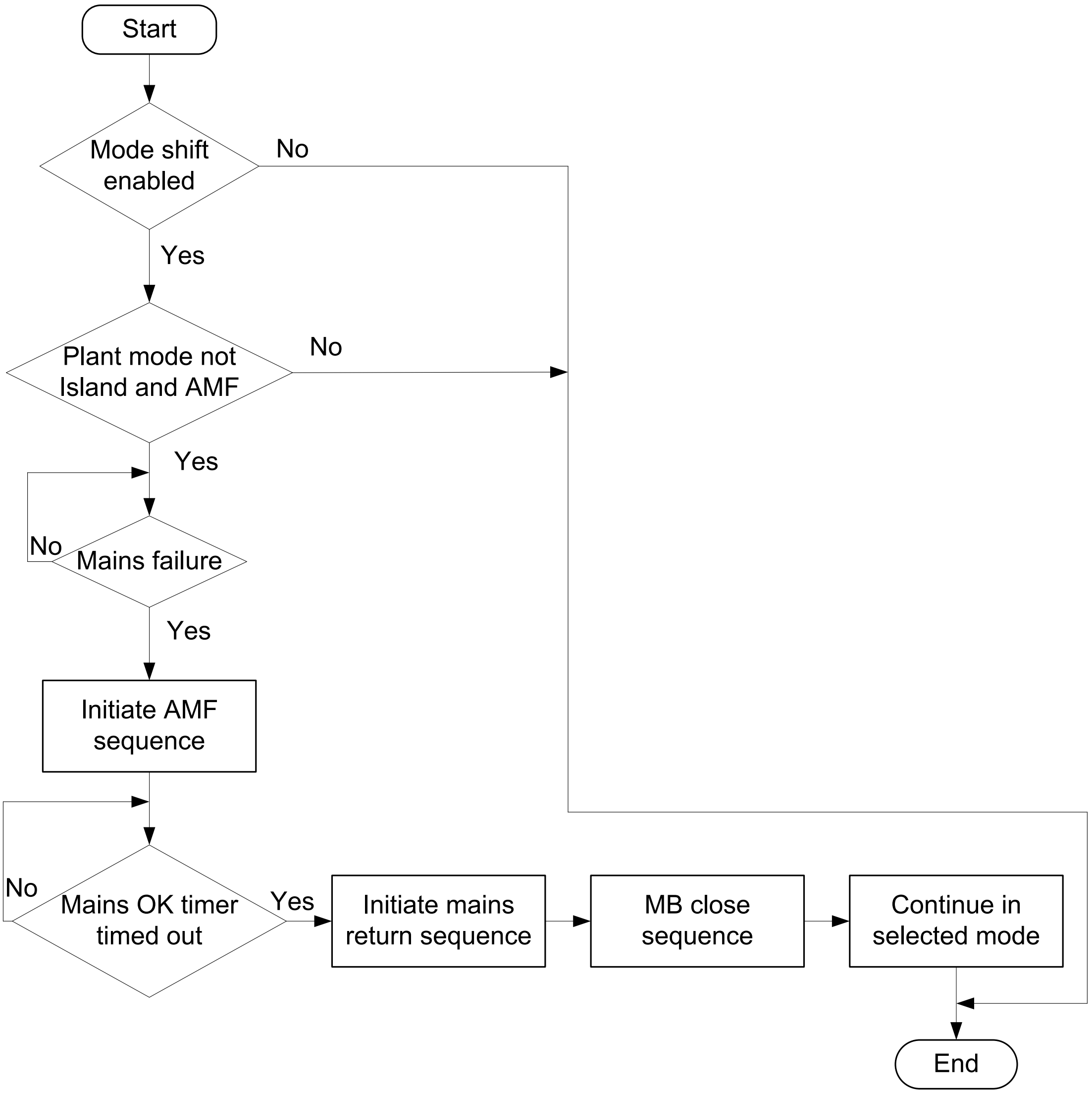
For power management, you need to select the plant mode in the genset and mains controllers.

Genset controller: `Power management rules > Plant/genset mode > Modes`

Name	Range	Details
`Genset mode`	• Island operation • Auto mains failure • Peak shaving • Fixed power • Mains power export • Load take over • Power management	For power management, select *Power management* in the genset controller. The other modes are only relevant in the genset controller if it is running as a single genset controller.
`Mode shift`	Off, On	Mode shift is only relevant if the controller is running as a single genset controller. **On**: If there is a mains failure, the controller runs in automatic mains failure (AMF) until the mains recovers. **Off**: If there is a mains failure, the controller does not change mode.

Mains controller: `Power management rules > Plant/genset mode > Modes`

Name	Range	Details
`Plant mode`	• Island operation • Auto mains failure • Peak shaving • Fixed power • Mains power export • Load take over	For power management, select the relevant mode in the mains controller.
`Mode shift`	Off, On	**On**: If there is a mains failure, the controller runs in automatic mains failure (AMF) until the mains recovers. See the flowchart below. **Off**: If there is a mains failure, the controller does not change mode.



7.2.2 Mains settings

More information
See the **MAINS controller** chapter for the mains functions and settings.

7.3 Connected, consumed and available power

7.3.1 Power calculations

The controllers continuously calculate the **nominal**, **consumed** and **available power** for each section. The power management system (PMS) uses these values.

The controller uses two sets of power calculations:

- **PMS power**: The power sources that are under power management control and available for automatic power management functions in the section.
- **Connected power**: All the power sources in the section.

PMS power

PMS power is used for the power management calculations. PMS power only includes the power supplied by sources under PMS control.

The power is included in the PMS power calculations as follows:

- **GENSET** controller:

    - The controller is in AUTO mode.
    - The genset is running.
    - The generator breaker is closed (that is, the genset is connected).
- **MAINS** controller:
    - The controller is under PMS control.
    - The breaker is closed.

Connected power

The connected power shows the overall supply and load situation for the section, without being restricted by the power management state of the power sources. It includes all the sources that are connected to the section (that is, breaker closed and supplying power).

Nominal power

The nominal power (also called *P nom.*) is the power that the connected sources can supply.

For PMS power, the nominal power is the sum of the nominal power for the connected gensets in AUTO mode (and, if applicable, mains, solar and storage).

For connected power, the nominal power is the sum of the nominal power for the connected sources:

Nominal power = Σ Nominal power of connected sources

Consumed power

The consumed power (also called *P used*) is produced by the gensets (and, if applicable, mains, solar and storage). The controllers can therefore use the sources' AC measurements to calculate the consumed power.

The consumed power calculations assume that no unknown power sources are connected to the busbar.

The consumed power is also the sum of the power consumed by all of the loads in the system, for example, motors, pumps and lighting.

For PMS power, the consumed power is the sum of the power produced by the connected sources in AUTO mode.

For connected power, the consumed power is the sum of the power produced by the connected sources.

Consumed power = Σ Power from sources

Available power

The available power (also called *P avail.*) is the difference between the nominal power and the consumed power.

For PMS power, the available power calculation uses the **connected consumed power**, and NOT the PMS consumed power. The PMS available power thus shows whether the PMS generators can meet the section's power needs. If a generator in manual mode is supplying the section, the PMS available power can be negative.

For connected power, the available power is the difference between the nominal power and the consumed power for the connected sources.

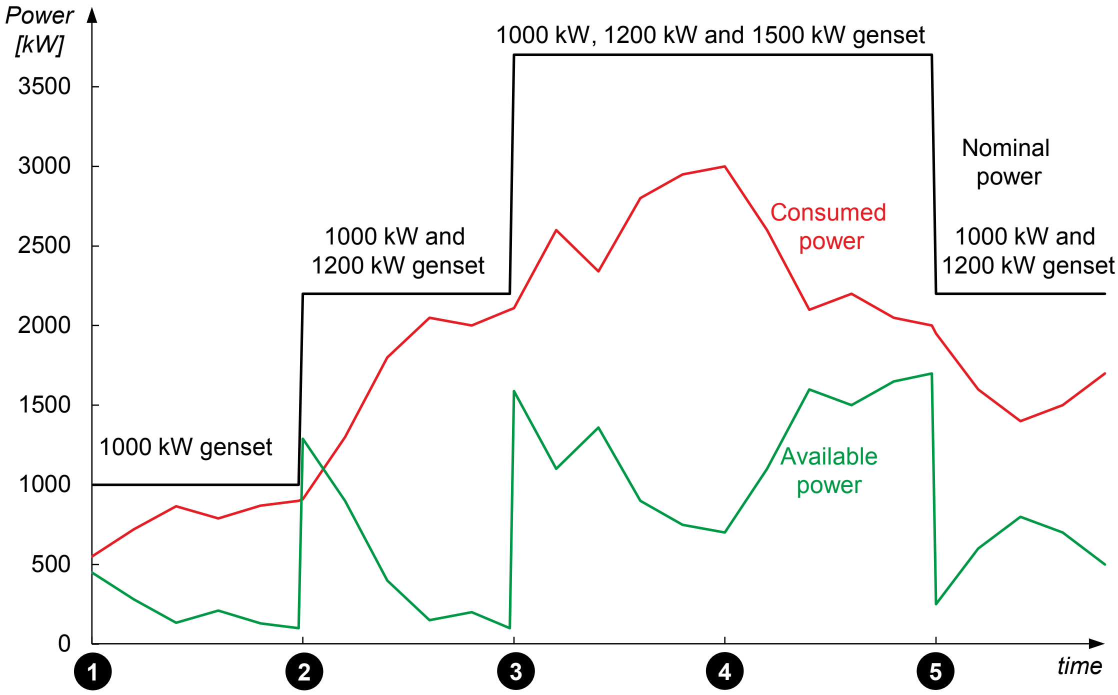
Available power = Nominal power - Total consumed power

The section can use the available power immediately, without starting more gensets. The section should always have some available power for sudden load increases.

Interaction between the power types

The following graph shows an example of how the nominal power, consumed power and available power could interact over time.

The example is a system with three gensets, with nominal powers of 1000 kW, 1200 kW and 1500 kW respectively.



1. At the start of the period, the 1000 kW genset is running.
2. The load gradually increases, and so the power management system starts the 1200 kW genset. The available power jumps up when the genset starts.
3. The load continues to increase, and so the power management system starts the 1500 kW genset.
4. The system runs, consuming power from all three gensets.
5. Towards the end of the period, the load decreases, so that the power management system stops the 1500 kW genset.

7.3.2 Power reservation

The power reservation inputs and parameters are used in the PMS available power calculation for the section. If these inputs and/or parameters are changed, the changes are broadcast to the rest of the section and also saved in the other controllers in the section.

NOTE Do not specify too much available power. The load-dependent start parameters ensure that the section normally has some available power. *Secured mode* and *Reserved power* each provide additional available power. Therefore *Secured mode* and *Reserved power* are not normally used simultaneously.

Reserved power

For *Reserved power*, the power management reduces the PMS power available by the reserved power *Set point*:

Available power = Nominal power - Consumed power - Reserved power

Parameters

`Power management rules > Power reservation > Reserved power`

Parameter	Range	Notes
`Enable`	Not enabled, Enabled	**Not enabled**: The power management ignores the reserved power set point. Available power = Nominal power - Consumed power

Parameter	Range	Notes
		Enabled: The system subtracts the reserved power from the available power.
`Set point`	0 kW to 30 MW	The reserved power that the controller must subtract from the available power.

7.3.3 N + X

The N + X function connects extra generators. That is, the power management runs more gensets than required by the load-dependent start. X refers to the multiple of the nominal power for the largest running generator that must be connected. See the example.

It is only possible to activate N + X if the genset controller is in AUTO mode.

`Power management rules > Power reservation > N + X`

Name	Range	Details
`N + X setup`	N + X OFF N + [1 to 8]	The system starts and connects the specified multiple of the nominal power for the largest running generator.

Example

The system consists of one 1.5 MW genset and 9 x 500 kW gensets. *N + X setup* is **N + 2**.

Scenario 1: The 1.5 MW genset and a 500 kW genset are running. The extra power required is therefore 2 x 1.5 MW (the biggest running). N + X therefore starts and connects an extra **six** of the 500 kW gensets.

Scenario 2: Four 500 kW gensets are running. The extra power required is therefore 2 x 500 kW (the biggest running). N + X therefore starts and connects an extra **two** of the 500 kW gensets.

7.3.4 Power analogue outputs

In genset, mains and BTB controllers, you can configure analogue outputs with functions for a power value in a section. The controller calculates these values from the information from all the controllers in the section.

Power value analogue outputs

Function	I/O	Units	Details
`System power management > Monitoring > Plant > Section | PMS P avail. [%]`	Analogue output	-100 to 100 %	The PMS available power as a percentage of the PMS nominal power in the section. This can be negative. For example, the gensets in AUTO mode cannot supply the whole load, and a generator under manual control is supplying power to the section.
`System power management > Monitoring > Plant > Section | PMS P used [%]`	Analogue output	-100 to 100 %	The PMS power used as a percentage of the PMS nominal power in the section.

Applications

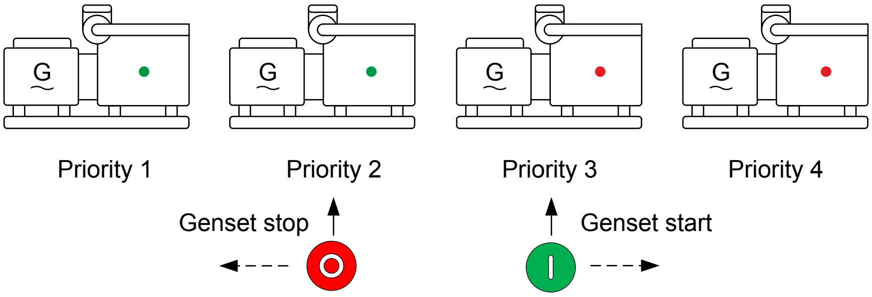
An analogue output with a power value may be wired to a switchboard instrument, to help with troubleshooting. For example, use `Section | PMS P avail. [%]` to troubleshoot load-dependent start and stop.

7.4 Genset priority

7.4.1 Genset start and stop priority order

Each genset has a priority that the power management can use to determine which genset to start (or stop) when a genset start (or stop) is needed.

The priorities are used to create a genset priority order, as shown in the following example. The gensets with priority 1 and 2 are running, while the gensets with priority 3 and 4 are stopped. All the **GENSET** controllers are in AUTO mode.



If a genset start is needed, the first non-running genset in the priority order is started. Note that the **GENSET** controller must also be in AUTO mode, and the genset must be *Ready for operation*.

In this example, the genset with priority 3 is started. If the genset fails to start, or if the power management needs another genset to start, the next genset in the order (the genset with priority 4) is started.

Similarly, if a genset stop is needed, the last running genset in the priority order is stopped. In this example, the genset with priority 2 is stopped.

NOTE Poorly selected genset priorities can lead to inefficient operation in a system that consists of gensets of different sizes. This is because the power management ensures that the gensets run according to their priority order, even if it is not the most efficient configuration.

Genset priority example

The system consists of genset A (1000 kW), genset B (500 kW) and genset C (200 kW). The system requires 800 kW.

- If genset A has priority 1, then only genset A will run to supply the load.
- However, if genset C has priority 1, and genset B priority 2, then all three gensets have to run. This is because the power management ensures that the gensets run according to their priority order to provide the power required by the load.

Priority in the system

The power management has one genset priority order, which includes all the **GENSET** controllers in the system. The genset priority order does not change when bus tie breakers open to create new sections. The order does not change when bus tie breakers close to join sections.

Priority in sections

Within a section, the power management uses the genset priority order for the **GENSET** controllers that are in the section.

If a bus tie breaker opens and splits the section, then the genset priority order for each section consists of only the **GENSET** controllers in each section.

Similarly, if a bus tie breaker closes to join two sections, then the genset priority order for the new section consists of all the **GENSET** controllers in the new section.

Priority in a section example

The system has six **GENSET** controllers. Gensets A, B and C are in section 1. Gensets D, E and F are in section 2. The bus tie breaker between sections 1 and 2 is open.

The genset priority order is:
- Genset F, priority 1
- Genset C, priority 2
- Genset D, priority 3
- Genset A, priority 4
- Genset B, priority 5
- Genset E, priority 6

For section 1, the genset priority order is: C, A, B. For section 2, the genset priority order is: F, D, E.

7.4.2 Priority selection method

`System power management > Priority > Selection`

Parameter	Range	Notes
`Method`	• Manual absolute • Total running hours • Fuel optimisation • Manual relative • Running hours relative • Fuel optimisation + running hours	**Manual absolute**: The genset priority is defined using a digital input or the Modbus interface. The controllers have an application-wide priority list. If a bus tie breaker is opened to create new busbar sections, the controllers use the application-wide priority list to create a priority list is used for each section. See Manual priority. **Total running hours** See Running hours for priority. **Fuel optimisation** See Fuel optimisation. **Manual relative**: This is meant for applications with for multiple mains connections. The controllers have an application-wide priority list. However, when a bus tie breaker closes, the gensets in the section that was running get the first priority. **Running hours relative**: The genset priority is assigned to ensure that the genset running hours are all within the same range or offset. See Running hours for priority. **Fuel optimisation + running hours** See Fuel optimisation and running hours.
`Transmit`	• Off • Running hours	**Off**: **Running hours**:

7.4.3 Manual priority

The controller priorities are always synchronised. If you manually change the priority in one controller, then the priorities in all the other controllers are automatically updated.

If *Manual* is selected as the priority selection method, then you can select the genset priorities manually. For *Manual* the priorities are only set by the operator, and the controllers do not automatically change the genset priorities.

A new genset priority order should be carefully considered, since it may cause genset starts and stops. If all the **GENSET** controllers are in MANUAL mode while you set the genset priority, this prevents unwanted automatic genset starts and/or stops.

Digital input (optional)

Function	I/O	Type	Details
`System power management > Priority > 1st priority`	Digital input	Pulse	This input makes the controller the first priority.

NOTE You can also use the display commands parameter to allow users to set the priority from the display. Under `Local > Command sources > Active sources > Display commands`, select **First priority**.

Setting the genset priority using the 1st priority input

You can set the genset priority manually by using the 1st priority input on the gensets in the reverse of the priority order you want.

1st priority example

The system consists of gensets A, B, C and D. You want genset A to have priority 1, genset B to have priority 2, genset C to have priority 3 and genset D to have priority 4.

1. Activate the **1st priority** input to the controller in the following order: D, C, B, A. Wait about 10 seconds between each input activation.
2. The priority order is then A, B, C, D.

7.4.4 Running hours for priority

You can use running hours for priority to ensure that all the gensets have about the same running hours. This method checks the running hours at regular intervals. It places the gensets with the lowest running hours at the front of the priority order, while the gensets with the highest running hours are at the back of the priority order. If the genset priorities are different from the running gensets, the genset(s) with the lowest number of running hours is started, and the genset(s) with the highest number of running hours is stopped.

If two (or more) gensets have exactly the same number of running hours, the genset priority is decided using the controller *Controller ID* numbers. The controller with the lowest *Controller ID* has the first priority.

Parameters

`System power management > Priority > Running hours`

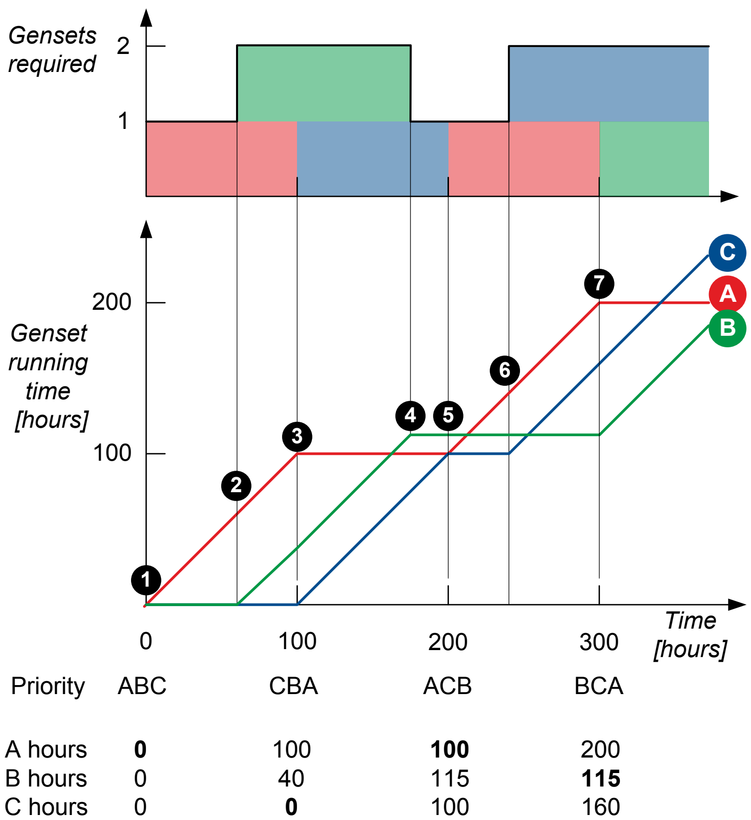
Parameter	Range	Notes
`Activate priority update`	1 to 20000 h	The regular interval for re-evaluating the genset priority, based on running hours.
`Method`	• Total • Relative • Load profiled	**Total** • The priority is based on the total running hours for each genset. **Relative** • The priority is based on the running hours for each genset since the timer was last reset (similar to a trip meter in a car). You can use `Relative` to avoid a situation where gensets with significantly different running times are over- or under-used. For example, if `Total` is used, then an older genset might not run at all until the newer gensets get up to the same number of running hours. **Load profiled**

Parameter	Range	Notes
		• The priority is based on the load-weighted total running hours for each genset.

Example Swap timer for the Total and Trip methods

There are three gensets (A, B, C) in the system. The *Activate priority update* is 100 hours. All the gensets have 0 running hours.

The following graph shows how the running hours priority determines which gensets run, as well as the effect when more than one genset is required.

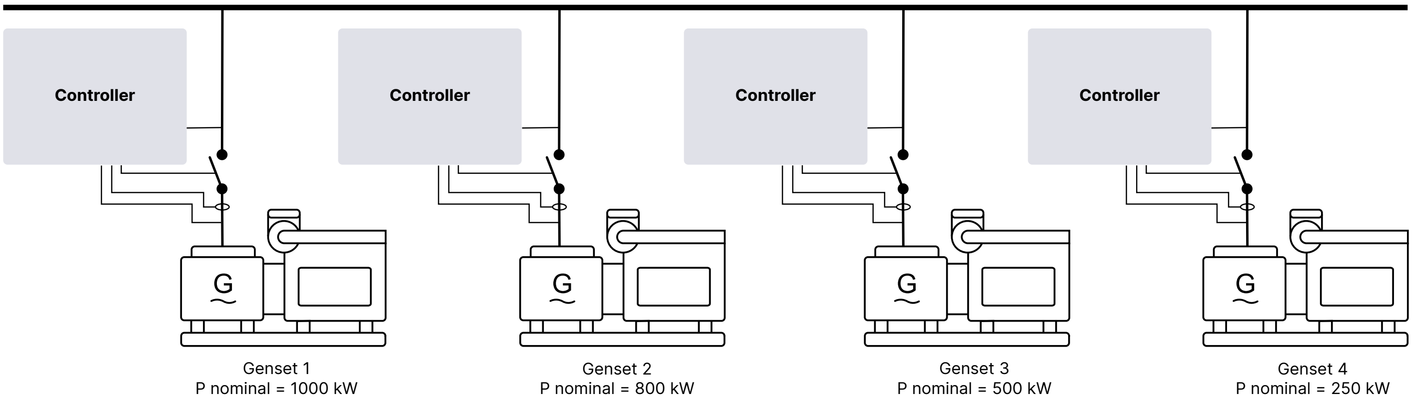


The operation is as follows:

1. The genset priority is A, B, C. Genset A runs.
2. At 60 hours, the load increases, and an additional genset is required. Genset B starts.
3. The swap timer reaches 100 hours. The genset priority changes to C, B, A. Genset C starts. Genset A stops.
4. At 175 hours, the load decreases, and only one genset is required. Genset B stops.
5. The swap timer reaches 200 hours. The genset priority changes to A, C, B. Genset A starts. Genset C stops.
6. At 240 hours, the load increases, and an additional genset is required. Genset B starts.
7. The swap timer reaches 300 hours. The genset priority changes to B, C, A. Genset B starts. Genset A stops.

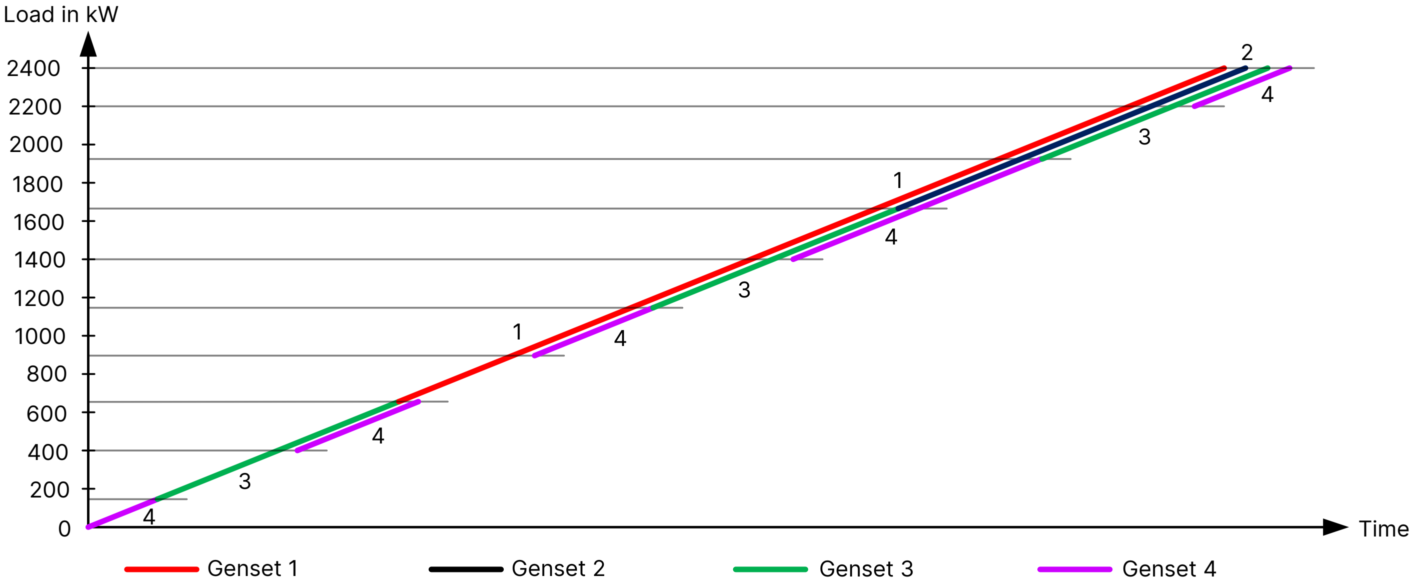
7.4.5 Fuel optimisation

If *Fuel optimisation* is selected, the genset priorities are disabled, and the gensets start and stop according to the load. The fuel optimisation function can be useful if the application consists of gensets with different nominal powers. The function is best described with an example:



Four gensets, with different nominal powers, are shown above. Fuel optimisation is activated, so there are no genset priorities. The power management continuously calculates the optimised set of gensets to run.

The diagram below shows which gensets run as the load increases. In this example the load-dependent start limit is 100 kW. That is, when available power drops below 100 kW, the next genset starts. After the next genset starts, another one may stop to optimise the fuel consumption.



1. For fuel optimisation, the smallest possible genset (number 4) starts.
2. After that, genset 3 takes the load alone, since a bigger genset is not yet required.
3. Next, genset 4 starts again. At this point, two gensets are running, since the nominal power of gensets 3 and 4 is smaller than the nominal power of genset 2.
4. As the load increases, some gensets are stopped, and some bigger ones are started.
5. For the maximum load, all the gensets run in parallel.

NOTE With fuel optimisation, it is still possible to use asymmetrical load sharing, or normal load sharing.

7.4.6 Fuel optimisation and running hours

If *Fuel optimisation + running hours* is selected, the power management ignores the genset priorities, and the gensets start and stop according to the running hours. If two or more gensets have the same running hours, the optimum genset combination is selected according to the load.

7.5 Genset start and stop

7.5.1 How it works

The power management automatically starts and stops gensets. Gensets are started to ensure that the required power is always available. Gensets are stopped when enough power is available, for more efficient operation.

AUTO mode for automatic genset starts and stops

The load-dependent start function sends a genset start command when an additional genset is required to satisfy the system's power requirements. The load-dependent stop function sends a genset stop command when the system's power requirements will be satisfied even after that genset is stopped.

The load-dependent start function is active whenever at least one **GENSET** controller is in AUTO mode. However, the function will only start additional gensets when there are additional **GENSET** controllers are available in AUTO mode.

The load-dependent stop function is active whenever at two **GENSET** controllers are in AUTO mode. However, the power management will not stop the last connected genset.

Only **GENSET** controllers in AUTO mode are included in the available power calculations. Power from **GENSET** controllers that are in MANUAL mode is not included.

Blackout and genset starts

The blackout recovery sequence responds immediately to a dead busbar.

More information
See Blackout recovery.

7.5.2 Load-dependent start configuration

Load-dependent start defines when the power management automatically starts gensets. The power management starts gensets when the section load increases, for example, if the operator starts some equipment.

If the PMS available power is negative, the power management starts another genset immediately, and does not wait for the load-dependent start timer.

These parameters apply to **GENSET** controllers in AUTO mode.

Define the overall load-dependent start and stop configuration.

`Power management rules > Load-dependent start/stop > Configuration`

Parameter	Range	Notes
`Minimum load`	0 kW to 20 MW	
`Power selection`	• kW • kVA	**kW** • The calculations are based on the active power (P). **kVA** • The calculations are based on the apparent power (S).
`Method`	• Power • Percent	**Power** • The calculations are based on the PMS available active power in kW, or the PMS available apparent power in kVA. **Percent** • The calculations are based on the total consumed active (or apparent) power as a percentage of PMS nominal active (or apparent) power.

Parameter	Range	Notes
		NOTE The *Percent* method can be better if the genset sizes are very different.

Define the first set of start parameters. By default, the power management uses these parameters.

`Power management rules > Load-dependent start/stop > Start 1`

Parameter	Range	Notes
`P available limit`	1 kW to 20 MW	*kW* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS power is not available for the delay period, the power management starts the next genset in the priority order.
`S available limit`	1 kVA to 20 MVA	*kVA* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS apparent power is not available for the delay period, the power management starts the next genset in the priority order.
`Load limit`	1 to 100 %	*Method* = *Percent* must be selected, otherwise this parameter is ignored. The load percentage is the total power consumed, as a percentage of the PMS nominal power. If the load percentage exceeds this parameter for the *Delay* period, the power management automatically starts and connects another genset. If *kW* is selected, this limit is based on the percentage of active power. If *kVA* is selected, this limit is based on the percentage of apparent power.
`Delay`	0 s to 16.5 min	If the load exceeds the limit for the whole of the delay period, then the power management starts the next genset in the priority order.

Define the second set of start parameters. By default, the power management ignores these parameters.

`Power management rules > Load-dependent start/stop > Start 2`

Parameter	Range	Notes
`P available limit`	1 kW to 20 MW	*kW* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS power is not available for the delay period, then the power management starts another genset, according to the priority order.
`S available limit`	1 kVA to 20 MVA	*kVA* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS apparent power is not available for the delay period, the power management starts another genset, according to the priority order.
`Load limit`	1 to 100 %	*Method* = *Percent* must be selected, otherwise this parameter is ignored. The load percentage is the total power consumed, as a percentage of the PMS nominal power. If the load percentage exceeds this parameter for the *Delay* period, then the power management automatically starts and connects another genset. If *kW* is selected, then this limit is based on the percentage of active power. If *kVA* is selected, then this limit is based on the percentage of apparent power.
`Delay`	0.0 s to 16.5 min	If the load exceeds the limit for the whole of the delay period, the power management starts another genset, according to the priority order.

Example

Start load limit example

The system consists of three gensets. Genset A has a nominal power of 1000 kW. Gensets B and C each have a nominal power of 500 kW. The total power consumed in the system (that is, the load) is 900 kW. The *Power selection* is *kW*. The *Method* is *Percent*. The *Load limit* is 90 %.

Example 1: Gensets A and B are running. The total nominal power connected is Genset A nominal power + Genset B nominal power = 1500 kW.
The load percentage is 900 kW / 1500 kW = 0.6 = 60 %. The power management does not start another genset.

Example 2: Only Gensets B and C are running. The total power connected is 1000 kW. The load percentage is 900 kW / 1000 kW = 0.9 = 90 %. If the load percentage remains at 90 % (or more) for the *Delay* time, the power management starts another genset.

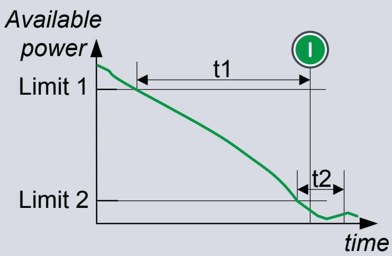
Two sets of load-dependent start parameters

You can use both sets of load-dependent start parameters:

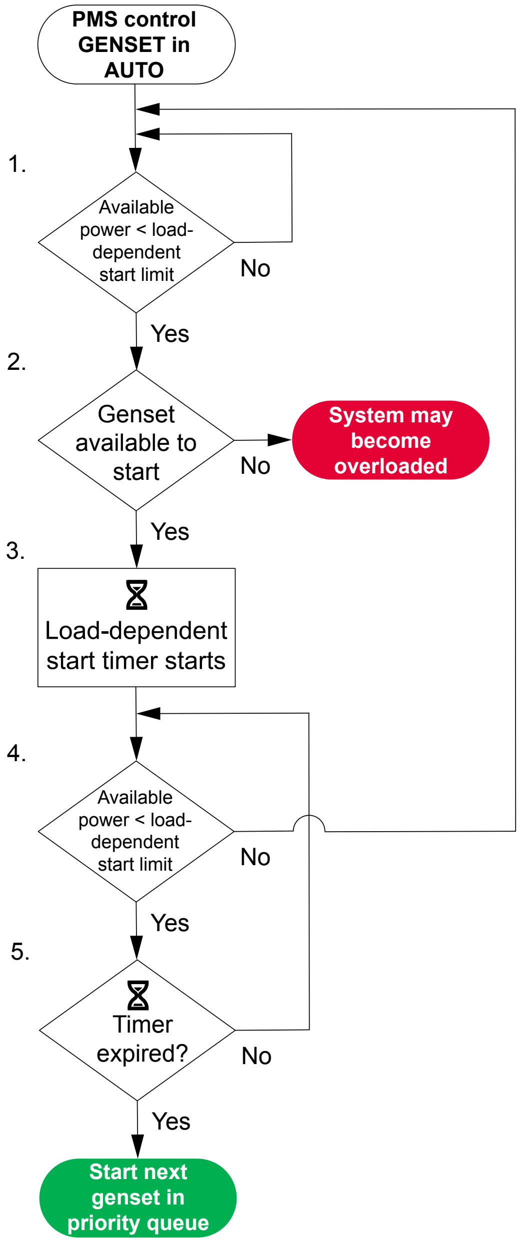
- Configure one parameter set for low available power, with a long timer setting.
  - The timer period helps to ensure that the genset start really is needed.
- Configure the other parameter set with a low timer setting for very low available power.
  - This ensures that the power management responds quickly to a very low available power.

Two sets of start parameters example

The graph shows available power and time, with two sets of start parameters. In this example, Limit 1 is exceeded for Timer 1, and so the power management starts a genset.



7.5.3 Load-dependent start flowchart



1. The controller checks if the PMS available power is below the start limit.
2. The controller checks if a genset can be started.
   - If a genset cannot be started the system may become overloaded.
3. The controller starts the load-dependent start timer.
4. The controller checks if the PMS available power remains below the start limit.
5. If the timer expires the power management starts the next available genset in the priority order.

7.5.4 Load-dependent stop configuration

This configuration defines when the power management automatically stops gensets. The power management stops gensets when the section load decreases.

These parameters apply to **GENSET** controllers in AUTO mode.

Define the overall load-dependent start and stop configuration.

`Power management rules > Load-dependent start/stop > Configuration`

Parameter	Range	Notes
`Power selection`	• kW • kVA	**kW** • The calculations are based on the active power (P). **kVA**

Parameter	Range	Notes
		• The calculations are based on the apparent power (S).
`Method`	• Power • Percent	• **Power**: The calculations are based on the PMS available active power in kW, or the available apparent power in kVA. • **Percent**: The calculations are based on the total consumed active (or apparent) power as a percentage of PMS nominal active (or apparent) power. Note: The *Percent* method can be better if the genset sizes are very different.

Define the first set of stop parameters. By default, the power management uses these parameters.

`Power management rules > Load-dependent start/stop > Stop 1`

Parameter	Range	Notes
`P available limit`	1 kW to 20 MW	*kW* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS power would be available for the *Delay* period if a genset was stopped, then the power management stops a genset, according to the priority order.
`S available limit`	1 kVA to 20 MVA	*kVA* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS apparent power would be available for the *Delay* period if a genset was stopped, then the power management stops a genset, according to the priority order.
`Load limit`	1 to 100 %	*Method* = *Percent* must be selected, otherwise this parameter is ignored. For the stop *Load limit*, the load percentage is the total power consumed, as a percentage of the PMS nominal power that would be connected **if a genset was stopped**. If the load percentage is lower than this limit for the *Delay* period, then the power management automatically disconnects and stops a genset. If *kW* is selected, then this limit is based on the percentage of active power. If *kVA* is selected, then this limit is based on the percentage of apparent power.
`Delay`	5 s to 16.5 min	If the load is less than the limit for the whole of the *Delay* period, then the PMS stops a genset, according to the priority order.

Define the second set of stop parameters. By default, the power management ignores these parameters.

`Power management rules > Load-dependent start/stop > Stop 2`

Parameter	Range	Notes
`P available limit`	1 kW to 20 MW	*kW* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS power would be available for the *Delay* period if a genset was stopped, then the power management stops a genset, according to the priority order.
`S available limit`	1 kVA to 20 MVA	*kVA* and *Method* = *Power* must be selected, otherwise this parameter is ignored. If this amount of PMS apparent power would be available for the *Delay* period if a genset was stopped, then the power management stops a genset, according to the priority order.
`Load limit`	1 to 100 %	*Method* = *Percent* must be selected, otherwise this parameter is ignored.

Parameter	Range	Notes
		For the stop *Load limit*, the load percentage is the total power consumed, as a percentage of the PMS nominal power that would be connected **if a genset was stopped**. If the load percentage is lower than this limit for the *Delay* period, then the power management automatically disconnects and stops a genset. If *kW* is selected, then this limit is based on the percentage of active power. If *kVA* is selected, then this limit is based on the percentage of apparent power.
`Delay`	5 s to 16.5 min	If the load would be less than the limit for the whole of the *Delay* period if a genset was stopped, the power management stops a genset, according to the priority order.

Example

Stop load limit example

The system consists of three gensets. Genset A has a nominal power of 1000 kW. Gensets B and C each have a nominal power of 500 kW. The priority is A, B, C. The total power consumed in the system (that is, the load) is 700 kW. The *Power selection* is *kW*. The *Method* is *Percent*. The *Load limit* is 60 %.

Example 1: Gensets A, B and C are running. For the load percentage calculation, the total nominal power connected if genset C was stopped is Genset A nominal power + Genset B nominal power = 1500 kW.
The load percentage is 700 kW / 1500 kW = 0.47 = 47 %. If the load percentage remains below the *Load limit* for the *Delay* time, the power management stops genset C.

Example 2: Only gensets A and B are running. For the load percentage calculation, the total nominal power connected if Genset B was stopped is Genset A nominal power = 1000 kW. The load percentage is 700 kW / 1000 kW = 0.7 = 70 %. The power management does not stop genset B.

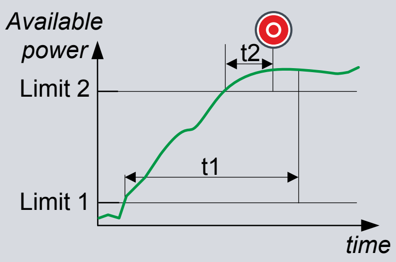
Two sets of load-dependent stop parameters

You can use both sets of load-dependent stop parameters:

- Configure one parameter set for high available power, with a long timer setting.
  - The timer period helps to ensure that the genset stop really is needed.
- Configure the other parameter set with a low timer setting for very high available power.
  - This ensures that the power management responds quickly to a very high available power.

Two sets of stop parameters example

The graph shows available power and time, with two sets of stop parameters. In this example, Limit 2 is exceeded for Timer 2, and so the power management stops a genset.

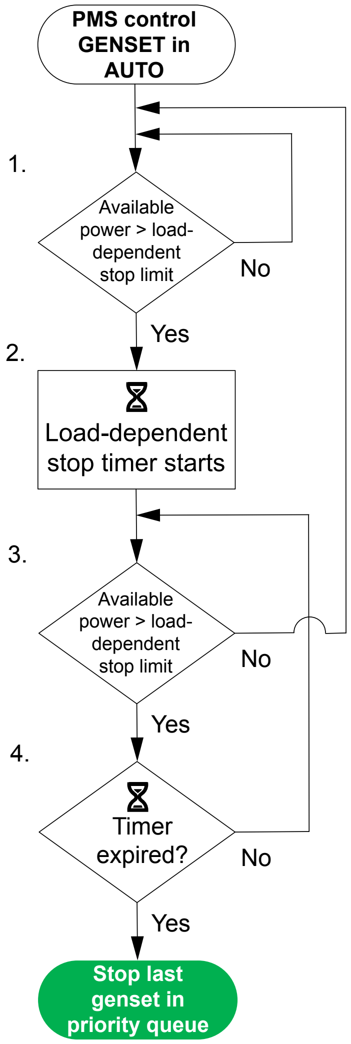


Conditions that block load-dependent stops

The following can block load-dependent stops in the section:

- The load-dependent stop will mean that the minimum number of gensets are not running
  - See `Power management rules > Number of gensets connected > Minimum set [1/2]`

7.5.5 Load-dependent stop flowchart



1. The controller checks if the PMS available power is more than the stop limit.
   - The load-dependent stop limit + the nominal power of the lowest priority running genset.
2. The controller starts the load-dependent start timer.
3. The controller checks if the PMS available power remains below the start limit.
4. If the timer expires the power management stops the last running genset in the priority order.

7.5.6 Power method for load-dependent start and stop

For the *Power* method, the power management starts or stops gensets with **GENSET** controllers in AUTO mode, based on the section's PMS available power.

The *Power* method may be based on active power (P, in kW) (*kW*) or apparent power (S, in kVA) (*kVA*). The available power genset start and stop function calculations are the same for apparent power as they are for active power.

kVA is typically selected if the connected load is inductive and the power factor is below 0.7.

The following example shows how the parameters interact with the PMS nominal power, connected consumed power and PMS available power.

Load-dependent start

If the PMS available power is less than the *Load-dependent start* limit for the specified time, then the first genset that is ready to start (in the priority order) is started and connected.

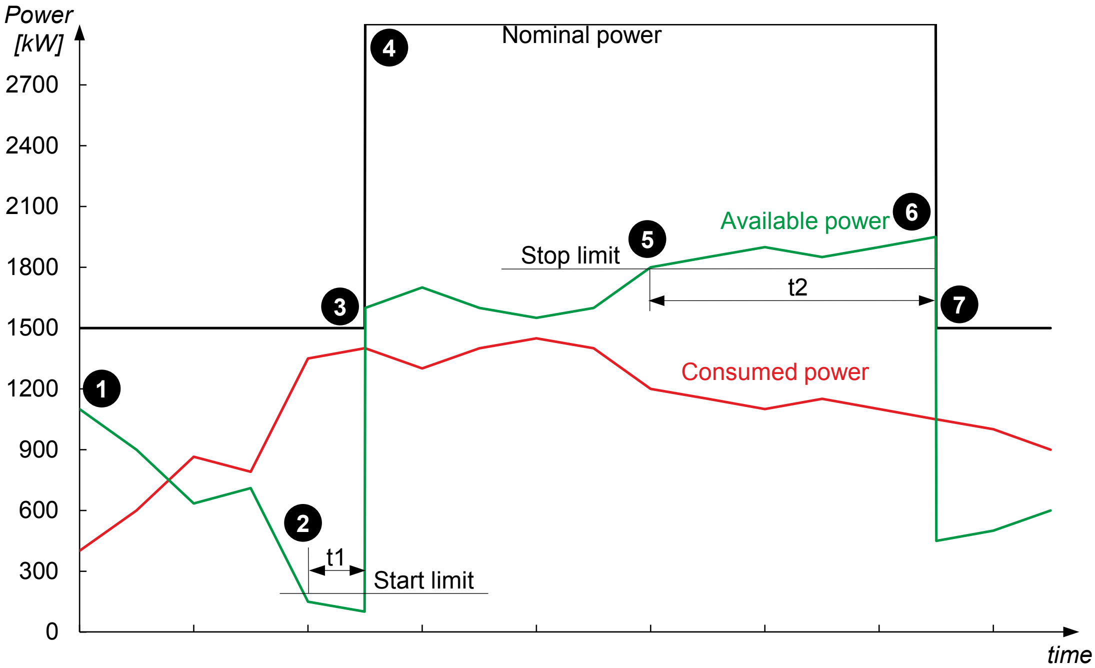
Load-dependent stop

The power management calculates what the PMS available power would be if the connected genset that is last in the priority order is stopped. If this is higher than the *Load-dependent stop* limit for the specified time, that genset will be stopped.

Example

The system consists of two gensets, each with a nominal power of 1500 kW. The load-dependent start set point is 150 kW. The load-dependent stop set point is 300 kW.

- The load-dependent start delay (t1) is 1 minute.
- The load-dependent stop delay (t2) is 5 minutes.



1. One genset is running and the PMS nominal power is 1500 kW. The consumed power rises, and so the PMS available power drops.
2. The PMS available power is 150 kW. The load-dependent start timer starts.
3. The PMS available power remains below 150 kW, and so the power management sends a command to the second genset to start.
4. The second genset starts, and both gensets supply the load.
5. The consumed power drops to 1200 kW. The PMS available power is now 1800 kW. This is equal to the nominal power of the genset that is last in the priority order plus the load-dependent stop set point. Therefore, the load-dependent stop timer starts.
6. The PMS available power remains above 1800 kW, and so the power management send a command to the second genset to stop.
7. The second genset stops, and the first genset supplies the load.

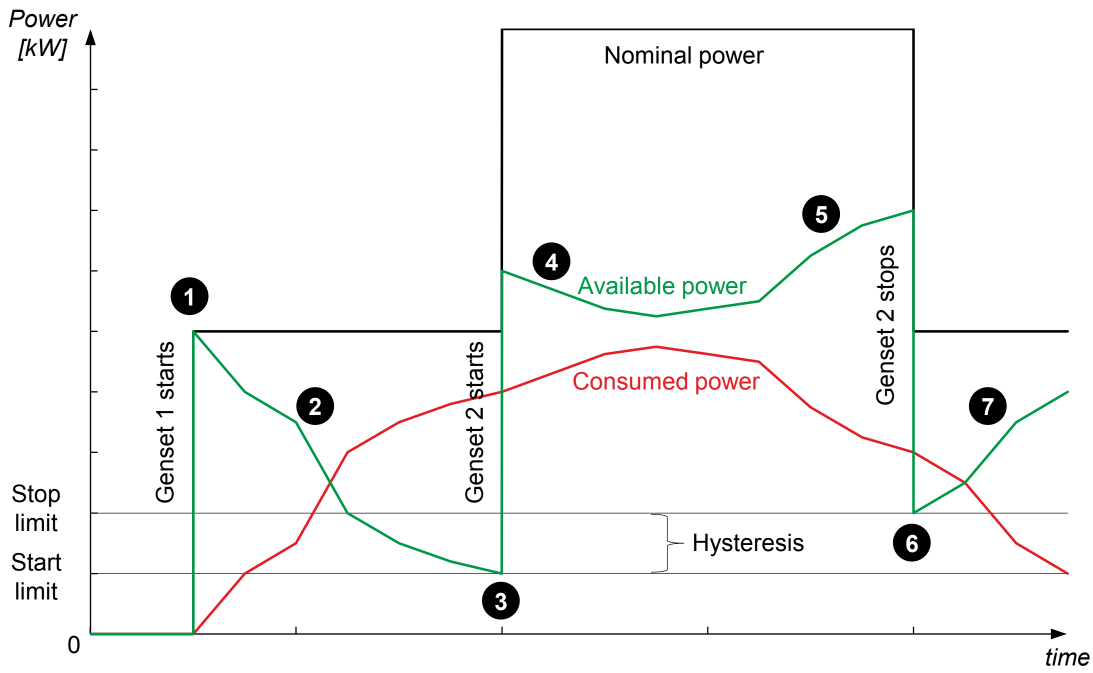
7.5.7 Power method and hysteresis

For the power method:

Hysteresis = Load-dependent stop limit - Load-dependent start limit

For stable operation, the load-dependent stop limit must be larger than the load-dependent start limit.

The following graph of PMS available power shows an example of the hysteresis between the stop and start for the power method. The section consists of two equally sized gensets. The start and stop delays are 0 seconds. At the beginning of the period shown on the graph, the section is not powered.



1. The PMS available power jumps up when genset 1 starts and connects to the busbar.
2. As time passes, the section load increases, which makes the PMS available power fall.
3. The PMS available power falls until it reaches the load-dependent start limit. Genset 2 is started.
4. The PMS available power jumps up when genset 2 starts, then drops as the section load continues to increase.
5. The section load decreases, and the available power increases, until PMS available power = genset 2 nominal power + load-dependent stop limit.
6. Genset 2 stops. The PMS available power drops to the load-dependent stop limit.
7. The section load continues to decrease, and the PMS available power continues to increase.

7.5.8 Percent method for load-dependent start and stop

For the *Percent* method, the power management starts/stops gensets with **GENSET** controllers in AUTO mode based on the load measured at each genset.

The controller calculates the genset load percentage:

Genset load percentage = Measured genset load / Nominal genset power

The *Percent* method is a simple, robust method. However, the available power is proportional to the section load. The available power may therefore be too low at low loads, and/or too high at high loads. If this is a problem, use the *Power* method.

Load-dependent start

If the genset load percentage is higher than the *Load-dependent start* limit, then the first genset that is ready to start (in the priority order) is started and connected.

Load-dependent stop

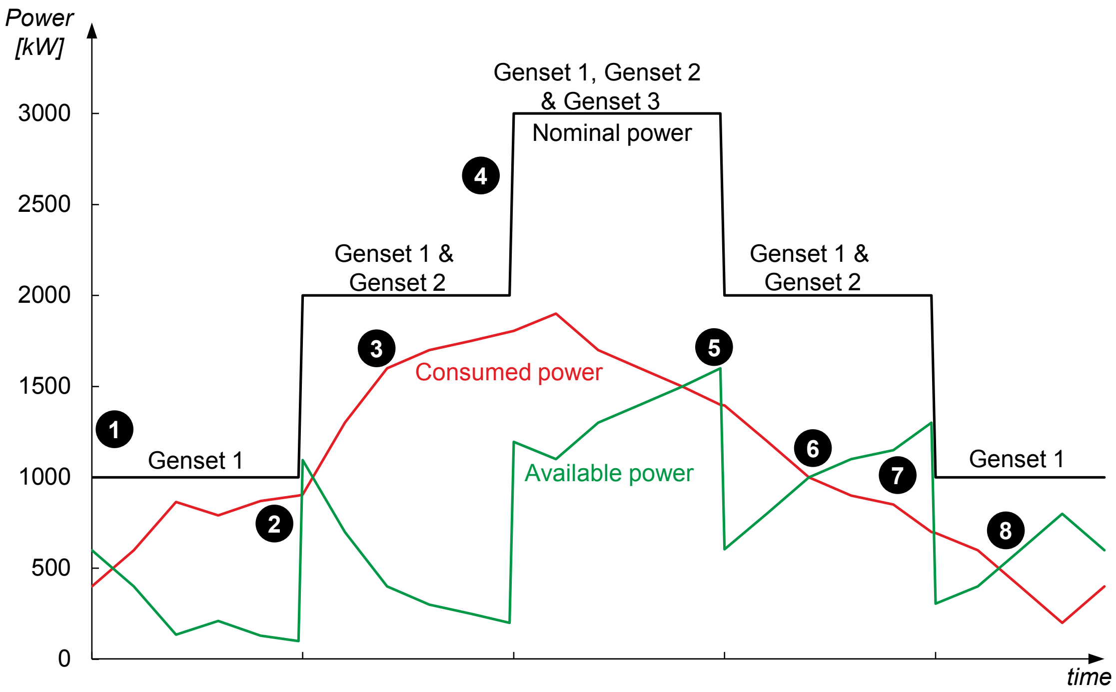
The power management calculates what the genset load percentage would be if the connected genset that is last in the priority order is stopped. If this is lower than the *Load-dependent stop* limit, that genset will be stopped.

Example

The following graph shows how the genset load percentage start and stop function works. The system consists of three 1000 kW gensets that use load sharing.

Genset load-dependent start limit: 90 %

Genset load-dependent stop limit: 70 %



1. Genset 1 is running.
2. The load builds up until it reaches 900 kW, which is 90 % of genset 1's nominal power. The power management starts the next genset in the priority order.
3. Genset 2 starts, and the load builds up until it reaches 1800 kW, which is 90 % of the nominal power for genset 1 and genset 2. The power management starts the next genset in the priority order.
4. Genset 3 starts, and gensets 1, 2 and 3 run. After a while the load starts to decrease.
5. The load reaches 1400 kW, which is 70 % of the nominal power for genset 1 and genset 2, after genset 3 is stopped. The power management therefore stops the last running genset in the priority order.
6. Genset 3 stops, and gensets 1 and 2 run. The load decreases.
7. The load reaches 700 kW, which is 70 % of the nominal power for genset 1, after genset 2 is stopped. The power management therefore stops the last running genset in the priority order.
8. Genset 2 stops, and genset 1 runs. The load is less than 90 %, so no additional gensets start. There are no other running gensets, so the genset stop function is inactive.

7.5.9 Percent method and hysteresis

For the percent method the load-dependent start and stop hysteresis depends on:

- The nominal power of the gensets
- The priority of the gensets
- The number of connected gensets
- The load-dependent stop limit must be LOWER than the load-dependent start limit.

Equally sized gensets example

The section has three 1000 kW gensets. The priority order is A, B, C. `Start 1 > Load limit` is 90 %, and `Stop 1 > Load limit` is 70 %.

Genset A always runs.
Genset B starts when the load is 900 kW, and stops when the load is 700 kW. The hysteresis is 200 kW.
Genset C starts when the load is 1800 kW, and stops when the load is 1400 kW. The hysteresis is 400 kW.

Different gensets example

Genset A has a nominal power of 2000 kW and has first priority. Genset B has a nominal power of 1000 kW and has second priority. Genset C has a nominal power of 500 kW and has third priority. `Start 1 > Load limit` is 90 %, and `Stop 1 > Load limit` is 70 %.

Genset A always runs.
Genset B starts when the load is 1800 kW, and stops when the load is 1400 kW. The hysteresis is 400 kW.
Genset C starts when the load is 2700 kW, and stops when the load is 2100 kW. The hysteresis is 600 kW.

7.5.10 Non-connected genset

The non-connected genset function stops a genset from running for too long without connecting. The function is only active when the controller is in AUTO mode. That is, if a genset is running with its breaker open, this function stops the genset when its timer expires.

The function may be needed in the following situations:

- The operator first starts the genset with the **GENSET** controller in MANUAL mode, and then switches to AUTO mode.
- There has been a precautionary genset start, but the busbar stabilised, and the started genset was not needed.

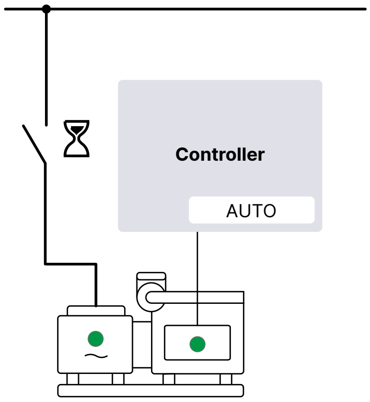
`Local power management > Non-connected genset > Stop timer`

Parameter	Range	Notes
`Delay`	10.0 s to 10 min	The timer starts when both of these conditions are met: 1. The genset start sequence is finished. 2. The genset is ready to connect. The timer resets if any of the following happens: • The breaker close sequence starts. • The stop sequence starts. • There is a genset alarm. When the timer expires, the controller stops the genset engine.

How the non-connected genset function works

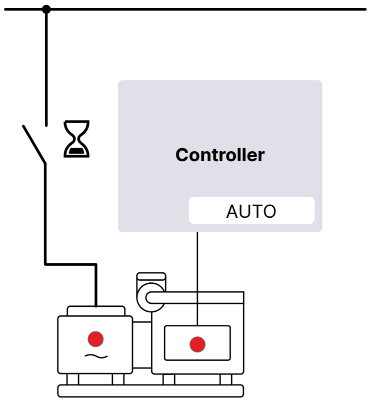
Non-connected genset running in AUTO

The timer starts ....



... the timer expires.

The power management stops the genset.



7.5.11 Number of gensets connected

These parameters determine the *Minimum* number of connected gensets required for the section.

Minimum

Defines the minimum number of gensets connected with their **GENSET** controllers in AUTO mode. Note that gensets with **GENSET** controllers in MANUAL mode are not included. You can use these parameters to guarantee a minimum level of power available.

`Power management rules > Number of gensets connected > Minimum set [1/2]`

Parameter	Range	Notes
`Set point`	0 to 32	The minimum set point. The power management system starts more gensets if fewer gensets are connected than this set point. The load-dependent stop function does not stop another genset if this would result in fewer connected gensets than this set point. The minimum number of gensets continue to run, even if the load is low and the load-dependent stop function otherwise would stop one or more gensets.

`Power management rules > Number of gensets connected > Automatic start`

Parameter	Range	Notes
`Multi-start set [1 or 2]`	Auto calculation Start [1 to 32] DG	When the system starts, the specified number of gensets are started.

Power management rules > Number of gensets connected > Selection

Parameter	Range	Notes
Multi-start selection	Multi-start set [1 to 2]	Select the multi-start set.

7.6 Blackout

7.6.1 Blackout and blackout recovery conditions

Blackout recovery is the power management system's attempt to recover from a blackout by connecting to another power source, or starting one or more gensets automatically, when a dead busbar is detected.

When there is at least one controller under power management control, the blackout recovery sequence always responds to a blackout and cannot be disabled.

Blackout conditions

A blackout is present if the following conditions are all met, **at all controllers** in the section *:

- The phase-to-phase voltage is less than 10 % of the nominal voltage (V_{L-L} < 10 % of V_{nom}).
  - This percentage is fixed.
  - If one or more controllers in the section do not detect a blackout, the controller(s) that detected the blackout activate the *Blackout detection mismatch* alarm.
- The generator breakers are open.
  - That is, there are no gensets connected.
- The blackout detection delay timer has run out (`Busbar > AC setup > Blackout detection > Blackout delay`).

NOTE * If a controller cannot communicate with the other controllers in the section, then that controller is forced to manual control (and does not start blackout the blackout recovery sequence).

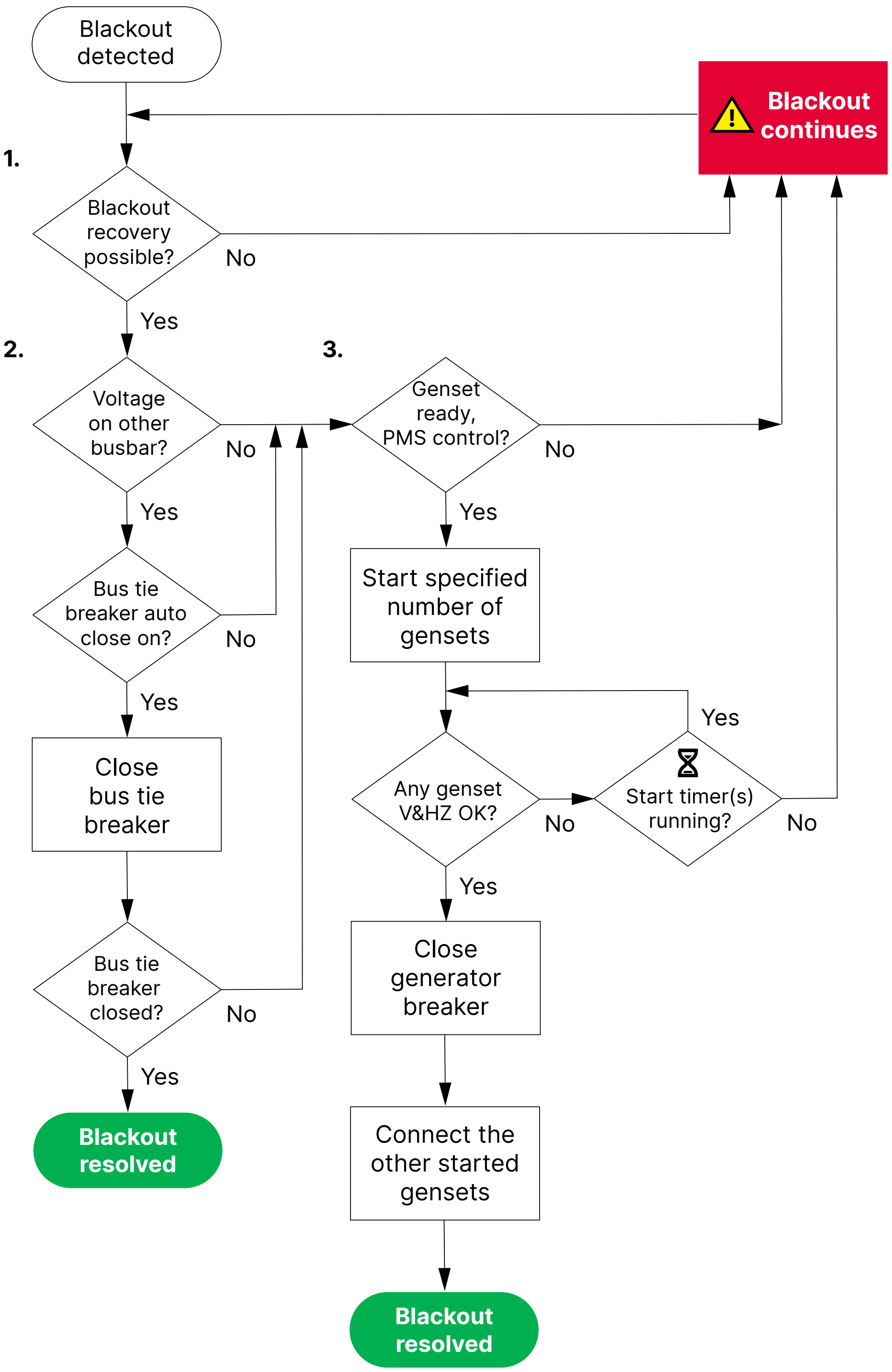
If one or more of the blackout conditions disappear, there is no longer a blackout.

Conditions that prevent blackout recovery

If any of the following conditions are present in the section, the power management will not start the blackout recovery sequence:

- A breaker position is unknown.
- There is a short circuit.
  - A digital input with the function `Breakers > [Breaker] > Feedback > [*B] short circuit` was activated.
- There is a blocking alarm.
  - The alarm action determines whether the alarm is a blocking alarm.

7.6.2 Blackout recovery flowchart



1. After a blackout is detected, the power management checks whether blackout recovery is possible. If any conditions that prevent blackout recovery are present, then the blackout recovery is not attempted.
2. The power management checks whether there is power on another busbar.
   - If there is power on another busbar, and the bus tie breaker can be closed automatically, the controller sends the signal to the bus tie breaker to close. This resolves the blackout.
   - If there is no other busbar, or if the bus tie breaker cannot be closed automatically, or if the bus tie breaker fails to close, the controller attempts to use genset start to resolve the blackout.
3. The power management checks whether there are any **GENSET** controllers under power management control, with gensets ready to start.
   a. The power management changes all **GENSET** controllers in MANUAL mode to AUTO mode.
   b. The power management sends a start signal to the number of gensets specified, according to their position in the genset priority order. Gensets that are not ready to start are not sent a start signal.

c. The power management sends the first genset that has running feedback and its voltage and frequency within range an acknowledge signal. The first genset closes its breaker immediately. If the breaker does not close within the *Closing failure* time, the breaker close signal is sent to the next genset to start.
d. Any other gensets that start are synchronised to the busbar, and their breakers are closed.
e. The blackout is resolved when a genset has successfully connected to the busbar. The power management controller switches back to normal operation. All the gensets that were sent a start signal are allowed to start and connect to the busbar. After the load-dependent stop timer expires, the power management controller will stop the lowest priority gensets if they are not required to power the load.

7.7 Load sharing

7.7.1 How it works

When gensets operate in parallel, supplying power to the same busbar, the operation cannot be stable unless the loading on the gensets is controlled. To efficiently control the gensets' operation, the power management must perform **load sharing** for the gensets.

The voltage and frequency for paralleled gensets on the same busbar are forced to exactly the same values. As a result, the busbar voltage and genset speed alone do not provide the information needed for load sharing calculations.

The **load sharing** is achieved by using the **DEIF network**.

Load sharing possibilities

Load sharing is done over the DEIF network, which uses CAN bus power management communication. Use the `Asymmetric load sharing` parameters to set it up. If you want equal load sharing, use the same set point in all the controllers.

7.7.2 Load sharing over the DEIF network

The controllers can share the load (both active power (P) and reactive power (Q)) over the DEIF network (CAN bus power management communication).

Load sharing over the **DEIF network** occurs automatically when the controllers are under power management control, provided all the necessary I/O settings and parameters are configured. The load sharing can be equal or asymmetrical.

NOTICE

DEIF network load sharing

Only DEIF controllers can be used for load sharing over the DEIF network. No other vendors' controllers can be used for load sharing over the DEIF network.

7.7.3 Asymmetric P load sharing

Asymmetric power (P) load sharing allows you to select certain gensets to run at their optimum efficiency. The load on the other gensets then fluctuates to absorb variations. It can also be used in mixed systems with both gensets and hybrid controllers.

Asymmetric P load sharing can also be configured so that, as far as possible, a particular genset supplies a base load.

Asymmetric P load sharing can also be configured so that, if the asymmetric load sharing limit is exceeded, this can switch to either equal load sharing (default) or to adjust the set point.

Asymmetric P load sharing is done by power management over the **DEIF network**.

Hardware

The following hardware is required for asymmetric P load sharing.

Name	Details
DEIF network	The DEIF network is used for asymmetric P load sharing.
GOV control	The controller must control the genset governor for active power load sharing.

Control types

For controllers in power management control, if enabled, the power management uses asymmetric P load sharing to share the load between the connected assets. The shared load may be the total system load.

Parameters

`Power management rules > Asymmetric load sharing > Start when an asymmetric set point is exceeded`

Parameter	Range	Notes
`Enable`	• Enabled • Not enabled	**Not enabled** • The **GENSET** controller shares the load equally with the other **GENSET** controllers. • If other **GENSET** controllers have asymmetric P load sharing enabled, then the **GENSET** controller without asymmetric P load sharing shares the load equally with the other gensets without asymmetric P load sharing. **Enabled** • Asymmetric P load sharing is active for the **GENSET** controller. • The power management runs the genset(s) with asymmetric P load sharing enabled at their set points while the remaining genset(s) supply the rest of the load. • If more than one genset has asymmetric P load sharing enabled, then the genset with the highest priority also has the highest asymmetric P load sharing priority.
`Set point`	10.0 to 600.0 % of nominal active power	The asymmetric P load sharing set point for the genset. Whenever possible, the power management system adjusts the load of lower priority gensets, and gensets without asymmetric P load sharing enabled, so that the gensets with asymmetric P load sharing enabled can run at their set point.

Base load

For a selected genset to supply a P **base load**, asymmetric P load sharing must be enabled in its **GENSET** controller. If asymmetric P load sharing is enabled in more than one controller, then the P **base load** genset must always have the highest priority in the section.

More information

See Governor regulation function for the base load parameters.

How it works

When asymmetric P load sharing is enabled for gensets, then, whenever possible, these gensets run at their asymmetric P load sharing set points. If it is not possible for all the gensets with asymmetric P load sharing enabled to run at their set points, then only the highest priority genset(s) run at their set points. The lowest priority connected genset(s) supply the remaining, fluctuating load.

Load-dependent start and stop

The load-dependent starts and stops are based on either active power (P, in kW) or apparent power (S, in kVA). The load-dependent start and stop parameters are independent of the asymmetric P load sharing parameters.

The load-dependent start and stop parameters determine how many gensets are connected. The asymmetric P load sharing parameters determine the load distribution among the connected gensets.

7.7.4 DEIF network load sharing failure

The *P load sharing failure* and *Q load sharing failure* alarms alert the operator to the failure of the DEIF network load sharing. Other alarms are also activated if communication is lost in the DEIF network.

More information
See Regulation alarms for the load sharing failure alarms.

7.8 Ground relay

The ground relay function ensures that the star point of only one connected genset is connected to ground during island operation. This prevents circulating currents between the generators.

NOTE The relay for this function must be selected in each genset controller.

How it works

The ground relay function follows the following principles:

- If the genset is not connected to the busbar (that is, the genset breaker is open), the ground relay does not consider the rest of the system.
  - If the close condition is met, the ground relay is closed.
  - If the open condition is met, the ground relay is open.
- If more than one genset is connected to the busbar, then power management ensures that only the ground relay of the biggest genset stays closed. The ground relays of all other gensets are opened.
  - If the gensets are the same size, then the ground relay of the connected genset with the highest priority is closed.
- A new genset can connect to the busbar. If it is bigger (or the same size and a higher priority) than the genset with the closed ground relay, the new genset keeps its ground relay closed. The other genset opens its ground relay.
- The close condition, open condition and ground relay type are configurable.

Safety

The ground relay function is NOT supported in a **Single DG** application, even if the controller has power management.

More information
When a genset controller is in racked out breaker mode it is not possible to close the ground relay.

Digital outputs

Function	I/O	Type	Details
`Auxiliary > Ground relay > Ground relay [A/B]`	Digital output	Continuous	The output is activated to close the corresponding ground relay.

Digital inputs (optional)

Function	I/O	Type	Details
`System power management > Ground relay > Ground relay position feedback [A/B]`	Digital input	Continuous	The input must be activated when the corresponding ground relay is closed.

Parameters

`Power management rules > Ground relay > Enable`

Name	Range	Description
Ground relay	Not enabled, Enabled	Enable the function.

`Power management rules > Ground relay > Ground relay configuration`

Name	Range	Description
Relay type	Continuous Pulse	**Continuous**: When the ground relay must be closed, the *Output A* output selected is activated continuously. **Pulse**: Configure Output A to open and Output B to close the ground relay. Ground relay breaker feedback is required.
Close configuration	Hz/V OK RPM MPU level RPM EIC level Start active	Ground relay close condition. **Hz/V OK**: The ground relay closes if the generator voltage and frequency are okay. **RPM MPU level**: The ground relay closes when the RPM measured by the MPU reaches the *RPM level*. **RPM EIC level**: The ground relay closes when the RPM from the EIC reaches the *RPM level*. **Start active**: The ground relay closes when the genset start is active.
Open configuration	After cooldown After extended stop	Ground relay open condition. **After cooldown**: The genset breaker is open, and the cooldown must be completed before the controller opens the ground relay. **After extended stop**: The genset breaker is open, the cooldown is complete, and the extended stop must be completed before the controller opens the ground relay.
RPM level	0 to 4000 RPM	If *RPM MPU level* or *RPM EIC level* is selected, the RPM must reach this value before the controller closes the ground relay.

Ground relay failure alarms

`Power management rules > Ground relay`

Name	Range	Description
`Ground relay general failure`	1.0 to 30.0 s	An alarm for the unusual situation where power management expects a genset's ground relay to close, but it does not. This may be due to a physical fault with the ground relay.
`Ground relay open failure`	1.0 to 30.0 s	Ground relay open failure. The controller deactivated its output, but the ground relay did not open before the timer ran out.
`Ground relay close failure`	1.0 to 30.0 s	Ground relay close failure. The controller activated its output, but the ground relay did not close before the timer ran out.
`Ground relay position failure`	1.0 to 30.0 s	Ground relay position failure. The breaker feedbacks are inconsistent for the specified time.

NOTE There is always an overlap where both ground relays are connected when transferring the ground relay from one genset to another.

7.9 Local or remote control

The controller can be in local or remote control mode. This mode determines which commands can be used to start the plant. Note that both the local and remote control modes allow the plant to start in AUTO mode.

`Local > Mode > Command mode`

Name	Range	Description
Selected mode	Remote control; Local control	**Remote control**: The plant can be started remotely, for example, by a digital input or through Modbus communication. **Local control**: The plant can be started from the display (local operator).

7.9.1 Local control

All operation is done from the display. In island operation any genset controller display can be used.

The mains controller display must be used in load takeover, mains power export, and fixed power. The mains controller mode must be AUTO.

7.9.2 Remote control

Island operation

In island operation, an *Auto start/stop* input on any of the genset controllers can be used to start the plant.

NOTE DEIF recommends wiring the *Auto start/stop* input to all of the controllers to ensure that automatic operation can continue even though a genset is taken out for service and/or the power supply to the controller is disconnected.

In island operation, AUTO or MANUAL can be selected on the genset controllers. The remote start signal still works for the controllers in AUTO mode.

Parallel to mains

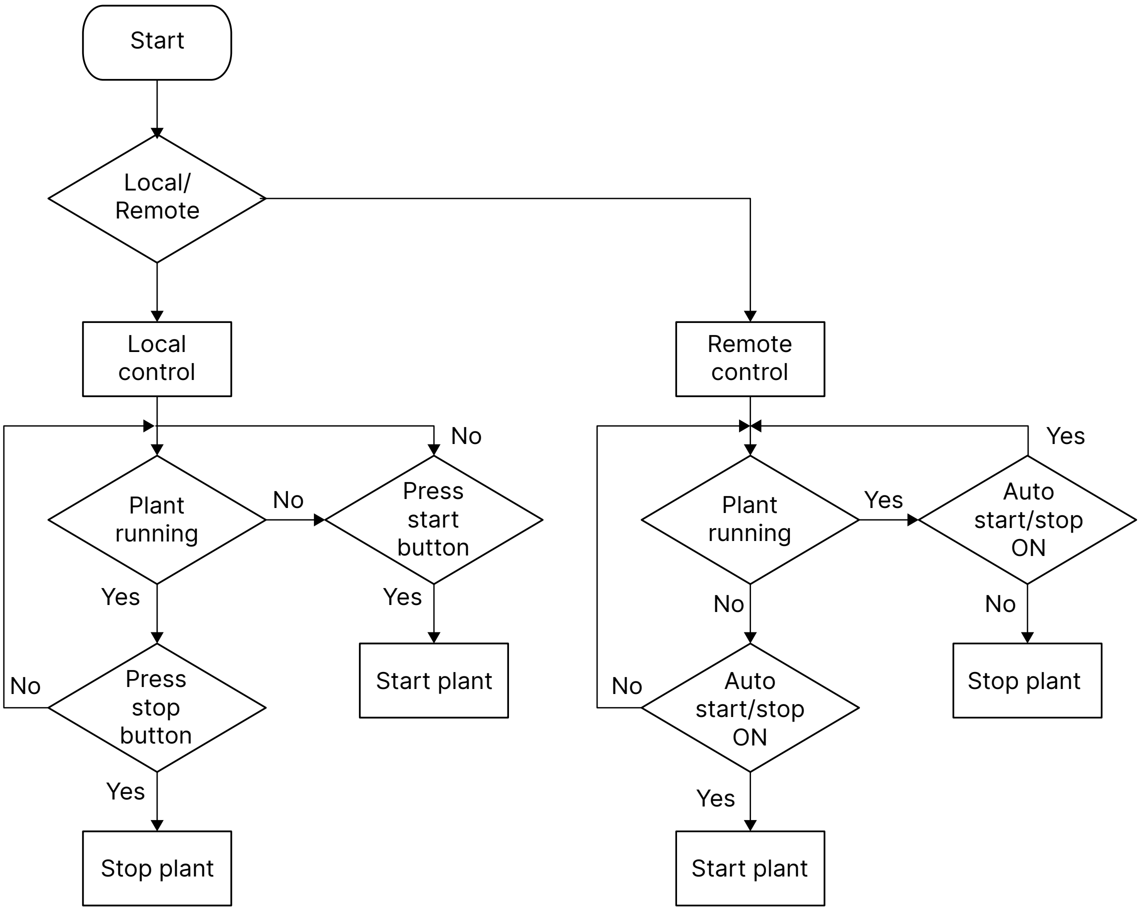
In load take-over, mains power export, and fixed power operation, the *Auto start/stop* input on the mains controller must be used for starting the plant.

7.9.3 Starting the plant

How the plant is started

Plant mode	Local	Remote
Island mode	Display on genset controllers	Auto start/stop on genset controllers
Fixed power mode	Display on mains controller	Auto start/stop on mains controller
Mains power export	Display on mains controller	Auto start/stop on mains controller
Load takeover	Display on mains controller	Auto start/stop on mains controller

NOTE For peak shaving and AMF, in response to the imported power (peak shaving) or mains failures (AMF), automatic operation starts automatically.



7.10 Power management alarms

7.10.1 Single-line hazard

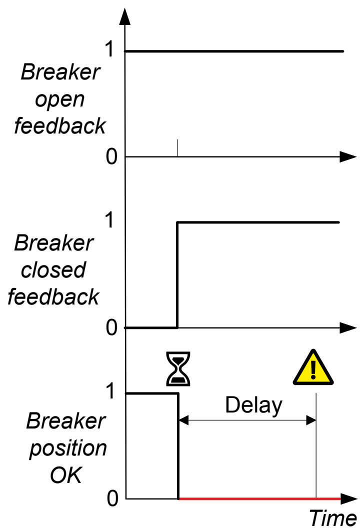
This alarm is activated if there is a problem with the single-line application configuration.

`System > Monitoring > Single-line hazard`

7.10.2 Breaker # feedback position failure

This alarm is for redundant breaker feedback position failure.

The alarm is based on the externally controlled breaker feedback signals, which are digital inputs to the controller. The alarm is activated if the breaker *Closed* and *Open* feedbacks are both missing for longer than the delay time. The alarm is also activated if the breaker *Closed* and *Open* feedbacks are both present for longer than the delay time.



`Breakers > Breaker # feedback monitoring > Position failure`

This alarm is always enabled. The alarm action is *Warning, Latch enabled*.

Parameter	Range	Default
`Delay`	1 s to 1 h	1 s

7.10.3 Missing all controllers

This alarm communicates a network failure.

The alarm is based on the network between the controllers included in the single-line application drawing. The alarm is activated when the controller cannot communicate over the network with any other controllers. If this alarm is activated, the *Missing controller ID #* alarms are not activated. .

This alarm is always enabled.

`System > Monitoring > Missing all controllers`

7.10.4 Missing controller ID

This alarm communicates a communication failure with one or more controllers in the single-line application drawing.

The alarm is activated when a controller is present on the single-line application drawing, but the controller displaying the alarm cannot communicate with it.

The alarm is always enabled, the alarm action is *Warning*. The alarm parameters are not visible.

7.10.5 Duplicate controller ID

Each controller is delivered with this default alarm to communicate that there is another controller with the same *Controller ID* in the network.

The alarm is based on the network between the controllers included in the single-line application drawing. The alarm is activated when the controller detects another controller with the same *Controller ID* as itself.

This alarm is always enabled.

`System > Monitoring > Duplicate controller ID`

7.10.6 Missing any controller

This alarm informs the operator that there is a communication failure with one or more controllers.

The alarm is based on the network between the controllers included in the single-line application drawing. The controller activates the alarm if there is at least one controller in the single-line application drawing that it cannot communicate with. This alarm is not suppressed by *Missing all controllers*.

This alarm is always enabled.

`System > Monitoring > Missing any controller`

7.10.7 Missing controllers

This alarm informs the operator that there is a communication failure with one or more controllers. The alarm is based on the network between the controllers included in the single-line application drawing. The controller activates the alarm when the number of missing controllers in the section reaches the set point. This alarm is not suppressed by *Missing all controllers*.

When the alarm is activated, the power management system changes the mode of the remaining controllers in the section according to the parameters in `System > Monitoring > Mode while controller missing`.

NOTICE
Missing controllers If controller(s) are missing, then the power management cannot know their operating information, including the breaker positions. Evaluate the risks before configuring this set point.

`System > Monitoring > Missing controllers`

Parameter	Range
`Missing controllers`	2 to 32

7.10.8 BTB # position failure

This alarm is activated when BTB # has a breaker position failure.

`System > Monitoring > BTB # position failure`

Name	Range	Details
Delay	1.0 to 5.0 s	To activate the alarm, the position failure must be present while the delay timer runs.

7.10.9 Single-line missing/none active

This alarm communicates that the single-line application drawing cannot be read from the controller, or that no single-line application drawing is configured for the controller.

The alarm is always enabled and the action is *Warning*. The alarm parameters are not visible in PICUS.

7.10.10 Different single-line configurations

This alarm communicates that different single-line application drawings are present on one or more controllers in the system.

This alarm is activated when a single-line application drawing is written to a controller, but not *Broadcast* to the remaining controllers. The alarm is always enabled, and the action is *Warning*. The alarm parameters are not visible in PICUS.

7.10.11 Controller not part of system

This alarm communicates that the controller has a *Controller ID* that is not included in the single-line application drawing. Check the Application single-line application drawing in PICUS.

The alarm is always *Enabled*, and the action is *Warning*. The alarm parameters are not visible in PICUS.

7.10.12 Controller type mismatch

This alarm communicates when a controller's type does not match the controller type with its *Controller ID* in the single-line application drawing.

This alarm is activated when the *Controller ID* is assigned to an incorrect controller type in the single-line application drawing, and the single-line application drawing is written to the controller. The alarm parameters are not visible in PICUS.

Controller type mismatch example

A **GENSET** controller has *Controller ID* 1, but on the single-line application drawing *Controller ID* 1 is assigned to a **MAINS** controller. The alarm is activated when the single-line application drawing is written to the controller.

7.10.13 PMS disabled due to an error

This alarm communicates that there is an internal error in the power management software. Power management is disabled.

The alarm action is *Warning*.

The alarm parameters are not visible in PICUS.

7.10.14 Short-circuit limitation

This alarm is activated in a genset, mains or BTB controller when the power in the busbar section exceeds the alarm set point.

`Power management rules > Short circuit > Short-circuit limitation`

Name	Range	Details
`Section P>`	0 kW to 30 GW	The maximum power expected in the section.
`Section P> factor`	1.0 to 25.5	The multiple of the maximum power to activate the alarm.
`Delay`	0.0 to 999.0 s	To activate the alarm, the set point must be exceeded while the delay timer runs.

8. SINGLE genset controller

8.1 About the SINGLE genset controller

SINGLE genset controller with mains breaker

A **SINGLE genset** controller with mains breaker controller controls and protects a prime mover and generator (that is, a genset), the generator breaker, and a mains breaker. There are no other controllers on the single-line application drawing.

SINGLE genset controller with no mains breaker

A **SINGLE genset** controller with no mains breaker controls and protects a prime mover and generator (that is, a genset) and the generator breaker. There are no other controllers on the single-line application drawing.

8.1.1 SINGLE genset controller functions

	Functions

Pre-programmed sequences	• Genset start sequence and genset stop sequence
	  ◦ Running detection (Multiple feedback options: Frequency, MPU/W/NPN/PNP (RPM), Digital input, Oil pressure)
	  ◦ Run coil and/or stop coil for engine control
	  ◦ Temperature-dependent cooldown
	• Breaker sequences
	  ◦ Generator breaker close sequence (with synchronisation)
	  ◦ Generator breaker open sequence (with de-loading)
	  ◦ Mains breaker close sequence (with synchronisation) *
	  ◦ Mains breaker open sequence (with de-loading) *
	• Generator breaker blackout close (black busbar negotiation)

Genset regulation	• PID regulators for analogue outputs
	• P regulators for relay outputs
	  ◦ *Relay period time* and *Minimum ON time* configurable
	• Set point selection
	  ◦ Select mode or external set point, using digital input, PICUS, Modbus, and/or CustomLogic or CODESYS
	• Governor modes
	  ◦ Fixed frequency
	  ◦ Fixed active power
	  ◦ Frequency droop (controller regulation emulates droop)
	  ◦ Fixed RPM
	  ◦ External set point: Frequency offset, or Power set point
	  ◦ Manual
	  ◦ Off
	• AVR modes
	  ◦ Fixed voltage
	  ◦ Fixed reactive power
	  ◦ Fixed cos phi
	  ◦ Voltage droop (controller regulation emulates droop)
	  ◦ External set point: Voltage offset, Reactive power set point, or cos phi set point
	  ◦ Manual
	  ◦ Off
	• Configurable power ramp up, power ramp down

	Functions
	• Temperature-dependent power derate settings (3 sets)
Mains	• Configurable supervision • Mains power measurement from 4th current measurement, or analogue input
4th current	• Measure power from/to the mains, or for earth or neutral protections *

Counters	• Counters, to edit or reset
	  ◦ Start attempts
	  ◦ Running time (total and trip)
	  ◦ Generator breaker operations and trips
	  ◦ Mains breaker operations and trips *
	  ◦ Energy export (active and reactive)
	  ◦ External breaker operations
	• Energy counters with configurable digital outputs (for external counters)
	  ◦ Energy export (active and reactive)

NOTE * Only in a **SINGLE genset** controller with mains breaker.

8.2 SINGLE genset controller principles

8.2.1 Plant mode

You can select the single genset plant mode in the controller.

`Power management rules > Plant/genset mode > Modes`

Name	Range	Details
`Plant mode`	Island operation Auto mains failure Peak shaving Fixed power Mains power export Load take over	Select the plant mode.
`Mode shift`	Off, On	**Off**: No automatic mode shift for a mains failure. **On**: If there is a mains failure, and the plant mode is not island or AMF, then the controller changes the plant mode to AMF.

8.2.2 Remote control

Island operation

When the controller is in AUTO mode, if it is possible, the controller closes the mains breaker.

If the *Auto start/stop* input is then activated, the genset starts/stops.

8.2.3 Genset nominal settings

The nominal settings are used in a number of key functions. For example, many protection settings are based on a percentage of the nominal settings.

Engine > Nominal settings > Nominal settings #*

Parameter	Range	Comment
Nominal RPM	100 to 50000 RPM	When an MPU/W/NPN/PNP is used to measure the engine speed, then the nominal engine speed is used for the overspeed and underspeed alarms.

NOTE * # is 1 to 4.

Generator > Nominal settings > Nominal settings #*

Nominal setting	Range	Notes
Voltage (V)	100.0 V to 25 kV	The phase-to-phase ** nominal AC voltage for the genset.
Current (I)	1.0 A to 9 kA	The maximum current flow in one phase (that is, L1, L2 or L3) from the genset during normal operation.
Frequency (f)	45.00 to 65.00 Hz	The system nominal frequency, typically either 50 Hz or 60 Hz. All the controllers in the system should have the same nominal frequency.
Power (P)	10.0 kW to 20 MW	The nominal active power may be on the genset or prime mover nameplate.
Apparent power (S)	12.5 kVA to 25 MVA	The nominal apparent power should be on the genset or generator nameplate.
Power factor (PF)	0.8000 to 1.0000	The power factor should be on the genset or generator nameplate.

NOTE * # is 1 to 4.
NOTE ** In a single-phase set up the nominal AC voltage is phase-to-neutral.

Calculation method

Generator > Nominal settings > Nominal settings # > Calculation method*

Calculation method	Options
Reactive power (Q) nominal	Q nominal calculated Q nominal = P nominal Q nominal = S nominal
P or S nominal	No calculation P nominal calculated S nominal calculated

NOTE * # is 1 to 4.

More information
See **Nominal power calculations** for more information.

8.2.4 Mains nominal settings

Mains > Nominal settings > Nominal settings #*

Nominal setting	Range	Notes
Voltage (V) > Nominal value source	User defined, Use generator nominal voltage	**User defined**: If this is selected, after the parameters are written, a field appears where you can set the nominal voltage.
Calculation method > Reactive power (Q) nominal	Q nominal calculated, Q nominal = P nominal, Q nominal = S nominal	**Q nominal calculated**: The controller uses the nominal settings to calculate the nominal reactive power (nominal Q) for the mains connection.
Calculation method > P or S nominal	No calculation, P nominal calculated, S nominal calculated	**P nominal calcuated**: The controller calculates the nominal active power (nominal P), and ignores any entered values.

Nominal setting	Range	Notes
		S nominal calculated: The controller calculated the nominal apparent power (nominal S), and ignores any entered values.
`Power (P) > Nominal`	10.0 kW to 20 MW	Configure the value according to the mains connection. Set the value to ensure the mains connection over-power protection is triggered at the correct time.
`Apparent power (S) > Nominal`	12.5 kVA to 25 MVA	Mains connection apparent power.
`Power factor (PF) > Nominal`	0.8000 to 1.0000	Mains connection power factor.

NOTE * # is 1 to 4.

More information
See Nominal power calculations.

8.3 Genset principles

8.3.1 Run coil or stop coil

The engine start and stop functions are suitable for genset start systems with either a run coil or a stop coil. A set of controller digital output terminals must be connected to and configured for either the run coil output, or the stop coil output.

Run coil and stop coil outputs

Function	I/O	Type	Details
`Engine > Controls > Run coil`	Digital output	Continuous	If all power to the controller is lost, then the genset stops. Required if there is no *Stop coil*.
`Engine > Controls > Stop coil`	Digital output	Continuous	If all power to the controller is lost, then the genset keeps running. Required if there is no *Run coil*.

8.3.2 Ready for operation

The genset is ready for operation when the following conditions are met:

- There are no alarms blocking the start.
- If configured, the *Start enable* digital input is activated.

8.3.3 Running detection

The controller can be configured to receive engine running feedback from a variety of measurements. There can be more than one running feedback measurement.

Running detection is a state calculated by the controller, and used by a number of functions. It is either OFF or ON. If any running feedback measurements show that the engine is running, then *Running detection* is ON.

Inputs and outputs

Function	I/O	Type	Details
`Engine > Feedback > Digital running detection`	Digital input	Continuous	Optional. External equipment activates the digital input when the engine is running.

The controller can also use the following inputs for running feedback.

Function	I/O	Type	Details
Frequency	Generator voltage measurements	Continuous	Always present. The controller uses the generator voltage measurements to calculate the frequency. The controller then compares the frequency with the detection set point. Note: The controller cannot measure the frequency at very low voltages. See the **Data sheet** for the measurement range. The voltage must also be at least 10 % of nominal for the controller to use the frequency for running detection. For safety, DEIF recommends that you install at least one other running detection input.
MPU	HSDI	Continuous	Optional. The MPU input is connected to an MPU mounted on the engine.
W	HSDI	Continuous	Optional. The W input is connected to the battery recharging generator and measures the engine speed. Alternatively, the W input can be connected to an NPN/PNP sensor.
`Engine > Measurements > Lube oil > Engine oil pressure [bar]`	Analogue input	Pressure in bar	Optional. This set of analogue input terminals are connected to a transducer for the engine oil pressure.

Parameters

`Engine > Running detection > MPU setup`

Parameter	Range	Comment
`Number of MPU teeth`	1 to 10000	The controller uses the number of teeth to calculate the engine speed from the MPU/W/NPN/PNP measurement signal.

`Engine > Running detection > Feedback type`

Parameter	Range	Comment
`Primary running feedback`	The available running feedbacks (depends on hardware)	Select one of the inputs as the primary running feedback. If the *Primary running feedback* does not detect running, but any other running feedback detects running, then the controller activates the *Primary running feedback failure* alarm.

`Engine > Running detection > RPM running detection`

Parameter	Range	Comment
`RPM`	0.0 to 50000.0 RPM	Running detection is ON when the engine speed measured by the MPU/W/NPN/PNP input is above this set point.
`Use engine speed`	Not enabled, Enabled	**Not enabled:** The MPU/W/NPN/PNP measurement is ignored and not used for running detection. **Enabled:** The MPU/W/NPN/PNP measurement is used as a running detection input.

`Engine > Running detection > Frequency running detection`

Parameter	Range	Comment
`Frequency`	10.0 to 100.0 Hz	Running detection is ON when the frequency measured by the generator voltage measurements is above this set point. For example: For a 60 Hz system, you can use a detection set point of 45 Hz.

`Engine > Running detection > Oil pressure running detection`

Parameter	Range	Comment
`Oil pressure` *	0.0 to 10.0 bar	Running detection is ON when the engine oil pressure is above this set point.
`Use oil pressure` *	Not enabled, Enabled	**Not enabled:** The engine oil pressure is ignored and not used for running detection. **Enabled:** The engine oil pressure is used as a running detection input.

NOTE * This parameter is only visible if the analogue input is configured.

Frequency running detection hysteresis

For stable operation, running detection has a fixed 2 Hz hysteresis.

Frequency running detection hysteresis examples

Example 1: The detection set point for frequency is 32 Hz. When the frequency rises above 32 Hz, running detection changes to ON. However, the frequency has to drop below 30 Hz for running detection to change to OFF.

Example 2: The detection set point for frequency is 45 Hz. When the frequency rises above 45 Hz, running detection changes to ON. However, the frequency has to drop below 43 Hz for running detection to change to OFF.

MPU/W input running detection hysteresis

For stable operation, running detection has a fixed 5 % hysteresis on the genset RPM.

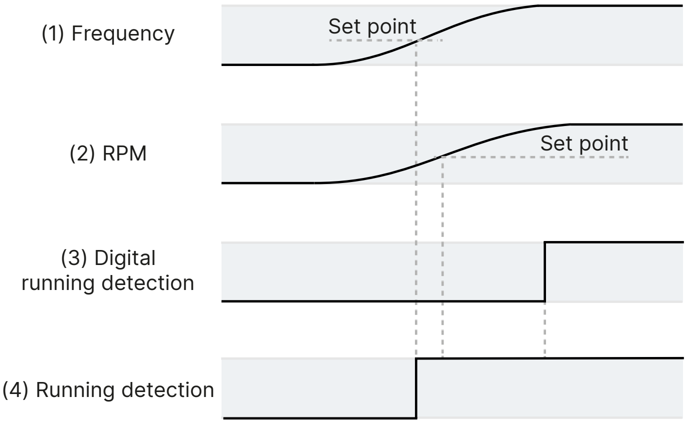
Oil pressure running detection hysteresis

For stable operation, running detection has a fixed 5 % hysteresis on the oil pressure.

Example: Running detection ON

The following sequence diagram is an example of how *Running detection* changes during an engine start. *Running detection* changes from OFF to ON when **one** running feedback detects that the engine is running.

Running detection ON sequence diagram

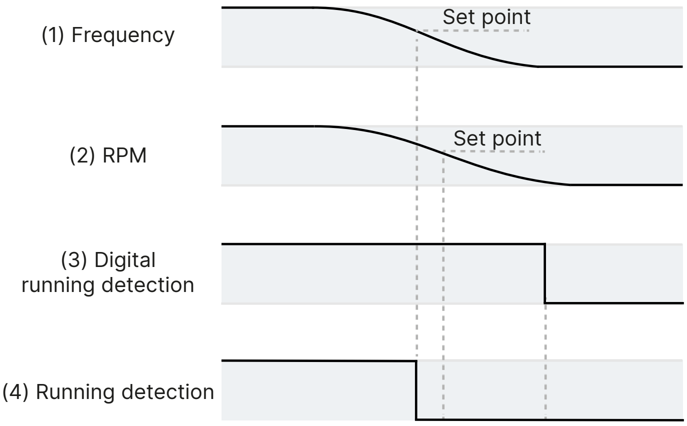


1. **Frequency**: The engine starts and the frequency rises above the set point.
2. **RPM**: (MPU/W/NPN/PNP input). The engine starts and the RPM rises above the set point.
3. **Digital running detection**: *Engine > Feedback > Digital running detection* (digital input). In the example, the response of this input is slower than the other running detection inputs.
4. **Running detection**: Running detection changes from OFF to ON when any running feedback (in this case, the frequency) rises above the *Detection set point*.

Example: Running detection OFF

The following sequence diagram is an example of how *Running detection* changes during an engine stop. *Running detection* changes from ON to OFF when **none** of the running feedbacks detect that the engine is running.

Running detection OFF sequence diagram



1. **Frequency**: The engine slows down and the frequency drops to 2 Hz below the set point.
2. **RPM**: (MPU/W/NPN/PNP input). The engine slows down and the RPM drops to 5 % below the set point.
3. **Digital running detection**: *Engine > Feedback > Digital running detection* (digital input). In the example, the response of this input is slower than the other running detection inputs.
4. **Running detection**: Running detection changes from ON to OFF when none of the running feedbacks detect that the engine is running.

Risks when using only frequency for running detection

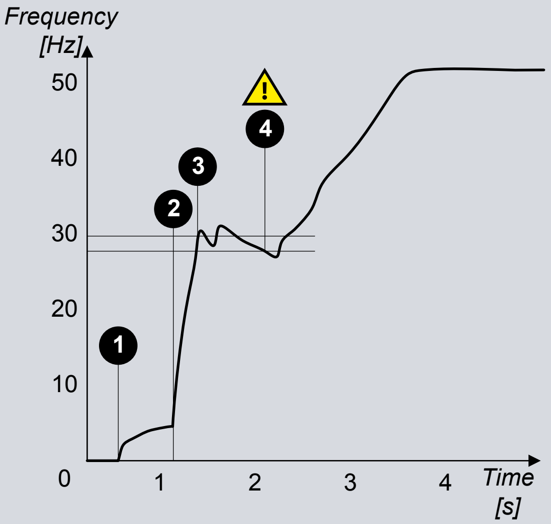
It is possible to only use frequency for running detection. However, using only frequency for running detection increases the risk of not detecting that the genset is running.

The software only uses the frequency measurements when the voltage is at least 10 % of the nominal voltage. This could cause trouble, since the voltage does not necessarily increase linearly with speed (this depends on the AVR).

If the frequency curve for the genset start up has a dip around the detection set point, the controller can interpret the dip as no running detection, and stop the genset. Increasing or decreasing the set point away from the dip would solve this problem.

Frequency running detection example

A genset start up frequency curve is given below.



1. Crank begins.
2. Fuel in.
3. If the running detection set point is 30 Hz, running detection is ON.
4. If the running detection set point is 30 Hz, the frequency drops 2 Hz below the set point, and running detection from frequency is OFF.
   - If there are no other running detection inputs, the controller immediately deactivates the run coil and/or activates the stop coil.

8.3.4 Regulation

The **SINGLE genset** controller can regulate both a governor (GOV) and an AVR.

More information
See Regulation for how regulation works.

8.4 Engine start

8.4.1 Engine start function

The controller software includes a pre-programmed engine start sequence. For the engine's start function, you must configure these inputs and outputs, and parameters.

If a parameter needs an input or output to be configured, then that parameter is not visible until an input or output is configured with the relevant function.

More information
See [Controller] protections for the engine start protections, and how to configure them.

Inputs and outputs

Required engine start output

Function	I/O	Type	Details
`Engine > Controls > Crank`	Digital output	Continuous	Connect this output to the engine crank.

Optional engine start inputs and outputs

Function	I/O	Type	Details
`Engine > Command > Start enable`	Digital input	Continuous	Optional. If this input is configured, it must be activated for the engine start sequence to start.
`Engine > Command > Warm up delay`	Digital input	Continuous	Optional. When the input is activated, the controller delays the engine warm up.
`Engine > Controls > Start prepare`	Digital output	Continuous	Optional. The *Start prepare* digital output may, for example, be wired to start a pump, so that the engine oil pressure can build up before cranking. Note that *Start prepare* does not have any provision for feedback. The *Start prepare* function is only a timer, and does not check whether, for example, the pump start was successful. The *Start prepare* digital output is not needed if the third party engine controller ensures that all start prepare conditions are okay before activating the *Start enable* digital input.
`Engine > Command > Crank delay`	Digital input	Continuous	Optional. When the input is activated, the controller delays the crank.
`Engine > Controls > Idle run`	Digital output	Continuous	Optional. Connect this output to the engine idle run if supported. Not all engines support this feature.
`Engine > Idle run > Low speed`	Digital input	Continuous	Optional. When the input is activated, the idle run is based on speed.
`Engine > Idle run > Temperature control`	Digital input	Continuous	Optional. When the input is activated, the idle run is based on temperature control.

Optional engine start commands

Function	I/O	Type	Details
`Engine > Command > Start engine`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to start the engine.
`Engine > Command > Start engine and close generator breaker`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to start the engine and then synchronise and close the breaker.

Required parameters

`Engine > Start sequence > Crank`

Parameter	Range	Comment
`Crank on`	1.0 s to 3 min	For the *Crank on* part of the start sequence, the controller activates the *Crank* output for this period.
`Crank off`	1.0 to 99.0 s	If there is no running detection during *Crank on*, then the controller deactivates the *Crank* output for this period.
`Disengage crank`	1 to 2000 RPM	The controller deactivates the *Crank* output when the engine speed reaches this set point, although the *Crank on* timer continues to run. This parameter only has an effect if an engine speed measurement (for example, an MPU/W/NPN/PNP) is configured.

Parameter	Range	Comment
		Even when *Disengage crank* is used, the start sequence tries to detect that the engine is running for the whole of the *Crank on* time.

`Engine > Start sequence > Start attempts`

This parameter limits the wear on the genset from too many start attempts.

Parameter	Range	Comment
`Normal`	1 to 100	This is the maximum number of start attempts if the digital input `Alarm system > Additional functions > Suppress alarm action` is not active. If the genset does not start after these attempts, the *Start failure* alarm is activated.
`Suppress alarm action`	1 to 10	This is the maximum number of start attempts if the digital input `Alarm system > Additional functions > Suppress alarm action` is active. If the genset does not start after these attempts, the *Start failure* alarm is activated.

`Engine > Running detection > Engine ready`

Parameter	Range	Comment
`Delay`	1.0 s to 5 min	After *Running detection* is ON, the engine must run for this period before the breaker close sequence can start.

Parameters (optional)

`Engine > Start sequence > Start prepare`

You must configure the `Engine > Start prepare` digital output to see these parameters.

Parameter	Range	Comment
`Start prepare`	0.0 s to 10 min	Optional. If the start conditions are OK, the controller activates the *Start prepare* output for this time. When the *Start prepare* timer expires, the controller activates the *Crank* output. See **Start prepare** in the **Engine start sequence**.
`Extended start prepare`	0.0 s to 10 min	Optional. The controller keeps the *Start prepare output* activated for this time during cranking.

`Engine > Start sequence > Run coil`

You must configure the `Engine > Controls > Run coil` digital output to see these parameters.

Parameter	Range	Comment
`Run coil before crank`	0.0 s to 10 min	Optional. The controller activates the *Run coil* output for this time before the *Crank* output is activated.
`During start attempts`	Pulse, Continuous	**Pulse**: If the start attempt fails, the controller deactivates the *Crank* output and the *Run coil*. **Continuous**: If the start attempt fails, the controller deactivates the *Crank* output. However, the *Run coil* remains activated until the maximum number of start attempts is reached.

Idle run start (optional)

You must configure the `Engine > Controls > Idle run` digital output to see these parameters.

You can configure an idle run start period for the engine. This allows the engine to warm-up before running at nominal speed.

If this is configured, the controller will activate the digital output `Engine > Controls > Idle run` before starting the engine. The controller then waits for one of the engine conditions (coolant temperature, oil temperature, external input condition, or the maximum timer) to be fulfilled before increasing to nominal speed.

During the idle run start period, the operator can override the period and press **Start** on the display, the controller then cancels the idle run start period and increases to nominal speed.

Additionally, during the idle run start period, the operator can press **Stop** to abort the engine start sequence and run the engine stop sequence.

Optional idle run start parameters

`Engine > Idle run start > Idle run`

Parameter	Range	Comment
`Enable`	Not enabled, Enabled	Enables the engine to idle run until a condition is true before changing to nominal speed.

`Engine > Idle run start > Minimum`

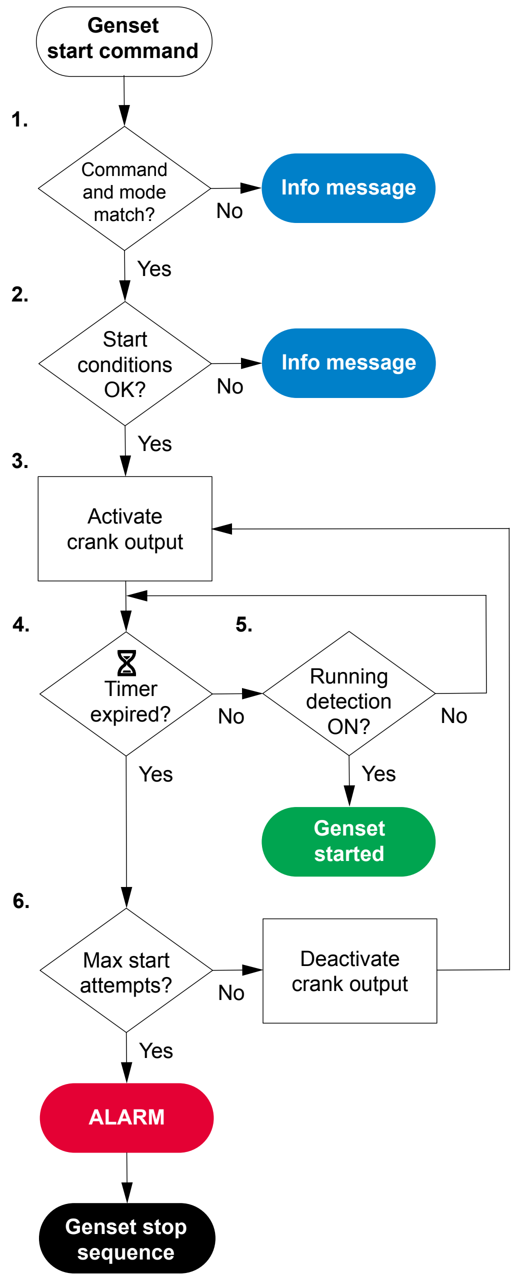
Parameter	Range	Comment
`Use`	Not enabled, Enabled	Uses minimum set point to determine if the engine is ready to increase to nominal speed.
`Delay`	0 s to 999 min	This is the minimum time the idle run start is active. *

NOTE * The minimum period can be overridden by pressing **Start** to cancel the idle run start period and increases to nominal speed.

8.4.2 Engine start flowchart

The following flowchart shows the sequence that the controller uses to start a genset. The engine start sequences are described in detail in the sections that follow.

Table 8.1 Engine start flowchart *

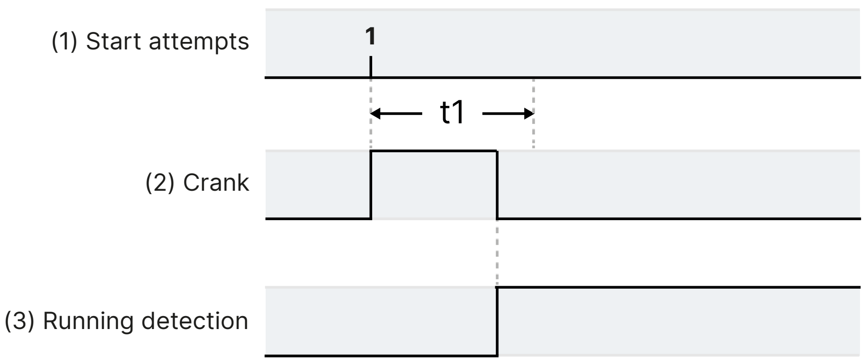


1. **Command and mode match**: The controller checks that the command source and the controller mode match:
   - In REMOTE mode, the command to start the genset can come from a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.
   - In LOCAL mode, the operator can press the push-button **Start** on the display unit. The controller ignores all other commands.
2. **Start conditions OK**: The controller checks whether the start conditions are OK:
   - If configured, the *Start enable* digital input is activated.
   - There are no active or unacknowledged alarms to prevent the genset start. These alarm actions prevent a genset start:
     - *Block GB*
     - *Trip generator breaker and stop engine*
     - *Trip generator breaker and shutdown engine*
3. **Crank output activated**: If all the start conditions are OK, the controller activates the *Crank* output and a timer.
4. **Running detection ON**: While the start timer runs, the controller checks whether *Running detection* is ON.
   - When the controller detects that the genset is running, the genset start is complete.
5. **Crank on timer expired**: If *Running detection* is OFF after the *Crank on* timer runs out, the controller checks the number of start attempts:
   - If the maximum number of start attempts has not been reached, the controller attempts to start the genset again.
   - If the maximum number of start attempts has been reached, the controller activates the *Start failure* alarm and stops the engine.

NOTE * The optional *Start prepare* function is not shown here.

8.4.3 Engine start sequence

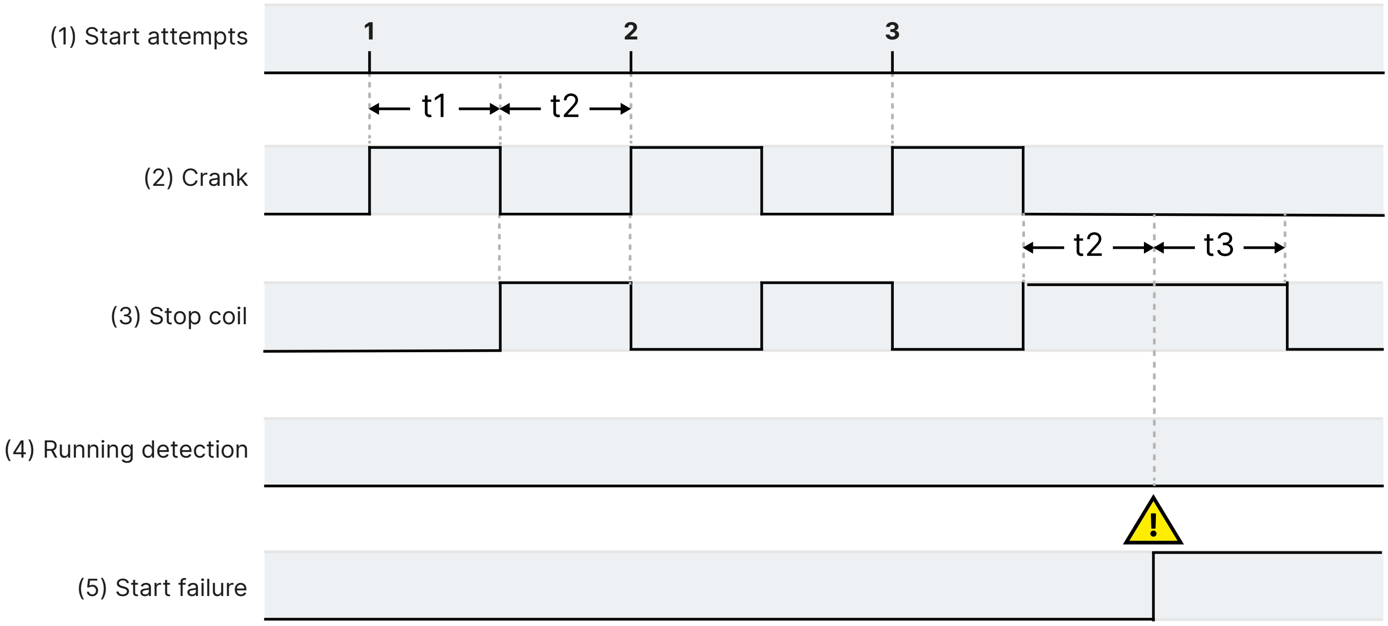
Successful engine start sequence for a stop coil system



t1 = Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)

1. **Start attempts**: The engine starts during the first start attempt.
2. **Crank**: `Engine > Controls > Crank` (digital output). The controller activates the *Crank* output. If *Running detection* changes from OFF to ON, cranking stops.
3. **Running detection**. The engine is regarded as started when *Running detection* is ON.

Failure of engine start sequence for a stop coil system



t1	Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)
t2	Crank off (`Parameters > Engine > Start sequence > Crank > Crank off`)
t3	Extended stop (`Parameters > Engine > Stop sequence > Extended stop`) (optional)

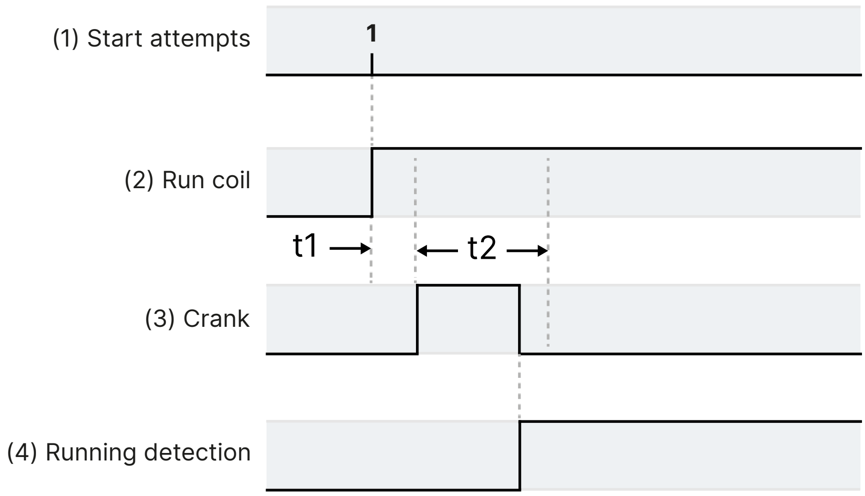
Failure of engine start sequence for a stop coil system:

1. **Start attempts**: `Parameters > Engine > Start sequence > Start attempts > Normal` = 3.
2. **Crank**: `Engine > Crank` (digital output). The controller activates the *Crank* output for the *Crank on* time, and deactivates it for *Crank off* time.
3. **Stop coil**: *Engine > Stop coil* (digital output). If *Running detection* is OFF after the *Crank on* time, then the controller activates the *Stop coil* for the time in the *Crank off* parameter. If all start attempts fail, the controller also activates the *Stop coil* for the time in *Extended stop > Stop coil activated*. This ensures that the engine is stopped if the engine start was not detected. The engine cannot be started during the *Extended stop > Stop coil activated* time.
4. **Running detection**. There is no running detection.
5. **Start failure**. The controller activates the *Start failure* alarm after the last unsuccessful start attempt.

Engine start sequence for a run coil system

In this example, the `Engine > Start sequence > Run coil > During start attempts` parameter is set to *Follow crank*. The engine speed (RPM measurement) and/or the *Remove start (release crank relay)* digital input do not disengage the crank before there is *Running detection*.

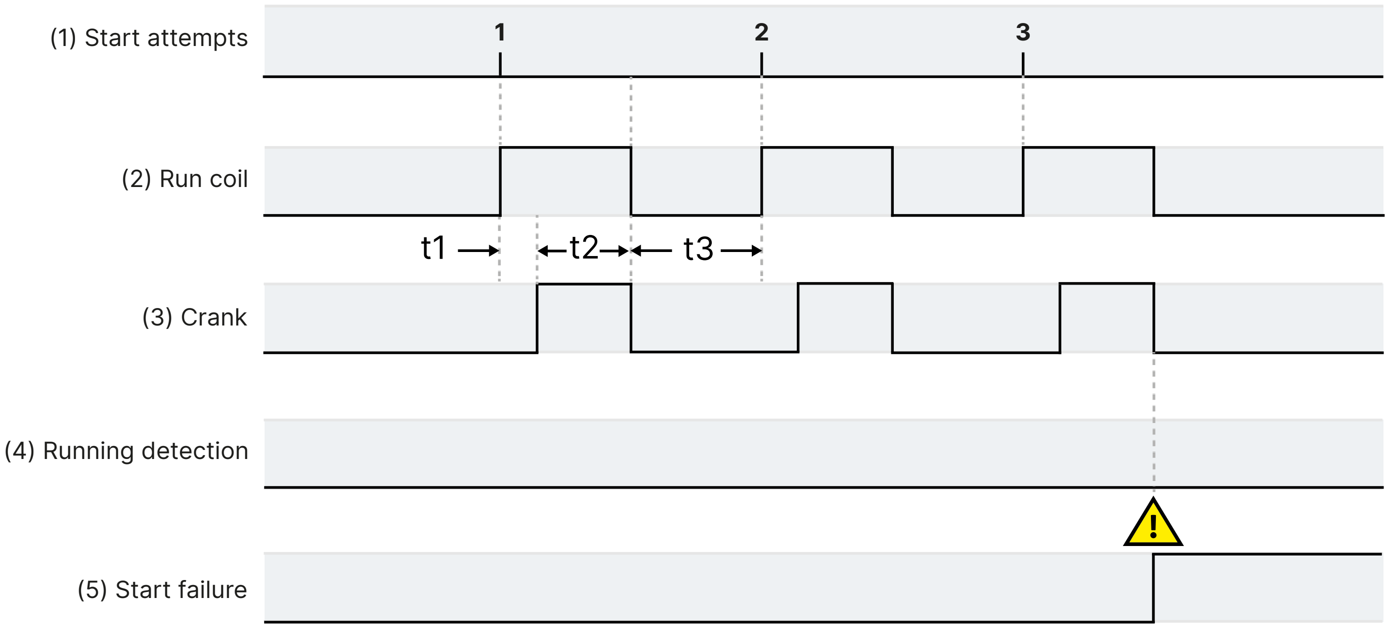
Successful engine start sequence for a run coil system



t1 = Run coil before crank (optional)
t2 = Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)

1. **Start attempts**: The engine starts during the first start attempt.
2. **Run coil**: `Engine > Run coil` (digital output). The controller activates the *Run coil* at the time in the *Run coil before crank* parameter. If *Running detection* is ON, the engine is regarded as started, and the *Run coil* remains activated.
3. **Crank**: `Engine > Crank` (digital output). The controller activates the *Crank* output. If *Running detection* changes from OFF to ON, cranking stops.
4. **Running detection**. The engine is regarded as started when *Running detection* is ON.

Failure of engine start sequence for a run coil system



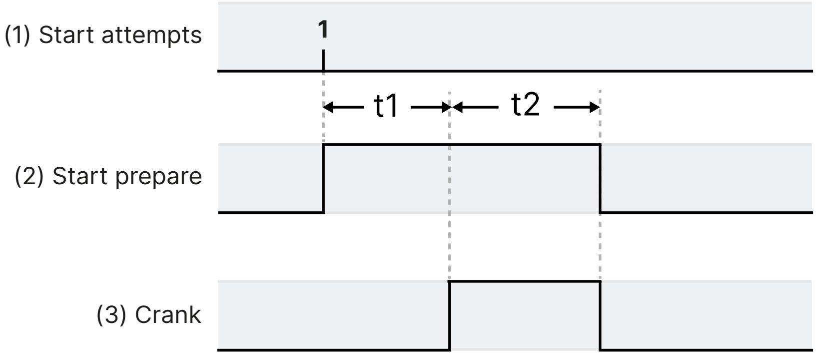
t1	Run coil before crank (optional)
t2	Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)
t3	Crank off (`Parameters > Engine > Start sequence > Crank > Crank off`)

1. **Start attempts**: `Parameters > Engine > Start sequence > Start attempts > Normal` = 3.
2. **Run coil**: `Engine > Controls > Run coil` (digital output). The controller activates the *Run coil* at the time in the *Run coil before crank* parameter. If *Running detection* is still OFF after cranking, the controller deactivates the *Run coil* for the time in the *Crank off* parameter. This ensures that the engine is stopped if the engine start was not detected. The engine cannot be started during the *Crank off* time.
3. **Crank**: `Engine > Controls > Crank` (digital output). The controller activates the *Crank* output for the *Crank on* time, and deactivates it for *Crank off* time.
4. **Running detection**. There is no running detection.
5. **Start failure**. The controller activates the *Start failure* alarm after the last unsuccessful start attempt.

Optional start prepare

You can use the optional `Engine > Controls > Start prepare` digital output with a stop coil or a run coil system.

Successful engine start sequence with start prepare



t1 = Start prepare (`Parameters > Engine > Start sequence > Start prepare > Start prepare`)

t2 = Extended start prepare (`Parameters > Engine > Start sequence > Start prepare > Extended start prepare`)

1. **Start attempts**
2. **Start prepare**: `Engine > Controls > Start prepare` (digital output) (optional).
   a. At the start of each start sequence, the controller activates the *Start prepare* output for the time in the *Start prepare* parameter (**t1**). All other engine start outputs (that is, *Stop coil*, *Crank*) are not activated during this time.
   b. If there is an *Extended start prepare* time (**t2**), then the *Start prepare* output remains activated for this time during cranking. If cranking stops before the extended start prepare timer stops, then the controller deactivates the *Start prepare* output.
3. **Crank**: `Engine > Controls > Crank` (digital output). After the *Start prepare* time, the controller activates the *Crank* output.

8.4.4 Interruption of the start sequence

These actions interrupt the engine start sequence:

- The *Emergency stop* digital input is activated (for example, from the operator, or a PLC).
- There is a *Stop engine* command.
  - For example: In LOCAL mode, the operator pushes the push-button **Stop** on the display unit.
- The following alarm actions:
  - *Trip generator breaker and stop engine*
  - *Trip generator breaker and shutdown engine*

The *Block* alarm action will not interrupt the genset start sequence after it has begun. However, the *Block* alarm action prevents a new genset start sequence from starting.

When the start sequence is interrupted, the controller does the following:

- Deactivates the *Crank* output.
- Activates the *Stop coil* output (if present). Alternatively, deactivates the *Run coil* output (if present).
- Deactivates the *Start prepare* output (if present).

There is no cooldown period when the engine start sequence is interrupted.

If *Running detection* is ON, the controller regards the engine as started. When the engine has started, the actions listed here do not interrupt the engine start sequence, but result in a engine stop instead. The engine stop normally includes the cooldown period configured in the controller. However, for a shutdown, there is no cooldown period.

8.5 Engine stop

8.5.1 Engine stop function

For a normal genset stop, the controller ensures that the genset runs for a cooldown period before stopping. If a shutdown alarm action shuts down the genset, there is no cooldown period. You can also configure an idle run stop period before the engine shuts down.

The controller software includes pre-programmed genset stop sequences. For the engine's stop function, you must configure these inputs and outputs, and parameters.

Parameters that need a hardware function are not visible until the function is assigned to an input or output.

Optional inputs and outputs

Function	I/O	Type	Details
`Engine > Command > De-load genset`	Digital input	Pulse	Optional. After the input is activated, the controller starts to de-load the genset.
`Engine > Command > Stop engine`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to stop the engine.
`Engine > Controls > Idle run`	Digital output	Continuous	Optional. Connect this output to the engine idle run if supported. Not all engines support this feature. This digital output is needed to use either idle run start and/or idle run stop.
`Engine > Command > Open generator breaker and stop engine`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to de-load and open the breaker, and then stop the engine.
`Engine > Command > Cooldown abort`	Digital input	Pulse	Optional. After the input is activated, the controller aborts the cooldown.

Parameters

`Engine > Stop sequence > Cooldown`

Parameter	Range	Comment
`Cooldown time` *	0 s to 165 min	This is the cooldown time if the digital input `Alarm system > Additional functions > Suppress alarm action` is not active. After the engine stop signal or command, the engine runs for this period before the controller activates the *Stop coil* (or deactivates the *Run coil*).

NOTE * If the digital input `Alarm system > Additional functions > Suppress alarm action` is active, the *Suppress alarm action* value is used instead of the *Cooldown time* value.

`Engine > Stop sequence > Extended stop`

Parameter	Range	Comment
`Extended stop`	1.0 to 99.0 s	The *Stop coil* remains activated for this period after *Running detection* is OFF. During this period a new start attempt is not possible.

Optional idle run stop

You can optionally configure an idle run stop period for the engine, allowing the engine to cool-down after taking load.

If this is configured, the controller will activate the digital output `Engine > Controls > Idle run` before stopping the engine. The controller then waits for one of the engine conditions (coolant temperature, oil temperature, external input condition, or the maximum timer) to be fulfilled before stopping the engine.

During the idle run stop period, the operator can override the period and press **Stop** on the display, the controller then cancels the idle run stop period and stops the engine.

Additionally, during the idle run stop period, the operator can press **Start** to abort the engine stop sequence and run the engine start sequence.

Optional. You must configure the `Engine > Controls > Idle run` digital output to see these parameters.

Optional parameters

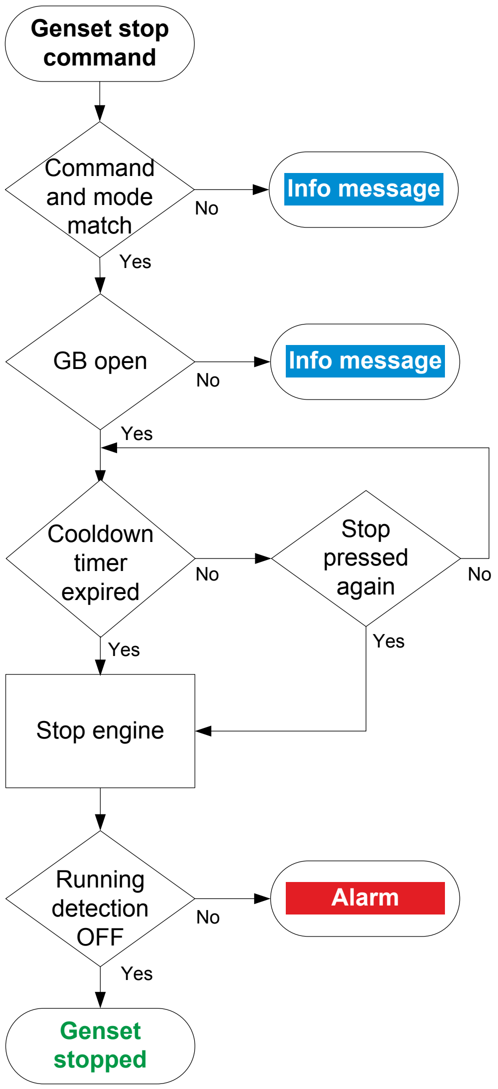
`Engine > Idle run stop > Minimum`

Parameter	Range	Comment
`Use`	Not enabled, Enabled	Uses minimum set point to determine if the engine is ready to stop.
`Delay`	0 s to 999 min	This is the minimum time the idle run stop is active.

8.5.2 Engine stop flowchart

The following flowchart shows how the controller normally stops a genset. An engine shutdown is described later.

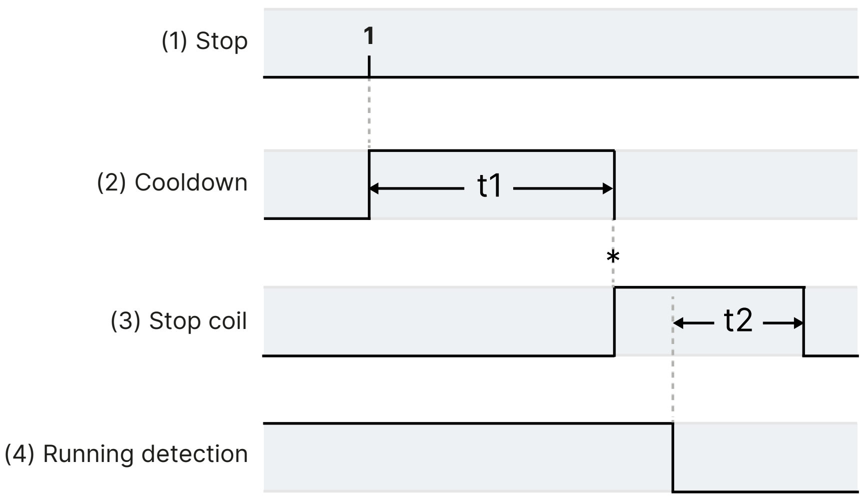
Table 8.2 Engine stop flowchart



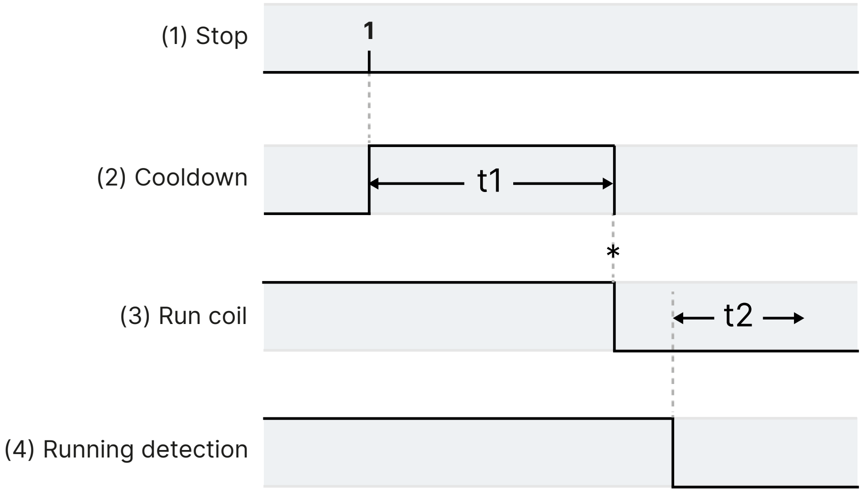
1. **Command and mode match**: The controller checks that the command source and the controller mode match:
   - In REMOTE mode, the command to stop the genset can come from a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.
   - In LOCAL mode, The operator can press the push-button **Stop** on the display unit. The controller ignores all other commands.
2. **GB open**: The controller checks whether the genset breaker is open. If the genset breaker is not open, the controller cancels the stop sequence and the display unit shows an info message.
3. **Cooldown timer expired**: The genset runs without load for the cooldown time. The controller checks whether the cooldown timer has expired or the stop button was pressed again.
   - If the cooldown timer has not expired, but the engine stop button was pressed again, the controller stops the cooldown.
4. **Stop engine**: To stop the engine:
   - Stop coil system: The controller activates the *Stop coil* output.
   - Run coil system: The controller deactivates the *Run coil* output.
5. **Running detection OFF**: The controller checks whether the engine has stopped.
   - If *Running detection* is ON, the controller activates an alarm.
   - If *Running detection* is OFF, the engine has stopped and the stop sequence has been completed successfully.

8.5.3 Engine stop sequence

Engine stop sequence for a stop coil system



Engine stop sequence for a run coil system



t1	Cooldown (`Parameters > Engine > Stop sequence > Cooldown > Cooldown time`)
t2	Extended stop (`Parameters > Engine > Stop sequence > Extended stop > Extended stop`)
*	Up to this point, the engine can be restarted immediately, without completing the stop sequence.

1. **Stop**. The stop command can come from the controller, an operator, or an external source. See Engine stop flowchart.
2. **Cooldown** (optional). The controller allows the genset to run for the time configured. There is no cooldown for shutdowns, an emergency stop, or an operator stop by pressing the engine stop push-button again. Temperature-dependent cooldown is also possible (see below).
3. **Stop engine**:
   - **Stop coil**: `Engine > Controls > Stop coil` (digital output). The controller activates the stop coil digital output until running feedback is OFF. The controller then keeps the stop coil activated for the time in the (optional) *Extended stop* parameter.
   - **Run coil**: `Engine > Controls > Run coil` (digital output). The controller deactivates the run coil digital output after the cooldown period. The genset cannot restart during the time in the (optional) *Extended stop* parameter.
4. **Running detection**. When the running detection is OFF, the controller regards the engine as stopped.

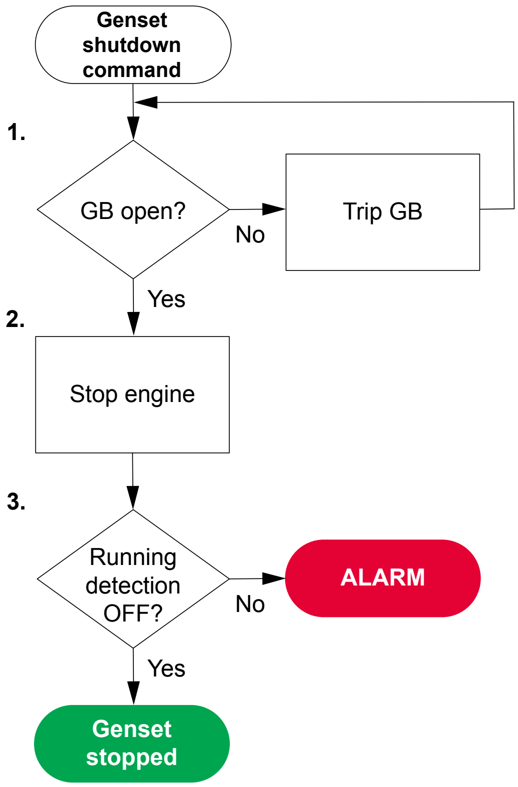
8.5.4 Engine shutdown flowchart

The engine is shut down for the following alarm action:

- Trip generator breaker and shutdown engine

The engine is also shutdown if the controller's *Emergency stop* input is deactivated.

Engine shutdown flowchart



1. **GB open**: The controller checks whether the generator breaker is open. If not, the controller trips the generator breaker.
2. **Stop engine**: The controller shuts down the engine:
   - Stop coil system: The controller activates the *Stop coil* output.
   - Run coil system: The controller deactivates the *Run coil* output.
3. **Running detection OFF**: If *Running detection* is still ON after the time allowed, the controller activates the *Stop failure* alarm.

NOTE The controller does not require the engine stop conditions to be met for an engine shutdown. Similarly, there is no cooldown time for an engine shutdown.

8.6 Generator breaker

8.6.1 How it works

The generator breaker (GB) connects the genset to the busbar. The genset must be running, and synchronised with the busbar, for the generator breaker to close. The generator breaker is an important part of the system safety, and trips to protect the genset from problems on the busbar. The generator breaker also trips to stop genset problems from disturbing the busbar.

General breaker information

More information
See the **Breakers, synchronisation and de-loading** chapter for more information on synchronisation and breakers. This includes the inputs and output functions and the parameters to configure.

[Breaker] refers to *Generator breaker*. The breaker abbreviation (*[*B]*) is *GB*.

Synchronisation

When the generator breaker close button is pressed, if the controller has an active regulation mode, it ignores the regulation mode and automatically regulates the genset to synchronise. When the generator breaker is closed, the controller returns to its previous regulation mode.

If the controller(s) regulation is off or under *Manual regulation*, the controller does not automatically regulate the genset to synchronise. The genset can be synchronised manually while the synchronisation timer is running if the controller is under *Manual regulation*.

Regardless of the regulation, if the synchronisation requirements are met (within the time available for synchronisation), the controller automatically closes the breaker.

De-loading

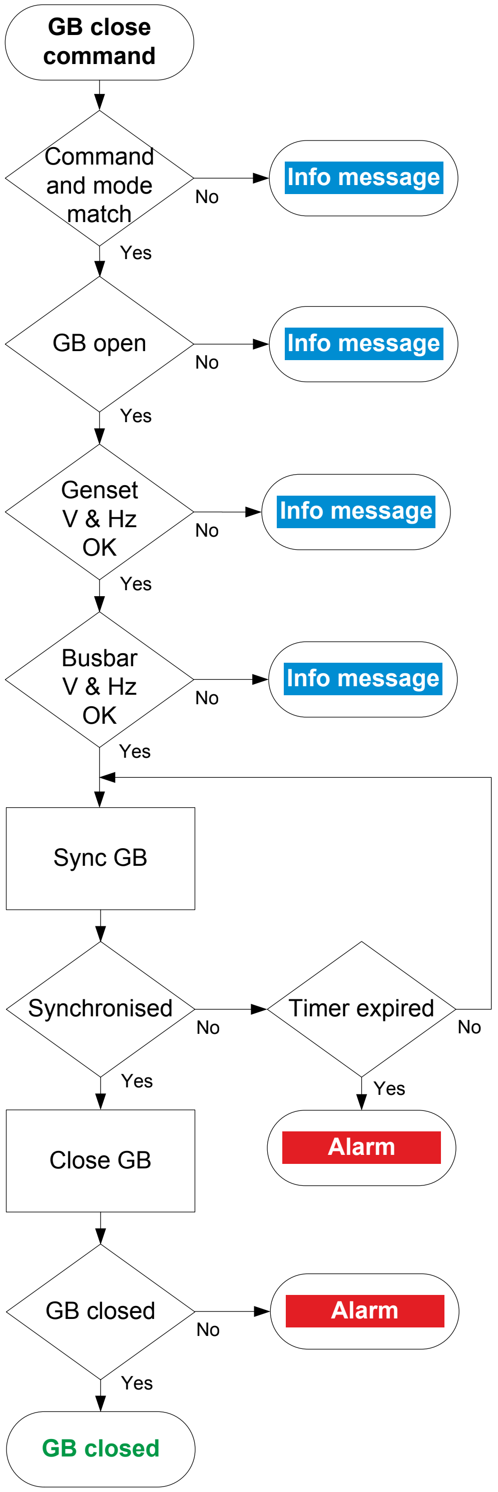
When the generator breaker open button is pressed, the controller checks whether the genset has an active regulation mode. If regulation is off, the controller trips the breaker (without de-loading).

If regulation is possible, the controller ignores its regulation mode and tries to de-load and open the breaker. The generator breaker must be de-loaded manually while the de-load timer is running if the controllers is under *Manual regulation*. When the generator breaker is open, the controller returns to its previous regulation mode.

8.6.2 Generator breaker close flowchart

The following flowchart shows the sequence that the controller normally uses to close the generator breaker.

Table 8.3 Generator breaker close flowchart



1. **Command and mode match**: The controller checks that the command source and the controller mode match:
   - In REMOTE mode, the command to close the breaker can come from a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.
   - In LOCAL mode, the operator can press the push-button **Close breaker** on the display unit. The controller ignores all other commands.
2. **GB open**: The controller checks whether the generator breaker is open. If the generator breaker is already closed, the sequence stops, and an info message is shown.
3. **Genset V & Hz OK**: The controller checks whether the voltage and frequency from the genset are within the allowed range*. If these are not in the range, then the controller cancels the close command and displays an info message.
4. **Busbar V & Hz OK**: The controller checks whether the voltage and frequency on the busbar are within range*. If these are not in the range, then the controller cancels the close command and displays an info message.
5. **Sync GB**: If the controller has an active regulation mode, it tries to synchronise the genset to the busbar.
   - When the genset and busbar are synchronised, the controller activates the *Breakers > Generator breaker > Control > GB close* output to close the breaker.
   - If the genset and busbar do not synchronise within the time allowed, the controller activates a *GB synchronisation failure* alarm.
6. **GB closed**: The controller checks whether the generator breaker has closed.
   - If the generator breaker has closed, the generator breaker close sequence has been completed successfully.
   - If the generator breaker has not closed, the controller activates the *GB closing failure* alarm.

*Note: See **Configure > Parameters > [A-side] / [B-side] > AC setup > Voltage and frequency OK** for these ranges.

8.6.3 Generator breaker open flowchart

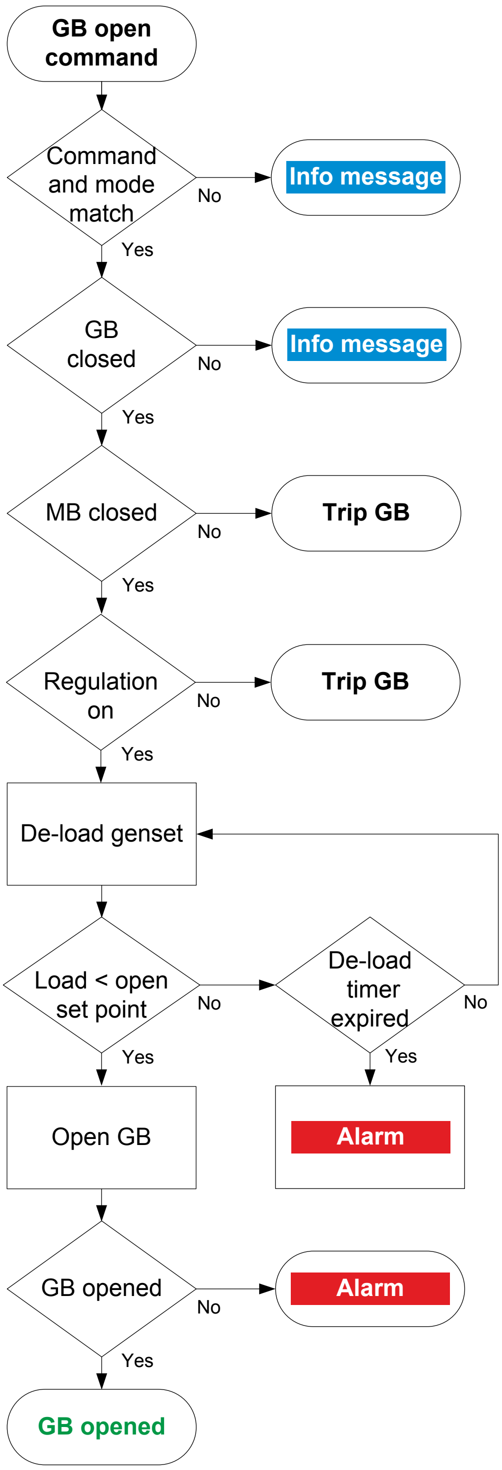
The following flowchart shows the sequence that the controller normally uses to open the generator breaker when the **SINGLE genset** controller controls both a generator breaker and a mains breaker.

More information
If the **SINGLE genset** controller does not control a mains breaker, see the Generator breaker open flowchart under **GENSET** controller.

The alarm action *Block* does not open a closed breaker, although it stops an open breaker from closing. If the controller or an operator sends a GB open command while *Block* is active, the controller uses this sequence.

The sequence to trip the generator breaker is described in another flowchart.

Table 8.4 Generator breaker open flowchart for single genset with mains breaker



1. **Command and mode match**: The controller checks that the command source and the controller mode match:
   - In REMOTE mode, the command to open the genset breaker can come from a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.
   - In LOCAL mode, the operator can press the push-button **Open breaker** on the display unit. The controller ignores all other commands.
2. **GB closed**: The controller checks whether the generator breaker is closed. If the generator breaker is open, the sequence ends.
3. **MB closed**: The controller checks whether the mains breaker is closed.
   - If the mains breaker is open, the controller trips the generator breaker, without de-loading.
4. **Regulation on**: The controller checks whether regulation is on.
   - If regulation is off, the controller trips the breaker.
   - If regulation is on, the controller tries to de-load the breaker.
   - If regulation is manual, an operator can manually de-load the breaker.
5. **De-load genset**: The controller adjusts the regulation to de-load the genset:
   - When the load is less than the set point for the breaker to open, the controller activates the `Breakers > Generator breaker > Control > GB open` output.
   - If the controller cannot de-load the breaker before the de-load timer expires, the controller activates the *GB de-load failure* alarm. The controller continues to try to de-load the breaker.
6. **GB opened**: The controller checks whether the generator breaker has opened:
   - If the generator breaker has opened, the generator breaker open sequence has been completed successfully.
   - If the generator breaker has not opened, the controller activates the *GB opening failure* alarm.

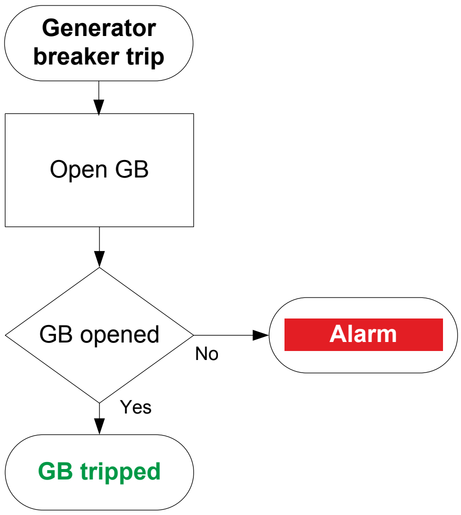
8.6.4 Generator breaker trip flowchart

The controller automatically trips the generator breaker (GB) for these alarm actions:

- Trip generator breaker
- Trip generator breaker and stop engine
- Trip generator breaker and shutdown engine

The generator breaker also trips if the controller's *Emergency stop* input is deactivated.

The controller does not require the genset stop conditions to be met for a breaker trip. Similarly, the breaker is not de-loaded for a trip.



1. **Open GB**: When a trip is required, the controller activates the `Breakers > Generator breaker > Controls > GB open` output to open the breaker.
2. **GB opened**: The controller checks whether the breaker has opened:
   - If the breaker has opened, the trip is successful.
   - If the breaker has not opened, the controller activates the *GB opening failure* alarm.

8.7 Mains principles

8.7.1 Mains voltage and frequency OK

Use these parameters to configure the mains voltage and frequency OK range.

`Local power management > Mains configuration > Voltage and frequency OK`

Name	Range	Details
`Low voltage hysteresis`	0 to 70 % of nominal voltage	If the voltage has been below the low voltage set point, the voltage has to rise by the hysteresis voltage before the controller can treat the voltage as okay.
`High voltage hysteresis`	0 to 20 % of nominal voltage	If the voltage has been above the high voltage set point, the voltage has to drop by the hysteresis voltage before the controller can treat the voltage as okay.
`Low frequency hysteresis`	0.0 to 20.0 % of nominal frequency	If the frequency has been below the low frequency set point, the frequency has to rise by the hysteresis frequency before the controller can treat the frequency as okay.
`High frequency hysteresis`	0.0 to 20.0 % of nominal frequency	If the frequency has been above the high frequency set point, the frequency has to drop by the hysteresis frequency before the controller can treat the frequency as okay.
`Voltage failure delay`	0.5 s to 16.5 min	The voltage failure sequence is activated if the voltage stays outside the required range for the duration of this timer.
`Voltage OK delay`	2 s to 165 min	The voltage must stay inside the required range for the duration of this timer before the controller can treat the voltage as okay.
`Low voltage`	30 to 100 % of nominal voltage	The low set point for the voltage okay range.
`High voltage`	100 to 130 % of nominal voltage	The high set point for the voltage okay range.
`Voltage failure sequence`	Start engine and open MB, Start engine, Open MB at ready engine	**Start engine and open MB**: If there is a voltage failure, the controller starts a genset and opens the mains breaker. **Start engine**: If there is a voltage failure, the controller starts a genset. **Open MB at ready engine**: If there is a voltage failure, open the mains breaker when the genset engine is ready.

Name	Range	Details
Unbalance voltage	2 to 100 % of nominal voltage	The voltage unbalance must be below this set point before the controller can treat the voltage as okay.
Frequency failure delay	0.5 s to 16.5 min	The frequency failure alarm is activated if the frequency stays outside the required range for the duration of this timer.
Frequency OK delay	2 s to 165 min	The frequency must stay inside the required range for the duration of this timer before the controller can treat the frequency as okay.
Low frequency	80.0 to 100.0 % of nominal frequency	The low set point for the frequency okay range.
High frequency	100.0 to 120.0 % of nominal frequency	The high set point for the frequency okay range.

8.7.2 Short-time parallel

You can uses these parameters to limit the time that the genset is parallel to the mains.

Breakers > Short-time parallel > Configuration

Parameter	Range
Overlap	Off, On
Overlap	0.10 to 99.90 s

8.7.3 Mains synchronisation controls

The mains parameters and breaker positions determine whether the controller will synchronise across a breaker.

Local power management rules > Mains configuration > Controls

Name	Range	Details
Back synchronisation	Not enabled, Enabled	**Not enabled**: The controller will not synchronise across the MB to the genset. **Enabled**: The controller can synchronise across the MB to the genset.
Synchronisation to mains	Not enabled, Enabled	**Not enabled**: The controller will not synchronise across the GB to the mains. The GB can however close if the MB is open, since no synchronisation is required. **Enabled**: The controller can synchronise across the GB to the mains.

8.7.4 External regulation of the mains

You can use parameters configure the mains regulation settings. You can use an analogue input for external regulation of the mains, as well as digital inputs to activate or deactivate different regulation.

Inputs and outputs

Function	I/O	Type	Details
Mains > External set points > Power set point [%]	Analogue input	-	If external power is activated, the controller calculates the external set point by using this input to multiply the *Mains power* set point.
Mains > External set points > Activate external power	Digital input	Pulse	After this input is activated, the controller uses the analogue input to regulate the mains power set point.
Mains > External set points > Deactivate external power	Digital input	Pulse	After this input is activated, the controller does not use the analogue input to regulated the mains power set point.

Function	I/O	Type	Details
Mains > Set point offsets > Active power > Activate offset [1 to 3]	Digital input	Continuous	When input [1 to 3] is activated, the controller adds active power offset [1 to 3] to the power set point.
Mains > Set point offsets > Cos phi > Activate offset [1 to 3]	Digital input	Continuous	When input [1 to 3] is activated, the controller adds cos phi offset [1 to 3] to the cos phi set point.

Power management rules > Mains power > External set points

Name	Range	Details
Mains power	-20 000 kW to 20 000 kW	Mains power set point. Use positive values for power from the mains connection.
Mains power	-100 to 100 % of nominal power	Mains power set point. Use positive values for power from the mains connection.
Mains power	In percent, In kW	**In percent**: The value configured in percent is used. **In kW**: The value configured in kW is used.

Power management rules > Mains power > Settings

Name	Range	Details
Controller settings cos phi	0.700 to 1.000	The mains cos phi set point.
Controller settings cos phi	Inductive, Capacitive	**Inductive**: The cos phi set point is inductive. **Capacitive**: The cos phi set point is inductive.
Controller settings Q	-100 to 100 % of nominal reactive power	The mains reactive power set point.
Controller settings cos phi or Q	• Fixed cos phi • Superior • Fixed Q	**Fixed cos phi**: The controller regulates the genset so that the mains export/import cos phi meets the set point. **Superior**: **Fixed Q**: The controller regulates the genset so that the mains export/import Q meets the set point.

Power management rules > Mains power > Active power

Name	Range	Details
Offset [1 to 3]	-100.0 to 100.0 % of nominal power	The controller offsets the mains power external set point by this amount.

Power management rules > Mains power > Fixed cos phi offset

Name	Range	Details
Offset [1 to 3]	0.0000 to 1.0000	The controller offsets the mains cos phi set point by this amount.
Offset [1 to 3]	Inductive, Capacitive	**Inductive**: The cos phi offset is inductive. **Capacitive**: The cos phi offset is inductive.

8.8 Mains breaker

8.8.1 How it works

The mains breaker (MB) connects the mains to the busbar. For the mains breaker to close, the mains must be live, and the busbar must be synchronised with the mains. The mains breaker is an important part of the system safety, and trips to protect the busbar from mains problems. The mains breaker also trips to stop busbar problems from disturbing the mains.

General breaker information

More information
See the **Breakers, synchronisation and de-loading** chapter for more information on synchronisation and breakers. This includes the inputs and output functions and the parameters to configure.

For the mains breaker of a **SINGLE genset** with mains breaker controller, the breaker abbreviation (*[*B]*) is *MB*. *[Breaker]* refers to *Mains breaker*.

The mains breaker open flowchart and the mains breaker blackout close flowchart for the **SINGLE genset** controller are given in this section.

Synchronisation

When the mains breaker close button is pressed, if the controller has an active regulation mode, it ignores the regulation mode and automatically regulates the genset to synchronise. When the mains breaker is closed, the controller returns to its previous regulation mode.

If the controller(s) regulation is off or under *Manual regulation*, the controller does not automatically regulate the genset to synchronise. The genset can be synchronised manually while the synchronisation timer is running if the controller is under *Manual regulation*.

Regardless of the regulation, if the synchronisation requirements are met (within the time available for synchronisation), the controller automatically closes the breaker.

De-loading

When the mains breaker open button is pressed, all of the following are required for de-loading:

- The genset must be connected.
- The genset must have an active regulation mode or be under *Manual regulation*.
- There must be a mains power measurement.

If de-loading is not possible, the controller trips the mains breaker (without de-loading).

If regulation is possible, the controller ignores its regulation mode and tries to de-load and open the breaker. The mains breaker must be de-loaded manually while the de-load timer is running if the controllers is under *Manual regulation*. When the mains breaker is open, the controller returns to its previous regulation mode.

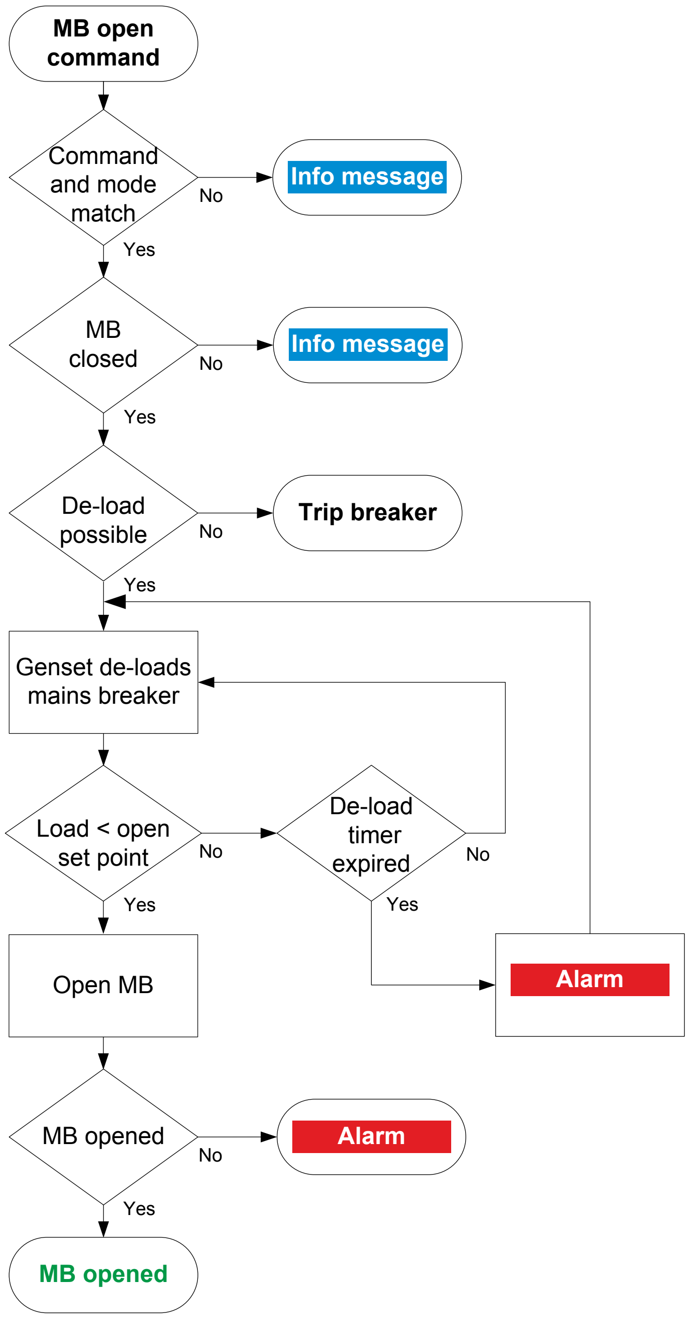
8.8.2 Mains breaker open flowchart

The following flowchart shows the sequence that the controller normally uses to open the mains breaker.

The alarm action *Block mains breaker* does not open a closed breaker, although it stops an open breaker from closing. If the controller or an operator sends an MB open command while *Block mains breaker* is active, the controller uses this sequence.

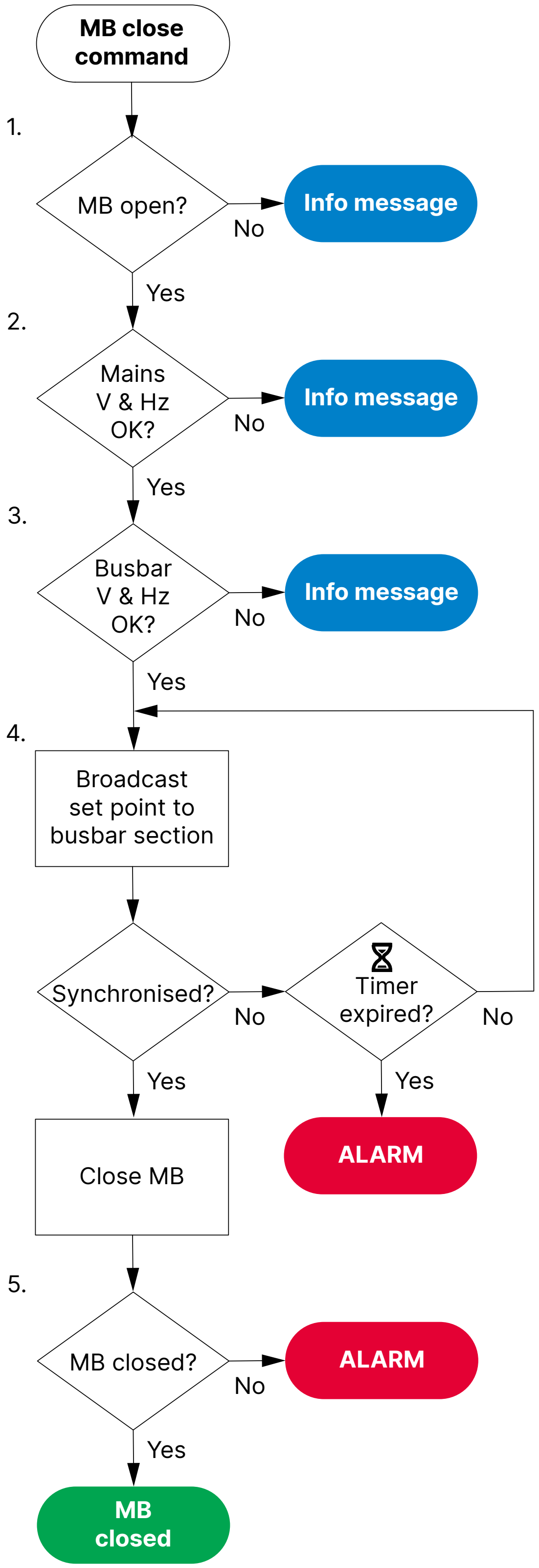
The sequence to trip the mains breaker is described in another flowchart.

Table 8.5 Mains breaker (MB) open flowchart



1. **Command and mode match**: The controller checks that the command source and the controller mode match:
   - In REMOTE mode, the command to open the genset breaker can come from a digital input, PICUS, Modbus, and/or CustomLogic or CODESYS.
   - In LOCAL mode, the operator can press the push-button **Open breaker** on the display unit. The controller ignores all other commands.
2. **MB closed**: The controller checks whether the breaker is closed. If the breaker is open, the sequence ends.
3. **De-load possible**: The controller checks de-loading is possible.
   - If de-loading is not possible, the controller trips the breaker.
   - If de-loading is possible, the controller tries to de-load the breaker.
4. **Genset de-loads mains breaker**: The controller regulates the genset.
   - When the load is less than the set point for the breaker to open, the controller activates the *Breakers > Mains breaker > Control > MB open* output.
   - If the controller cannot de-load the breaker before the de-load timer expires, the controller activates the *MB de-load failure* alarm. The controller continues to try to de-load the breaker.
5. **MB opened**: The controller checks whether the breaker has opened:
   - If the breaker has opened, the mains breaker open sequence has been completed successfully.
   - If the breaker has not opened, the controller activates the *MB opening failure* alarm.

8.8.3 Mains breaker close flowchart



1. **MB open**: The controller checks whether the breaker is open. If the breaker is already closed, the sequence stops, and an info message is shown.
2. **Mains V & Hz OK**: The controller checks whether the voltage and frequency are within the allowed range*. If these are not in the range, then the controller cancels the close command and displays an info message.
3. **Busbar V & Hz OK**:
   - The controller checks whether the voltage and frequency on the busbar are within range*. If these are not in the range, then the controller cancels the close command and displays an information message.
4. **Broadcast set point to busbar section**: The controller broadcasts the required set point on the busbar section.
   - If the mains and busbar are synchronised, the controller activates the `Breakers > Mains breaker > Controls > MB close` output to close the breaker.
   - If the mains and busbar do not synchronise within the time allowed, the controller activates an *MB synchronisation failure* alarm.
5. **MB closed**: The controller checks whether the breaker has closed.
   - If the breaker has closed, the breaker close sequence has been completed successfully.
   - If the breaker has not closed, the controller activates the *MB closing failure* alarm.

NOTE * See `Local power management / Mains configuration > Voltage and frequency OK` for these ranges.

8.8.4 Busbar blackout MB close flowchart

The mains breaker (MB) can close if the mains is live and there is a blackout on the busbar (that is, the genset is not connected). This is hard coded, and there are no other blackout close options for the mains breaker of a **SINGLE genset** controller.

Blackout conditions

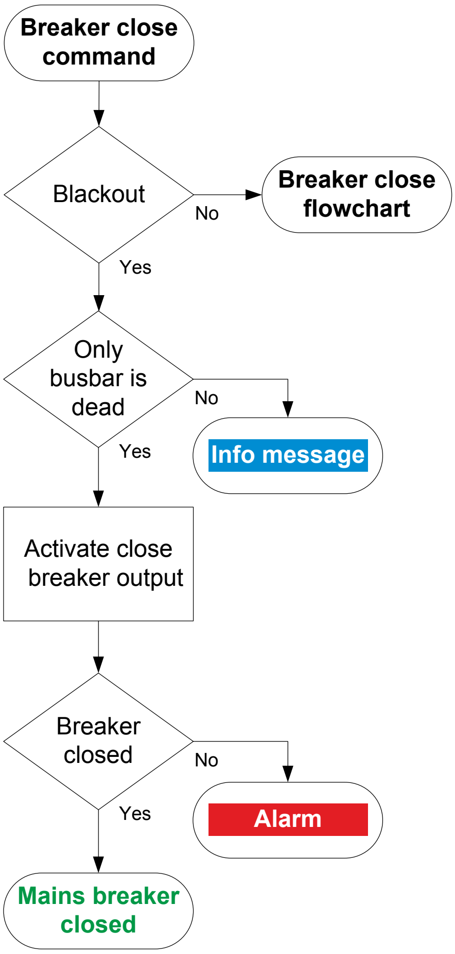
A blackout is present if the phase-to-phase voltage is less than 10 % of the nominal voltage (V_{L-L} < 10 % of V_{nom}). This percentage is fixed.

Conditions that prevent blackout close

If any of the following conditions are present, the controller will not allow the blackout close:

- The breaker position is unknown.
- There is a short circuit.
  - A digital input with the function `Breakers > Generator breaker > Feedback > GB short circuit` was activated.
- There is a blocking alarm.
  - The alarm action determines whether the alarm is a blocking alarm.
- The mains and/or generator AC measurements are not OK.
  - A measurement failure is detected on one or more of the phases.

Table 8.6 Blackout close flowchart



1. **Breaker close command**: An operator or a remote command attempts to close the mains breaker.
2. **Blackout**: The controller detects a blackout, and the conditions for blackout close are met.
3. **Only busbar is dead**: The controller checks whether the blackout is only on the busbar between the genset and the mains.
   - *Blackout only on the busbar*: The controller activates the close main breaker output.
4. **Breaker closed**: The controller checks whether the mains breaker has closed.
   - If the mains breaker has closed, the blackout close sequence has been completed successfully.
   - If the mains breaker has not closed the controller activates the *MB closing failure* alarm.

8.8.5 Mains settings in a SINGLE genset controller

If the controller has a mains connection, you can configure the mains settings.

Power management rules > Mains power > External set points

Name	Range	Details
Mains power	-20 000 kW to 20 000 kW	
Mains power	-100 to 100 %	
Mains power	In percent, In kW	

Power management rules > Mains power > Peak shaving

Name	Range	Details
Start generator	5 to 100 %	
Start generator	0.0 to 16.5 min	
Minimum load	0 to 100 %	
Stop generator	0 to 80 %	
Stop generator	0.0 to 16.5 min	

Power management rules > Mains power > Settings

Name	Range	Details
Controller settings cos phi	0.700 to 1.000	
Controller settings cos phi	Inductive, Capacitive	
Controller settings Q	-100 to 100 %	
Controller settings cos phi or Q	• Fixed cos phi • Superior • Fixed Q	

Power management rules > Mains power > Active power

Name	Range	Details
Offset 1	-100.0 to 100.0 %	
Offset 2	-100.0 to 100.0 %	
Offset 3	-100.0 to 100.0 %	

Power management rules > Mains power > Fixed cos phi offset

Name	Range	Details
Offset 1	0.0000 to 1.0000	
Offset 1	Inductive, Capacitive	
Offset 2	0.0000 to 1.0000	
Offset 2	Inductive, Capacitive	
Offset 3	0.0000 to 1.0000	
Offset 3	Inductive, Capacitive	

8.9 Other SINGLE genset controller functions

8.9.1 Engine communication

The controller supports J1939 communication with engines, as well as some proprietary protocols.

More information
See **iE 250 ML 300 Engine interface communication** for the details for each engine type.

Inputs and outputs

You can use controller inputs and outputs for the ECU.

Function	I/O	Type	Details
`Engine > ECU > Measurement list filter - available`	Digital input	Pulse	
`Engine > ECU > Measurement list filter - clear`	Digital input	Pulse	
`Engine > ECU > Log request (DM2)`	Digital input	Pulse	After this input is activated, the controller requests the DM2 log from the ECU.
`Engine > ECU > Log clear (DM2)`	Digital input	Pulse	After this input is activated, the controller requests the ECU to clear the DM2 log.
`Engine > ECU > ECU reset input`	Digital input	Pulse	After this input is activated, the controller requests the ECU to reset.
`Engine > Controls > ECU power`	Digital output	Continuous	You can use this output so that the ECU is only powered on when the engine needs to run.
`Engine > ECU > ...`	Analogue outputs	Various	Over 100 ECU outputs are available as analogue outputs. These can be connected to switchboard instruments for troubleshooting.

Parameters for controls

`Engine > ECU > Controls > Speed control (TSC1 / Custom)`

Parameter	Range	Notes
`Enable`	Not enabled, Enabled	**Enable**: Enable writing commands to the ECU.
`Source address`	0 to 255	EIC speed/Torque control source address.
`Use nominal RPM as reference`	Not enabled, Enabled	**Enabled**: Use the nominal RPM as the reference for the ECU.

`Engine > ECU > Controls > Cab message (CM1 / Custom)`

Parameter	Range	Notes
`Source address`	0 to 255	Selection of EIC J1939 CAB message 1 source address. The controller telegrams for DPF regeneration use this source address.

`Engine > ECU > Controls > CAN controls`

Parameter	Range	Notes
`Enable`	Not enabled, Enabled	**Enable**: Enable writing commands to the ECU.

`Engine > ECU > Controls > Droop`

Parameter	Range	Notes
`Droop settings`	None, Engine Control Unit (ECU), Emulated droop	**None**: The controller does not use droop. **Engine control unit (ECU)**: The controller sends the specified droop value to the ECU. **Emulated droop**: The controller emulates the specified droop.
`Droop value`	0.0 to 25.0 %	The specified droop.

Engine > ECU > Controls > Reset

Parameter	Range	Notes
Power off timer	1 to 300 s	The controller uses this timer with the digital output Engine > Controls > ECU power. This can be wired to turn the ECU power off.

Parameters for diagnostic alarms

Engine > ECU > Diagnostic alarms > ECU Red stop lamp

Engine > ECU > Diagnostic alarms > ECU Amber warning lamp

Engine > ECU > Diagnostic alarms > ECU Protect lamp

Engine > ECU > Diagnostic alarms > ECU Malfunction indicator lamp

Parameters for DPF controls

Engine > ECU > DPF controls > Controls

Parameter	Range	Notes
Aftertreatment Regeneration Inhibit Switch	Not enabled, Enabled	**Enabled**: The regeneration is inhibited.
Aftertreatment Regeneration Force Switch	Automatic, Forced	**Automatic**: The ECU automatically regenerates the DPF filter as required. **Forced**: Forces the regeneration of the DPF filter.

Parameters for specific manufacturers

Engine > ECU > Manufacture specific

Parameter	Range	Notes
Shutdown override > Enable	Not enabled, Enabled	
Parameters > Speed control	Standard J1939, [Manufacturer specific]	If the manufacturer has a proprietary speed control, you can select it here.

8.9.2 Non-connected genset

The non-connected genset function stops a genset from running for too long without connecting to the busbar. The function is only active when the controller is in REMOTE mode. That is, if a genset is running with its breaker open, this function stops the genset when its timer expires.

The function may be needed in the following situations:

- The operator first starts the genset with the controller in LOCAL mode, and then switches to REMOTE mode.
- There has been a precautionary genset start, but the busbar stabilised, and the started genset was not needed.

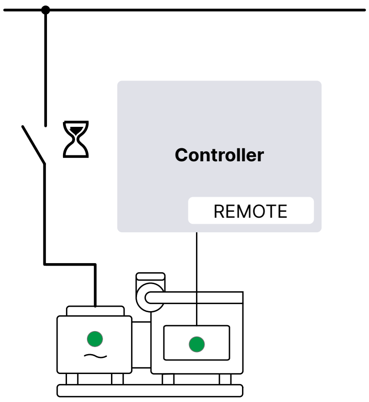
Local power management > Non-connected genset > Stop timer

Parameter	Range	Notes
Delay	10.0 s to 10 min	The timer starts when both of these conditions are met: 1. The genset start sequence is finished. 2. The genset is ready to connect. The timer resets if any of the following happens: • The breaker close sequence starts. • The stop sequence starts. • There is a genset alarm. When the timer expires, the controller stops the genset engine.

How the non-connected genset function works

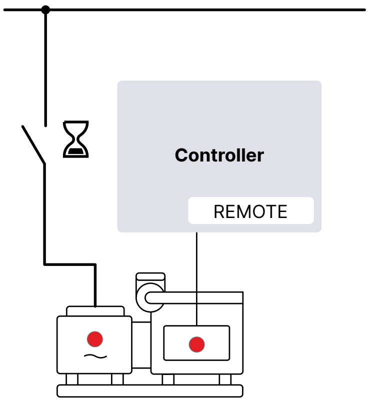
Non-connected genset running in REMOTE

The timer starts ....



... the timer expires.

The controller stops the genset.



8.9.3 Temperature-dependent power derating

The temperature-dependent power derating function reduces the genset nominal load by reducing the genset nominal power used by fixed power. The derating function can be configured for up to three temperature measurements.

Temperature-dependent power derating does not affect protections.

Analogue inputs and outputs

Function	I/O	Type	Details
`Engine > Power derate > Derate # temperature [C]` *	Analogue input	The measurement must be in °C.	This can measure any temperature, for example, the engine cooling water.
`Engine > Power derate > Temperature > Derate # temperature [C]` *	Analogue output	-	Optional. You can connect this output to a switchboard instrument to monitor the analogue input.

NOTE * # is 1 to 3.

Parameters

The analogue input(s) must be configured to see the power derate parameter and curve.

`Engine > Power derate > Temperature > Derate #` *

Parameter	Range	Comment
`Enable derate`	Not enabled, Enabled	**Not enabled**: Fixed power uses the genset nominal power, no matter what the derate temperature is.

Parameter	Range	Comment
		Enabled: The controller uses the power derating curve to derate the power within the configured range. See below.
`Setup`		Use this section to set up the power derate curve.

NOTE * # is 1 to 3.

8.9.4 Percentage-dependent power derating

The percentage-dependent power derating function reduces the genset nominal load by reducing the genset nominal power.

Input and output

Function	I/O	Type	Details
`Engine > Power derate > Percentage > Derate percentage [%]`	Analogue input	The measurement must be in %.	
`Engine > Power derate > Percentage > Derate percentage [%]`	Analogue output	-	Optional. You can connect this output to a switchboard instrument to monitor the analogue input.

Parameters

`Engine > Power derate > Percentage`

The analogue input must be configured to see the power derate parameter.

Parameter	Range	Comment
`Enable derate`	Not enabled, Enabled	**Not enabled**: The controller uses the genset nominal power, no matter what the derate percentage is. **Enabled**: The controller uses the analogue input to derate the nominal power.

8.9.5 Engine operating values as analogue inputs

In addition to analogue inputs described previously, you can use these analogue inputs to communicate engine operating values to the controller.

Analogue inputs

Function	I/O
`Engine > Measurements > Coolant > Engine coolant temperature [°C]`	Analogue input
`Engine > Measurements > Coolant > Engine coolant level [%]`	Analogue input
`Engine > Measurements > Lube oil > Engine oil temperature [°C]`	Analogue input
`Engine > Measurements > Lube oil > Engine oil pressure [bar]`	Analogue input

8.9.6 Engine operating values as analogue outputs

You can configure an analogue output with a function for an engine operating value from the ECU, the analogue input, or the MPU. The controller then adjusts the analogue output to reflect the engine operating value. For a list of the engine operating values, see the `Engine` analogue output functions in the controller.

Applications

An analogue output with an engine operating value may be wired to a switchboard instrument, to help the operator with troubleshooting. For example, the engine speed measured by the MPU can be displayed.

8.9.7 Fuel pump

To keep the level in a tank in the required range, you can use the controller's inputs and outputs to control a pump.

More information
See **Fuel pump** in the **GENSET controller** chapter for details.

8.9.8 Engine states as digital outputs

You can configure a digital output with a function for an engine state. The controller activates the digital output if the engine state is present. These can be useful for troubleshooting.

Digital outputs

Function	I/O	Type	Details
`Engine > State > Start prepare completed`	Digital output	Continuous	Activated when the start prepare is completed.
`Engine > State > Running`	Digital output	Continuous	Activated if there is running detection for the engine.
`Engine > State > Not running`	Digital output	Continuous	Activated if there is no running detection for the engine.

8.9.9 Digital AVR

The controller can work with a digital AVR.

More information
See **Digital AVR** in the **GENSET controller** chapter for details.

8.9.10 Close before excitation

You can configure the controller to start up the genset with the excitation switched off.

More information
See **Close before excitation** in the **GENSET controller** chapter for details.

8.9.11 Genset test

The test mode is activated by activating a digital input. The test stops automatically when the test timer runs out.

Digital input

Function	I/O	Type
`Local > Mode > Test`	Digital input	Pulse

`Local power management > Genset test`

Name	Range	Details
`Test`	1 to 100 %	The power from the genset during the test.
`Test`	0 s to 999 min	The test duration.

Name	Range	Details
`Test type`	Simple test, Load test, Full test	**Simple test**: The simple test starts the genset and runs it at nominal frequency with the generator breaker open. The test runs until the timer expires. **Load test**: The load test starts the genset and runs it at nominal frequency, then synchronises the generator breaker and produces the power in the test set point. The test runs until the timer expires. To run the load test, synchronisation to mains must be enabled. **Full test**: The full test will start the genset and run it at nominal frequency, synchronise the generator breaker and transfer the load to the generator before opening the mains breaker. When the test timer expires, the mains breaker will be synchronised, and the load is transferred back to the mains before the generator breaker is opened and the generator is stopped. To run the full test, synchronisation to mains must be enabled.
`Return mode`	Manual, Auto, No mode change, No regulation	The controller mode after the test.

8.9.12 Mains power measurement

If the controller knows the mains power, it attempts to de-load the mains breaker before opening it. The mains power can be calculated from the 4th current measurement, or the controller can use an analogue input function for mains power.

If the mains power is unknown, the controller trips the mains breaker when a command is given to open the mains breaker.

Analogue inputs

You can use an external transducer for the mains power measurement by assigning a function to an analogue input.

Function	I/O	Units	Details
`Mains > Analogue > P total [kW]`	Analogue input	kW	The analogue input is the active power at the mains breaker.
`Mains > Analogue > Q total [kvar]`	Analogue input	kvar	The analogue input is the reactive power at the mains breaker.
`Mains > Analogue > S total [kVA]`	Analogue input	kVA	The analogue input is the apparent power at the mains breaker.

The controller can handle both positive power values (that is, from the mains), and negative power values (that is, to the mains).

Parameters

`Mains > AC setup > Mains power measurement`

Parameter	Range	Notes
`Current source`	• None • I4 • Analogue input	**None**: No measurement of mains power. The controller does not attempt to de-load the mains breaker. **I4**: The controller uses the 4th current measurement to calculate the mains power. **Analogue input**: The controller uses an analogue input to measure the mains power.

8.9.13 Counters

You can view, edit and reset all the counters on the display unit under **Configure > Counters**. The counters include:

- Start attempts
- Total running hours and minutes

- Trip running hours and minutes
- Generator breaker operations and trips
- Mains breaker operations and trips
- Power export (active and reactive)

Running hours trip works like a car trip meter. For example, you can use this counter to track the running hours since the last maintenance.

Energy counter outputs

For each energy counter, you can configure a digital output to send a pulse every time a certain amount of energy is transferred.

Digital outputs

You must configure the digital output function to see the parameters.

Function	I/O	Type	Details
`Generator > Production counters > Active energy export pulse`	Digital output	Pulse	
`Generator > Production counters > Reactive energy export pulse`	Digital output	Pulse	

Parameters

`Generator > Production counters > Active energy export`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Generator > Production counters > Reactive energy export`

Parameter	Range	Comment
`Pulse every`	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Table 8.7 Energy counter function and corresponding parameter full names

[Counter pulse]	[Counter]
Active energy export pulse	Active energy export
Reactive energy export pulse	Reactive energy export

Application example for an energy counter output

1. Connect the digital output to an external counter.
2. Configure the digital output using the display unit or PICUS to *Active energy export pulse*.
3. Configure the *Pulse every* parameter to the value where you would like to send a pulse. For example, 100 kWh.
4. Configure the *Pulse length* to the required length of the pulse for your external counter. For example, 1 second.

With the example setup the controller sends a 1 second pulse to the external counter for each 100 kWh the controller logs.

8.9.14 Mains supervision

You can set up parameters for mains supervision. If there is a mains error (voltage or frequency outside the configured limits), then the controller can activate an alarm to open the breaker (to protect the asset). The controller can also show the mains status using digital outputs.

Parameters

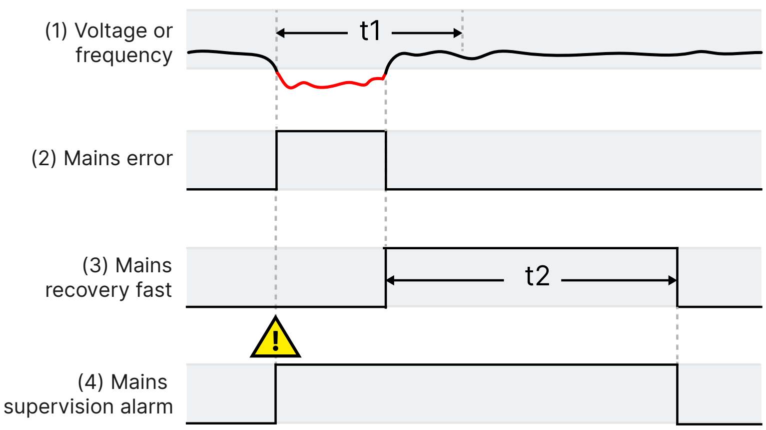
`Mains > AC setup > Supervision selector`

Parameter	Range	Notes
`Enable supervision`	Not enabled, Enabled	**Not enabled**: No mains supervision. **Enabled**: The controller can activate the mains supervision alarm. The mains supervision digital outputs show the mains supervision status.
`Recovery selector time`	0.1 s to 1 h	If the mains error lasts for less than this time, then *Recovery time fast* is used. If the error lasts for longer than this time, then *Recovery time slow* is used.
`Recovery time fast`	0.1 s to 1 h	This is used if the mains error stops within the *Recovery selector time*. The timer starts when the mains error stops.
`Recovery time slow`	0.1 s to 1 h	This is used if the mains error does not stop within the *Recovery selector time*. The timer starts when the mains error stops.
`Voltage low`	80.0 to 100.0 % of nominal voltage	There is a mains error if the mains voltage is below this level.
`Voltage high`	100.0 to 120.0 % of nominal voltage	There is a mains error if the mains voltage is above this level.
`Frequency low`	90.0 to 100.0 % of nominal frequency	There is a mains error if the mains frequency is below this level.
`Frequency high`	100.0 to 110.0 % of nominal frequency	There is a mains error if the mains frequency is above this level.

How it works

These sequence diagrams are examples of how mains supervision works.

Recovery time fast mains error

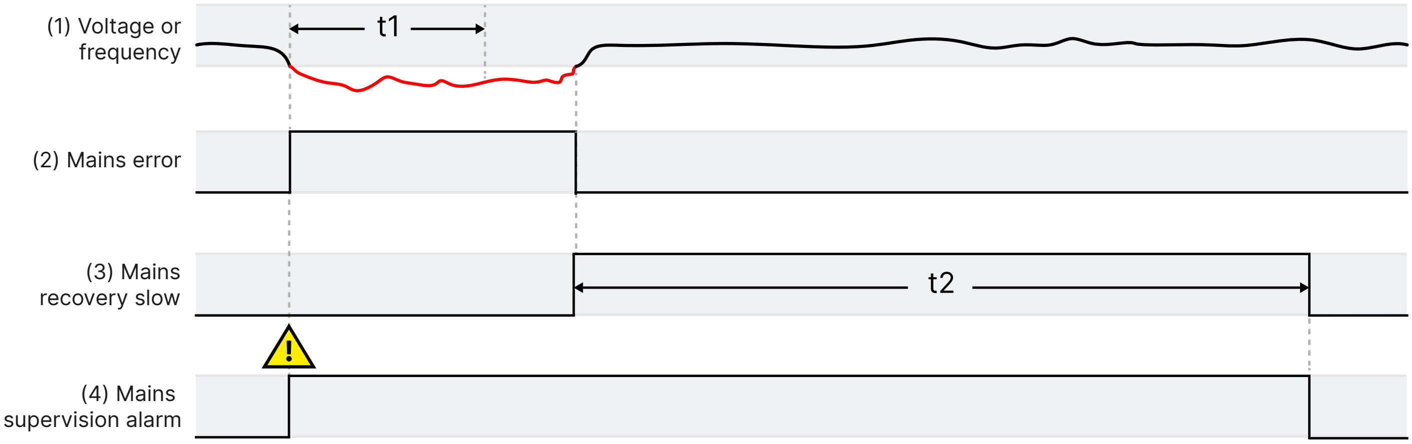


t1 = Recovery selector time (`Mains > AC setup > Supervision selector > Recovery selector time`)

t2 = Recovery time fast (`Mains > AC setup > Supervision selector > Recovery time fast`)

1. **Voltage or frequency**: The mains voltage or frequency is outside the configured limits for less than the *Recovery selector time*. The controller therefore uses the *Recovery time fast*.
2. **Mains error**: `Mains > Supervision > Mains error` (digital output) (optional). The controller activates this digital output while the mains voltage or frequency is outside the configured limits.
3. **Mains recovery fast**: `Mains > Supervision > Mains recovery fast` (digital output) (optional). The controller activates this digital output while the *Recovery time fast* timer is running.
4. **Mains supervision alarm**. The controller activates this alarm while there is a mains error, and while the recovery timer is running.

Recovery time slow mains error



t1 = Recovery selector time (`Mains > AC setup > Supervision selector > Recovery selector time`)

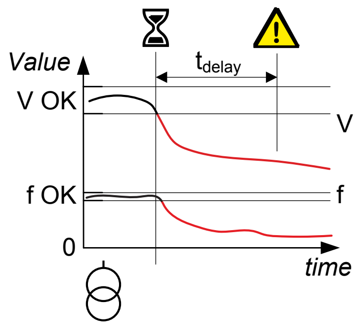
t2 = Recovery time slow (`Mains > AC setup > Supervision selector > Recovery time slow`)

1. **Voltage or frequency**: The mains voltage or frequency is outside the configured limits for more than the *Recovery selector time*. The controller therefore uses the *Recovery time slow*.
2. **Mains error**: `Mains > Supervision > Mains error` (digital output) (optional). The controller activates this digital output while the mains voltage or frequency is outside the configured limits.
3. **Mains recovery slow**: `Mains > Supervision > Mains recovery slow` (digital output) (optional). The controller activates this digital output while the *Recovery time slow* timer is running.
4. **Mains supervision alarm**. The controller activates this alarm while there is a mains error, and while the recovery timer is running.

8.9.15 Mains supervision alarm

The controller activates this alarm if the mains voltage or frequency is outside the range configured under `Mains > AC setup > Supervision selector`.

The alarm remains activated for the recovery time.



8.9.16 Mains supervision status as digital outputs

You can configure digital outputs with functions for the mains supervision status. The controller activates the digital output when the mains supervision state is activated. These outputs can be useful for troubleshooting.

Digital outputs

Function	I/O	Type	Details
Mains > Supervision > Mains error	Digital output	Continuous	Activated when there is a mains error.
Mains > Supervision > Mains recovery fast	Digital output	Continuous	Activated during the fast recovery period.
Mains > Supervision > Mains recovery slow	Digital output	Continuous	Activated during the slow recovery period.

8.10 SINGLE genset controller protections

8.10.1 Protections

Protections for the SINGLE genset controller

	Protections	Alarms
Engine	Emergency stop	1
	Overspeed (2 alarms)	2
	Under-speed (2 alarms)	2
	Power ramp up error	1
	Power ramp down error	1
	Crank failure	1
	Primary running feedback failure	1
	Start failure	1
	Stop failure	1
	Engine stopped (external)	1
	Engine started (external)	1
	Start enable removed during start	1
	Total running hours notification	1
	Trip running hours notification	1
Generator	Voltage or frequency not OK	1
Mains	Mains supervision alarm	1
Regulation	GOV regulation mode not selected	1
	GOV relay setup incomplete	1
	P load sharing failure	1
	AVR regulation mode not selected	1
	AVR relay setup incomplete	1
	Q load sharing failure	1

8.10.2 Alarm actions

The controller has the following alarm actions:

- Warning
- Block generator breaker
- Trip generator breaker
- Trip mains breaker*
- Trip generator breaker and stop engine
- Trip generator breaker and shutdown engine
- Controlled stop

NOTE * Not available in a SINGLE genset controller with no mains breaker.

8.10.3 Inhibits

The controller includes the following inhibits:

Controller inhibits

Inhibit	Disables the alarm when ...
Engine running	*Running detection* is ON.
Engine not running	*Running detection* is OFF.
Idle run active	The engine is idling.
Generator breaker closed	Based on the breaker feedbacks and validation, the generator breaker is closed.*
Generator breaker open	Based on the breaker feedbacks and validation, the generator breaker is open.*
Mains breaker closed**	Based on the breaker feedbacks and validation, the mains breaker is closed.*
Mains breaker open**	Based on the breaker feedbacks and validation, the mains breaker is open.*
Generator voltage present	The generator voltage is above 10 % of the nominal voltage.
No generator voltage	The generator voltage is below 10 % of the nominal voltage.
Generator frequency present	The generator frequency is above 10 % of the nominal frequency.
No generator frequency	The generator frequency is below 10 % of the nominal frequency.
Mains in parallel	The busbar section is connected to the mains.
Mains not in parallel	The busbar section is not connected to a mains.
Inhibit 1	A digital input, PICUS, Modbus, and/or CustomLogic or CODESYS activated *Inhibits > Activate inhibit 1*.
Inhibit 2	A digital input, PICUS, Modbus, and/or CustomLogic or CODESYS activated *Inhibits > Activate inhibit 2*.
Inhibit 3	A digital input, PICUS, Modbus, and/or CustomLogic or CODESYS activated *Inhibits > Activate inhibit 3*.

NOTE * There is no inhibit if there is breaker feedback failure.
NOTE ** Not available in the *SINGLE genset - No mains breaker* controller.

8.10.4 Breaker alarms

More information
The **Breakers, synchronisation and de-loading** chapter describes breaker handling and alarms in general.

The following table shows where to configure these alarms for the SINGLE genset controller, as well as which general alarm corresponds to each SINGLE genset controller alarm.

Generator breaker alarm names for the SINGLE genset controller

SINGLE genset alarm	Configure > Parameters >	General name
GB synchronisation failure	Breakers > Generator breaker monitoring > Synchronisation failure	Breaker synchronisation failure
GB de-load failure	Breakers > Generator breaker monitoring > De-load failure	Breaker de-load failure
Vector mismatch	Breakers > Generator breaker monitoring > Vector mismatch	Vector mismatch
GB opening failure	Breakers > Generator breaker monitoring > Opening failure	Breaker opening failure
GB closing failure	Breakers > Generator breaker monitoring > Closing failure	Breaker closing failure
GB position failure	Breakers > Generator breaker monitoring > Position failure	Breaker position failure
GB trip (external)	Breakers > Generator breaker monitoring > Tripped (external)	Breaker trip (external)
GB short circuit	Breakers > Generator breaker monitoring > Short circuit	Breaker short circuit
GB configuration failure	-	Breaker configuration failure
Phase sequence error genset	Generator > AC setup > Phase sequence error	Phase sequence error

Mains breaker alarm names for the SINGLE genset controller

SINGLE genset alarm	Configure > Parameters >	General name
MB synchronisation failure*	Breakers > Mains breaker monitoring > Synchronisation failure	Breaker synchronisation failure
MB de-load failure*	Breakers > Mains breaker monitoring > De-load failure	Breaker de-load failure
Vector mismatch*	Breakers > Mains breaker monitoring > Vector mismatch	Vector mismatch
MB opening failure*	Breakers > Mains breaker monitoring > Opening failure	Breaker opening failure
MB closing failure*	Breakers > Mains breaker monitoring > Closing failure	Breaker closing failure
MB position failure*	Breakers > Mains breaker monitoring > Position failure	Breaker position failure
MB trip (external)*	Breakers > Mains breaker monitoring > Tripped (external)	Breaker trip (external)
MB short circuit*	Breakers > Mains breaker monitoring > Short circuit	Breaker short circuit
MB configuration failure*	-	Breaker configuration failure
Phase sequence error mains	Mains > AC setup > Phase sequence error	Phase sequence error

NOTE * Not available in the SINGLE genset controller with no mains breaker.

8.10.5 AC alarms

More information
The **AC configuration and nominal settings** chapter describes AC alarms in general.

The following tables shows where to configure these alarms for the SINGLE genset controller.

Generator AC alarm names for the SINGLE genset controller

SINGLE genset controller alarm	Configure > Parameters >	General name
Generator over-voltage [1 to 2]	Generator > Voltage protections > Over-voltage [1 to 2]	Over-voltage
Generator under-voltage [1 to 3]	Generator > Voltage protections > Under-voltage [1 to 3]	Under-voltage
Generator voltage unbalance	Generator > Voltage protections > Voltage unbalance	Voltage unbalance
Positive sequence under-voltage	Generator > Voltage protections > Positive sequence under-voltage	Positive sequence under-voltage
Negative sequence voltage	Generator > Voltage protections > Negative sequence voltage	Negative sequence voltage
Zero sequence voltage	Generator > Voltage protections > Zero sequence voltage	Zero sequence voltage
Over-current [1 to 4]	Generator > Current protections > Over-current [1 to 4]	Over-current
Fast over-current [1 to 2]	Generator > Current protections > Fast over-current [1 to 2]	Fast over-current
Current unbalance (average calc.)	Generator > Current protections > Current unbalance (average calc.)	Current unbalance (average calc.)
Current unbalance (nominal calc.)	Generator > Current protections > Current unbalance (nominal calc.)	Current unbalance (nominal calc.)
Directional over-current [1 to 2]	Generator > Current protections > Directional over-current [1 to 2]	Directional over-current
Inverse time over-current	Generator > Current protections > Inverse time over-current	Inverse time over-current
Negative sequence current	Generator > Current protections > Negative sequence current	Negative sequence current
Zero sequence current	Generator > Current protections > Zero sequence current	Zero sequence current
Generator over-frequency [1 to 3]	Generator > Frequency protections > Over-frequency [1 to 3]	Over-frequency
Generator under-frequency [1 to 3]	Generator > Frequency protections > Under-frequency [1 to 3]	Under-frequency
Overload [1 to 5]	Generator > Power protections > Overload [1 to 5]	Overload
Reverse power [1 to 2]	Generator > Power protections > Reverse power [1 to 2]	Reverse power
Reactive power export [1 to 2]	Generator > Reactive power protections > Reactive power export [1 to 2]	Reactive power export
Reactive power import [1 to 2]	Generator > Reactive power protections > Reactive power import [1 to 2]	Reactive power import

Mains AC alarm names for the SINGLE genset controller

SINGLE genset controller alarm	Configure > Parameters >	General name
Mains over-voltage [1 to 3]	Mains > Voltage protections > Over-voltage [1 to 3]	Busbar over-voltage
Mains under-voltage [1 to 4]	Mains > Voltage protections > Under-voltage [1 to 4]	Busbar under-voltage
Mains voltage unbalance	Mains > Voltage protections > Voltage unbalance	Busbar voltage unbalance
Mains positive sequence under-voltage	Mains > Voltage protections > Positive sequence under-voltage	Busbar positive sequence under-voltage
Negative sequence voltage	Mains > Voltage protections > Negative sequence voltage	Negative sequence voltage
Zero sequence voltage	Mains > Voltage protections > Zero sequence voltage	Zero sequence voltage

SINGLE genset controller alarm	Configure > Parameters >	General name
Mains over-frequency [1 to 3]	Mains > Frequency protections > Over-frequency [1 to 3]	Busbar over-frequency
Mains under-frequency [1 to 4]	Mains > Frequency protections > Under-frequency [1 to 4]	Busbar under-frequency

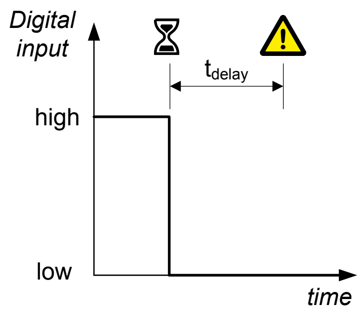
Other AC alarm names for the SINGLE genset controller

SINGLE genset controller alarm	Configure > Parameters >	General name
V< and Q< [1 to 2]	Generator > Additional protections > V< and Q< [1 to 2]	Low voltage low reactive power
Average over-voltage [1 to 2]	Generator > Additional protections > Average over-voltage [1 to 2]	Average over-voltage
Vector shift	Mains > Additional protections > Vector shift	Vector shift
ROCOF (df/dt)	Mains > Additional protections > ROCOF (df/dt)	Rate of change of frequency

8.10.6 Emergency stop

You can configure one of the controller's digital inputs as the emergency stop.

The alarm action is *Trip generator breaker and shutdown engine*, latch enabled.



Function	I/O	Type	Details
`Alarm system > Additional functions > Emergency stop`	Digital input	Continuous	Wire the emergency stop digital input so that it is normally activated. If the emergency stop digital input is not activated, then controller activates the *Emergency stop* alarm.

CAUTION

The Emergency stop is part of the safety chain

The *Emergency stop* is part of the safety chain, and this digital input function should only be used to inform the controller of the emergency stop. However, the controller's emergency stop input cannot be used as the system's only emergency stop. For example, if the controller is unpowered, it cannot respond to the emergency stop digital input.

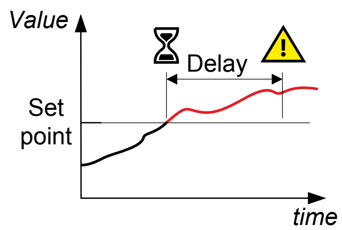
`Engine > Emergency stop > Emergency stop`

Parameter	Range
`Delay`	0.0 s to 1 min

8.10.7 Overspeed

These two alarms are for overspeed protection.

The alarm response is based on the genset speed, as measured by the MPU/W/NPN/PNP input.



Engine > Protections > Speed > Overspeed # *

In addition to these overspeed alarms, one of the controller's digital inputs can be connected to hardware that detects overspeed. A customised alarm for overspeed can then be configured on that digital input.

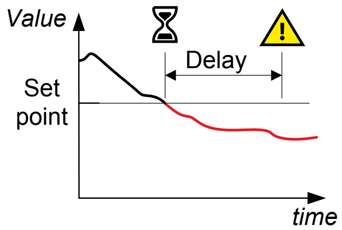
Parameter	Range
`Set point`	10.0 to 150.0 % of nominal speed
`Delay`	0.0 s to 3 min

NOTE * # is 1 or 2.

8.10.8 Underspeed

This alarm alerts the operator that a genset is running too slowly.

The alarm response is based on the engine speed as a percentage of the nominal speed. If the engine speed drops below the set point for the delay time, then the alarm is activated.



Engine > Protections > Speed > Under-speed # *

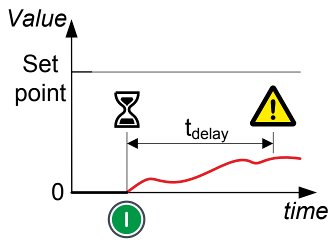
Parameter	Range
`Set point` (lower than)	0.0 to 100.0 % of nominal speed
`Delay`	0.0 s to 3 min

NOTE * # is 1 or 2.

8.10.9 Crank failure

The alarm response is based on the MPU/W/NPN/PNP input. This alarm is only available if the magnetic pickup (MPU) has been chosen as the primary running feedback.

The timer starts when cranking starts (that is, when the *Crank* output is activated). The alarm is activated if the set point has not been reached within the delay time.



Engine > Start sequence > Crank failure

Parameter	Range
Set point (lower than)	1 to 400 RPM
Delay	0.0 to 20.0 s

8.10.10 Oil pressure

This alarm is activated if the oil pressure exceeds the set point.

Engine > Protections > Pressure > Oil pressure # *

Parameter	Range
Set point	0.0 to 10.0 bar
Delay	0.0 s to 3 min

NOTE * # is 1 or 2.

8.10.11 Oil temperature

This alarm is activated if the oil temperature exceeds the set point.

Engine > Protections > Temperature > Oil temperature # *

Parameter	Range
Set point	0.0 to 200.0 °C
Delay	0.0 s to 3 min

NOTE * # is 1 or 2.

8.10.12 Coolant temperature

This alarm is activated if the coolant temperature exceeds the set point.

Engine > Protections > Temperature > Coolant temperature # *

Parameter	Range
Set point	0.0 to 200.0 °C
Delay	0.0 s to 3 min

NOTE * # is 1 or 3.

8.10.13 Coolant level

This alarm is activated if the coolant level is under the set point.

Engine > Protections > Level > Coolant level # *

Parameter	Range
Set point	0.0 to 100.0 %
Delay	0.0 s to 3 min

NOTE * # is 1 or 3.

8.10.14 Running detection not reached

This alarm is activated if the running detection level is not reached.

`Engine > Start sequence > Running detection not reached`

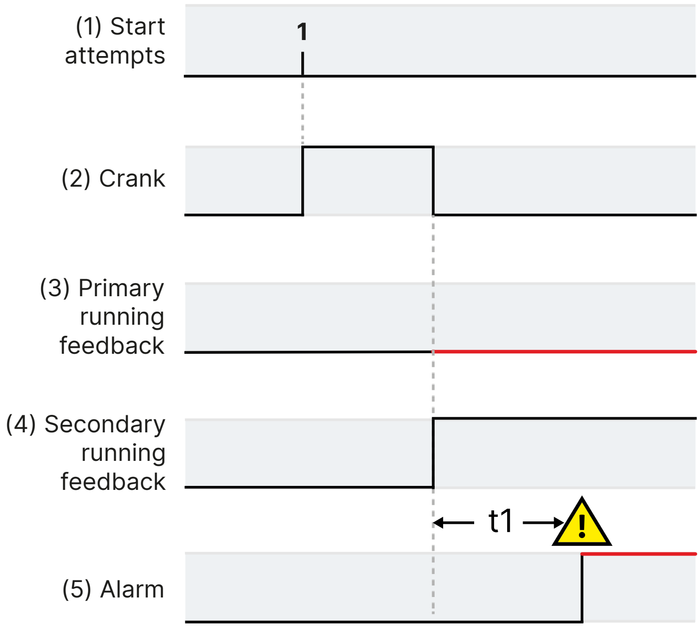
Parameter	Range
`Run detection not reached`	1 s to 20 min

8.10.15 Primary running feedback failure

This alarm is for genset running feedback failure. This alarm is only available if more than one running feedback is present. The alarm is activated if running is detected on any of the secondary running feedbacks but not on the primary running feedback.

The sequence diagram on the right shows how the primary running feedback failure alarm works.

1. **Start attempt**: The controller gets a start signal.
2. **Crank**: The controller activates the *Crank* output.
3. **Primary running feedback**: If the primary running feedback has failed, it does not detect the genset start.
4. **Secondary running feedback**: The secondary running feedback detects the genset start. The crank stops after running is detected. The alarm timer starts when running is detected on the secondary running feedback, but not on the primary running feedback.
5. **Alarm**: If the primary running feedback does not detect that the genset has started within the delay time (t1), the *Primary running feedback failure* alarm is activated.



`Engine > Running detection > Primary running feedback failure`

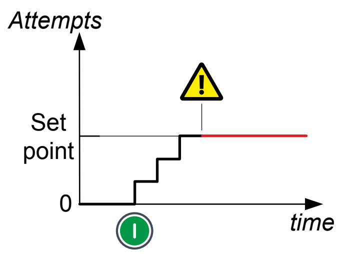
This alarm is always *Enabled*.

Parameter	Range
`Delay`	0.0 s to 3 min

8.10.16 Start failure

This alarm is for genset start failure.

If the genset has not started after the maximum number of start attempts are completed, the controller activates this alarm.



`Engine > Start sequence > Start failure`

8.10.17 Start enable removed during start

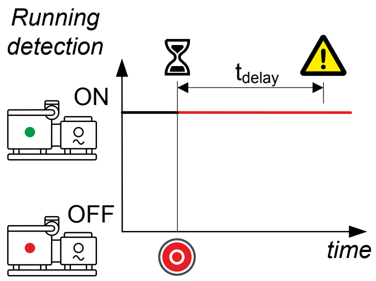
The alarm response is based on the engine start-up sequence. This alarm is activated if the engine start-up procedure is interrupted by the loss of the *Start enable* input before the engine has started.

Engine > Start sequence > Start enable remove during start

8.10.18 Stop failure

This alarm is for genset stop failure.

The controller attempts to stop the genset by activating the *Stop coil* output (if present) or alternatively, by deactivating the *Run coil* output (if present). If *Running detection* is still ON after the delay time, the controller activates this alarm.



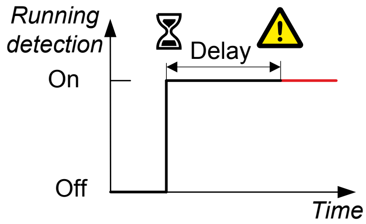
Engine > Stop sequence > Stop failure

Parameter	Range
Delay	10.0 s to 2 min

8.10.19 Engine started (external)

This alarm is to alert the operator to an externally-initiated engine start.

The alarm is activated if the controller did not initiate an engine start, but *Running detection* shows that the engine is running.

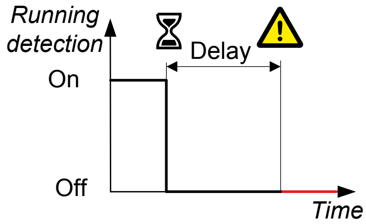


Engine > Start sequence > Engine started (external)

8.10.20 Engine stopped (external)

This alarm alerts the operator to an externally-initiated engine stop.

The alarm is activated if the controller did not initiate an engine stop, but *Running detection* shows that the engine has stopped.



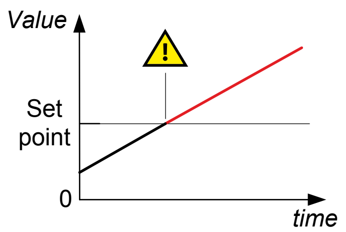
Engine > Stop sequence > Externally stopped

Parameter	Range
Delay	1 to 1200 s

8.10.21 Running hours notification

This alarm notifies the operator when the total running hours exceeds the set point.

The alarm response is based on the *Total running hours* counter.



`Engine > Maintenance > Service timer > Service timer # *`

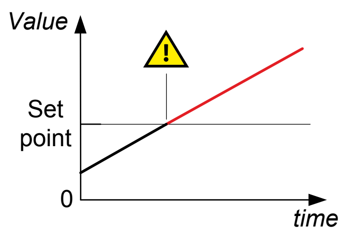
Parameter	Range
`Set point`	0 to 9000 h

NOTE * # is 1 to 4.

8.10.22 Trip running hours notification

This alarm notifies the operator when the trip running hours exceeds the set point.

The alarm response is based on the *Trip running hours* counter.



`Engine > Maintenance > Running hours trip`

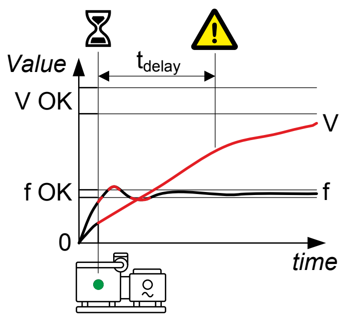
Parameter	Range
`Set point`	0 to 1,000,000 hours

8.10.23 Voltage or frequency not OK

This alarm alerts the operator that the voltage or frequency is not in the required operation range within a specified time after running detection is active.

A delay timer starts when running detection activates. If the voltage and frequency are not in the required operation ranges when the delay timer expires the alarm activates.

The alarm response is based on the voltage and frequency from the A-side.



`[A-side] > AC setup > Voltage or frequency not OK`

The alarm action is always *Block*.

Parameter	Range
`Delay`	1 s to 1 h

8.10.24 Magnetic pickup wire break

This alarm is activated if there is a magnetic pickup wire break.

`Engine > Running detection > Magnetic pickup wire break`

Parameter	Range
`Delay`	1 s to 1 h

9. GENSET controller

9.1 About the GENSET controller

A **GENSET** controller controls and protects a prime mover (for example, a diesel engine) and generator, as well as the generator breaker. A system can include a number of **GENSET** controllers.

The **GENSET** controllers work together to ensure effective power management. This includes load-dependent start and stop, and may include setting the genset priority order.

9.1.1 Functions

	Functions
Pre-programmed sequences	• Genset start and stop sequences • Breaker sequences • Generator breaker blackout close

Regulation	• PID regulators for analogue outputs
	• P regulators for relay outputs
	• Set point selection using digital input, Modbus, and/or CustomLogic
	• Governor:
	  ∘ Frequency regulation
	  ∘ Frequency and phase synchronisation
	  ∘ Active power load sharing
	  ∘ Fixed power
	• AVR:
	  ∘ Voltage regulation
	  ∘ Reactive power load sharing
	  ∘ Fixed reactive power
	  ∘ Fixed cos phi
	• Configurable power ramp up/down
	• Three sets of temperature-dependent power derate settings

Counters	• Display unit counters, to edit or reset:
	  ∘ Start attempts
	  ∘ Running hours (total and trip)
	  ∘ Breaker operations and trips
	  ∘ Power export (active and reactive)
	  ∘ External breaker operations
	• Energy counters with configurable digital outputs for external counters

Control type	• Power management system (PMS) control

Control modes	• AUTO mode:
	  ∘ Automatic power management
	  ∘ Automatic load-dependent genset start & stop
	  ∘ Automatic synchronisation & de-loading, and breaker control
	• MANUAL mode:
	  ∘ Operations only on operator command
	  ∘ Operator-initiated synchronisation and de-loading
	  ∘ Display buttons for genset start/stop, breaker open/close, and 1st priority
	• Change control mode (AUTO/MANUAL) from the display, from PICUS, or via Modbus

9.2 GENSET controller principles

9.2.1 Genset applications

The GENSET controllers described in this chapter work together in power management applications. Each GENSET controller only controls a genset and a generator breaker.

For an application with only one genset, you can use a SINGLE genset controller. The SINGLE genset controller can also control a mains connection.

More information
See the **SINGLE genset controller** chapter.

9.2.2 GENSET controller nominal settings

The controller nominal settings are used in a number of key functions. For example, many protection settings are based on a percentage of the nominal settings.

`Engine > Nominal settings > Nominal settings #` *

Parameter	Range	Comment
`Nominal RPM`	100 to 50000 RPM	When an MPU/W/NPN/PNP is used to measure the engine speed, then the nominal engine speed is used for the overspeed and underspeed alarms.

NOTE * # is 1 to 4.

Generator nominal settings

`Generator > Nominal settings > Nominal settings #` *

Nominal setting	Range	Notes
`Voltage (V)`	100.0 V to 25 kV	The phase-to-phase ** nominal AC voltage for the genset.
`Current (I)`	1.0 A to 9 kA	The maximum current flow in one phase (that is, L1, L2 or L3) from the genset during normal operation.
`Frequency (f)`	45.00 to 62.00 Hz	The system nominal frequency, typically either 50 Hz or 60 Hz. All the controllers in the system should have the same nominal frequency.
`Power (P)`	10.0 kW to 20 MW	The nominal active power may be on the genset nameplate.
`Apparent power (S)`	12.5 kVA to 25 MVA	The nominal apparent power should be on the genset or generator nameplate.
`Power factor (PF)`	0.8000 to 1.0000	The power factor should be on the genset or generator nameplate.

NOTE * # is 1 to 4.
NOTE ** In a single-phase set up the nominal AC voltage is phase-to-neutral.

`Generator > Nominal settings > Nominal settings # > Calculation method` *

Calculation method	Options
`Reactive power (Q) nominal`	Q nominal calculated Q nominal = P nominal Q nominal = S nominal
`P or S nominal`	No calculation P nominal calculated S nominal calculated

NOTE * # is 1 to 4.

More information
See Nominal power calculations for how these are used.

Busbar nominal settings

`Busbar > Nominal settings > Nominal settings # > Voltage (V) *`

Nominal setting	Range	Notes
`Nominal value source`	Use generator nominal voltage User defined	**Use generator nominal voltage:** • The phase-to-phase nominal voltage for the busbar is the same as the generator nominal voltage. **User defined:** • You can configure the phase-to-phase nominal voltage for the busbar.
`Voltage (V)` **	100.0 V to 25 kV	The phase-to-phase nominal voltage for the busbar. If there are no transformers between the genset and the busbar, the nominal voltage for the busbar will be the same as the nominal voltage for the genset.

NOTE * # is 1 to 4.
NOTE ** The `Nominal value source` must be configured as `User defined` and written to the controller, for the nominal voltage setting to be visible.

9.2.3 Run coil or stop coil

The engine start and stop functions are suitable for genset start systems with either a run coil or a stop coil. A set of controller digital output terminals must be connected to and configured for either the run coil output, or the stop coil output.

Run coil and stop coil outputs

Function	I/O	Type	Details
`Engine > Controls > Run coil`	Digital output	Continuous	If all power to the controller is lost, then the genset stops. Required if there is no *Stop coil*.
`Engine > Controls > Stop coil`	Digital output	Continuous	If all power to the controller is lost, then the genset keeps running. Required if there is no *Run coil*.

9.2.4 Running detection

The controller can be configured to receive engine running feedback from a variety of measurements. There can be more than one running feedback measurement.

Running detection is a state calculated by the controller, and used by a number of functions. It is either OFF or ON. If any running feedback measurements show that the engine is running, then *Running detection* is ON.

Inputs and outputs

Function	I/O	Type	Details
`Engine > Feedback > Digital running detection`	Digital input	Continuous	Optional. External equipment activates the digital input when the engine is running.

The controller can also use the following inputs for running feedback.

Function	I/O	Type	Details
Frequency	Generator voltage measurements	Continuous	Always present. The controller uses the generator voltage measurements to calculate the frequency. The controller then compares the frequency with the detection set point. Note: The controller cannot measure the frequency at very low voltages. See the **Data sheet** for the measurement range. The voltage must also be at least 10 % of nominal for the controller to use the frequency for running detection. For safety, DEIF recommends that you install at least one other running detection input.
MPU	HSDI	Continuous	Optional. The MPU input is connected to an MPU mounted on the engine.
W	HSDI	Continuous	Optional. The W input is connected to the battery recharging generator and measures the engine speed. Alternatively, the W input can be connected to an NPN/PNP sensor.
`Engine > Measurements > Lube oil > Engine oil pressure [bar]`	Analogue input	Pressure in bar	Optional. This set of analogue input terminals are connected to a transducer for the engine oil pressure.

Parameters

`Engine > Running detection > MPU setup`

Parameter	Range	Comment
`Number of MPU teeth`	1 to 10000	The controller uses the number of teeth to calculate the engine speed from the MPU/W/NPN/PNP measurement signal.

`Engine > Running detection > Feedback type`

Parameter	Range	Comment
`Primary running feedback`	The available running feedbacks (depends on hardware)	Select one of the inputs as the primary running feedback. If the *Primary running feedback* does not detect running, but any other running feedback detects running, then the controller activates the *Primary running feedback failure* alarm.

`Engine > Running detection > RPM running detection`

Parameter	Range	Comment
`RPM`	0.0 to 50000.0 RPM	Running detection is ON when the engine speed measured by the MPU/W/NPN/PNP input is above this set point.
`Use engine speed`	Not enabled, Enabled	**Not enabled:** The MPU/W/NPN/PNP measurement is ignored and not used for running detection. **Enabled:** The MPU/W/NPN/PNP measurement is used as a running detection input.

`Engine > Running detection > Frequency running detection`

Parameter	Range	Comment
`Frequency`	10.0 to 100.0 Hz	Running detection is ON when the frequency measured by the generator voltage measurements is above this set point. For example: For a 60 Hz system, you can use a detection set point of 45 Hz.

`Engine > Running detection > Oil pressure running detection`

Parameter	Range	Comment
`Oil pressure` *	0.0 to 10.0 bar	Running detection is ON when the engine oil pressure is above this set point.
`Use oil pressure` *	Not enabled, Enabled	**Not enabled:** The engine oil pressure is ignored and not used for running detection. **Enabled:** The engine oil pressure is used as a running detection input.

NOTE * This parameter is only visible if the analogue input is configured.

Frequency running detection hysteresis

For stable operation, running detection has a fixed 2 Hz hysteresis.

Frequency running detection hysteresis examples

Example 1: The detection set point for frequency is 32 Hz. When the frequency rises above 32 Hz, running detection changes to ON. However, the frequency has to drop below 30 Hz for running detection to change to OFF.

Example 2: The detection set point for frequency is 45 Hz. When the frequency rises above 45 Hz, running detection changes to ON. However, the frequency has to drop below 43 Hz for running detection to change to OFF.

MPU/W input running detection hysteresis

For stable operation, running detection has a fixed 5 % hysteresis on the genset RPM.

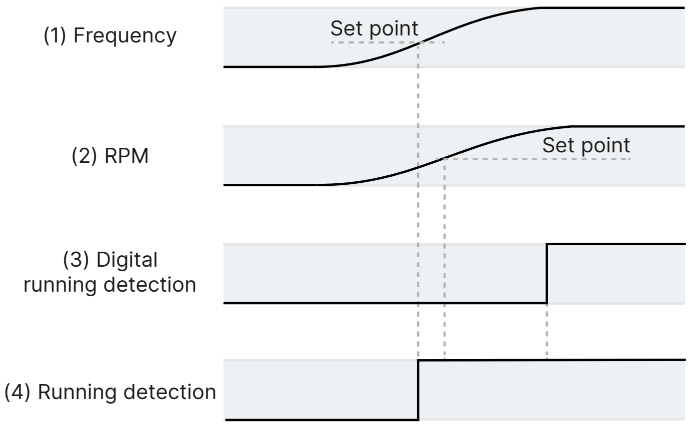
Oil pressure running detection hysteresis

For stable operation, running detection has a fixed 5 % hysteresis on the oil pressure.

Example: Running detection ON

The following sequence diagram is an example of how *Running detection* changes during an engine start. *Running detection* changes from OFF to ON when **one** running feedback detects that the engine is running.

Running detection ON sequence diagram

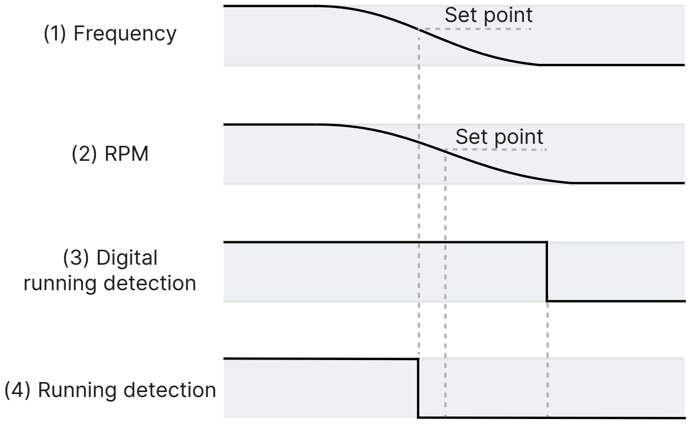


1. **Frequency**: The engine starts and the frequency rises above the set point.
2. **RPM**: (MPU/W/NPN/PNP input). The engine starts and the RPM rises above the set point.
3. **Digital running detection**: *Engine > Feedback > Digital running detection* (digital input). In the example, the response of this input is slower than the other running detection inputs.
4. **Running detection**: Running detection changes from OFF to ON when any running feedback (in this case, the frequency) rises above the *Detection set point*.

Example: Running detection OFF

The following sequence diagram is an example of how *Running detection* changes during an engine stop. *Running detection* changes from ON to OFF when **none** of the running feedbacks detect that the engine is running.

Running detection OFF sequence diagram



1. **Frequency**: The engine slows down and the frequency drops to 2 Hz below the set point.
2. **RPM**: (MPU/W/NPN/PNP input). The engine slows down and the RPM drops to 5 % below the set point.
3. **Digital running detection**: *Engine > Feedback > Digital running detection* (digital input). In the example, the response of this input is slower than the other running detection inputs.
4. **Running detection**: Running detection changes from ON to OFF when none of the running feedbacks detect that the engine is running.

Risks when using only frequency for running detection

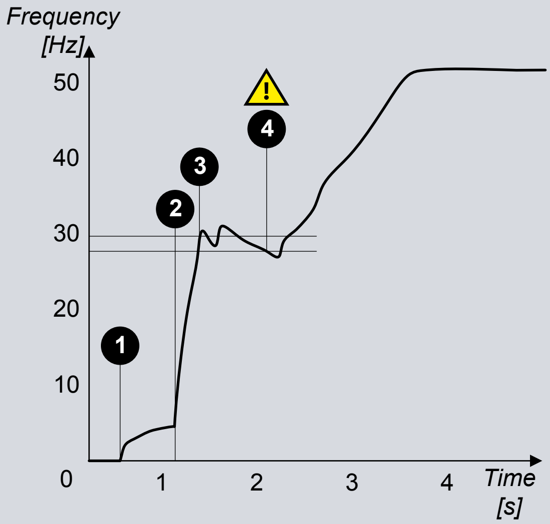
It is possible to only use frequency for running detection. However, using only frequency for running detection increases the risk of not detecting that the genset is running.

The software only uses the frequency measurements when the voltage is at least 10 % of the nominal voltage. This could cause trouble, since the voltage does not necessarily increase linearly with speed (this depends on the AVR).

If the frequency curve for the genset start up has a dip around the detection set point, the controller can interpret the dip as no running detection, and stop the genset. Increasing or decreasing the set point away from the dip would solve this problem.

Frequency running detection example

A genset start up frequency curve is given below.



	1. Crank begins. 2. Fuel in. 3. If the running detection set point is 30 Hz, running detection is ON. 4. If the running detection set point is 30 Hz, the frequency drops 2 Hz below the set point, and running detection from frequency is OFF. • If there are no other running detection inputs, the controller immediately deactivates the run coil and/or activates the stop coil.

9.2.5 Regulation

The GENSET controller can regulate both a governor (GOV) and an AVR.

More information
See Regulation for how regulation works.

9.2.6 Power management

The **GENSET** controller works together with the other controllers in the system to provide efficient power management. This includes blackout prevention and blackout recovery.

More information
See Power management for how power management works.

9.2.7 Load sharing

When a **GENSET** controller is under PMS control, it shares the load with other DEIF controllers using the DEIF network.

More information
See Power management and Load sharing for how it works.

9.2.8 Ready for operation

The genset associated with a **GENSET** controller is ready for operation when the following conditions are met:

- There are no alarms blocking the start.
- If configured, the *Start enable* digital input is activated.
- The **GENSET** controller is in PMS control.

9.2.9 AC configuration

How the general AC configuration description applies to the **GENSET** controller:

GENSET	General name
Generator	[A-side]
Busbar	[B-side]

More information
The AC configuration and nominal settings for general information about AC configuration.

9.2.10 Breaker configuration

For the **GENSET** controller, replace [Breaker] with "Generator breaker" in the descriptions.

More information
See Breakers, synchronisation and de-loading for how to configure breakers.

9.3 Engine start

9.3.1 Engine start function

The controller software includes a pre-programmed engine start sequence. For the engine's start function, you must configure these inputs and outputs, and parameters.

If a parameter needs an input or output to be configured, then that parameter is not visible until an input or output is configured with the relevant function.

More information
See [Controller] protections for the engine start protections, and how to configure them.

Inputs and outputs

Required engine start output

Function	I/O	Type	Details
`Engine > Controls > Crank`	Digital output	Continuous	Connect this output to the engine crank.

Optional engine start inputs and outputs

Function	I/O	Type	Details
`Engine > Command > Start enable`	Digital input	Continuous	Optional. If this input is configured, it must be activated for the engine start sequence to start.
`Engine > Command > Warm up delay`	Digital input	Continuous	Optional. When the input is activated, the controller delays the engine warm up.
`Engine > Controls > Start prepare`	Digital output	Continuous	Optional. The *Start prepare* digital output may, for example, be wired to start a pump, so that the engine oil pressure can build up before cranking. Note that *Start prepare* does not have any provision for feedback. The *Start prepare* function is only a timer, and does not check whether, for example, the pump start was successful. The *Start prepare* digital output is not needed if the third party engine controller ensures that all start prepare conditions are okay before activating the *Start enable* digital input.
`Engine > Command > Crank delay`	Digital input	Continuous	Optional. When the input is activated, the controller delays the crank.
`Engine > Controls > Idle run`	Digital output	Continuous	Optional. Connect this output to the engine idle run if supported. Not all engines support this feature.
`Engine > Idle run > Low speed`	Digital input	Continuous	Optional. When the input is activated, the idle run is based on speed.
`Engine > Idle run > Temperature control`	Digital input	Continuous	Optional. When the input is activated, the idle run is based on temperature control.

Optional engine start commands

Function	I/O	Type	Details
`Engine > Command > Start engine`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to start the engine.
`Engine > Command > Start engine and close generator breaker`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to start the engine and then synchronise and close the breaker.

Required parameters

`Engine > Start sequence > Crank`

Parameter	Range	Comment
`Crank on`	1.0 s to 3 min	For the *Crank on* part of the start sequence, the controller activates the *Crank* output for this period.
`Crank off`	1.0 to 99.0 s	If there is no running detection during *Crank on*, then the controller deactivates the *Crank* output for this period.
`Disengage crank`	1 to 2000 RPM	The controller deactivates the *Crank* output when the engine speed reaches this set point, although the *Crank on* timer continues to run. This parameter only has an effect if an engine speed measurement (for example, an MPU/W/NPN/PNP) is configured. Even when *Disengage crank* is used, the start sequence tries to detect that the engine is running for the whole of the *Crank on* time.

`Engine > Start sequence > Start attempts`

This parameter limits the wear on the genset from too many start attempts.

Parameter	Range	Comment
`Normal`	1 to 100	This is the maximum number of start attempts if the digital input `Alarm system > Additional functions > Suppress alarm action` is not active. If the genset does not start after these attempts, the *Start failure* alarm is activated.
`Suppress alarm action`	1 to 10	This is the maximum number of start attempts if the digital input `Alarm system > Additional functions > Suppress alarm action` is active. If the genset does not start after these attempts, the *Start failure* alarm is activated.

`Engine > Running detection > Engine ready`

Parameter	Range	Comment
`Delay`	1.0 s to 5 min	After *Running detection* is ON, the engine must run for this period before the breaker close sequence can start.

Parameters (optional)

`Engine > Start sequence > Start prepare`

You must configure the `Engine > Start prepare` digital output to see these parameters.

Parameter	Range	Comment
`Start prepare`	0.0 s to 10 min	Optional. If the start conditions are OK, the controller activates the *Start prepare* output for this time. When the *Start prepare* timer expires, the controller activates the *Crank* output. See **Start prepare** in the **Engine start sequence**.
`Extended start prepare`	0.0 s to 10 min	Optional. The controller keeps the *Start prepare output* activated for this time during cranking.

`Engine > Start sequence > Run coil`

You must configure the `Engine > Controls > Run coil` digital output to see these parameters.

Parameter	Range	Comment
`Run coil before crank`	0.0 s to 10 min	Optional. The controller activates the *Run coil* output for this time before the *Crank* output is activated.
`During start attempts`	Pulse, Continuous	**Pulse**: If the start attempt fails, the controller deactivates the *Crank* output and the *Run coil*. **Continuous**: If the start attempt fails, the controller deactivates the *Crank* output. However, the *Run coil* remains activated until the maximum number of start attempts is reached.

Idle run start (optional)

You must configure the `Engine > Controls > Idle run` digital output to see these parameters.

You can configure an idle run start period for the engine. This allows the engine to warm-up before running at nominal speed.

If this is configured, the controller will activate the digital output `Engine > Controls > Idle run` before starting the engine. The controller then waits for one of the engine conditions (coolant temperature, oil temperature, external input condition, or the maximum timer) to be fulfilled before increasing to nominal speed.

During the idle run start period, the operator can override the period and press **Start** on the display, the controller then cancels the idle run start period and increases to nominal speed.

Additionally, during the idle run start period, the operator can press **Stop** to abort the engine start sequence and run the engine stop sequence.

Optional idle run start parameters

`Engine > Idle run start > Idle run`

Parameter	Range	Comment
`Enable`	Not enabled, Enabled	Enables the engine to idle run until a condition is true before changing to nominal speed.

`Engine > Idle run start > Minimum`

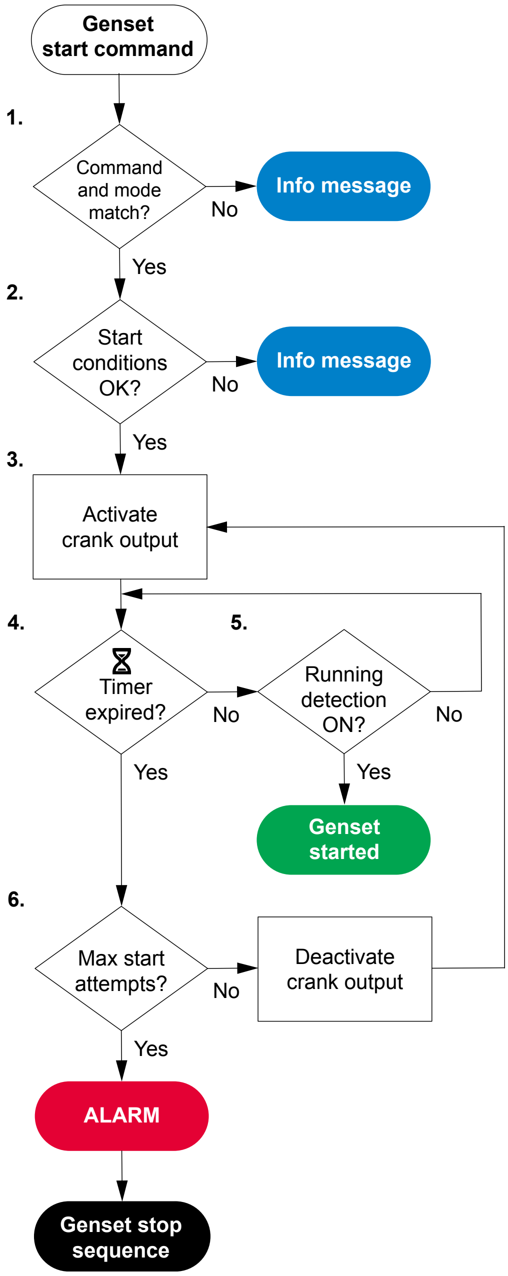
Parameter	Range	Comment
`Use`	Not enabled, Enabled	Uses minimum set point to determine if the engine is ready to increase to nominal speed.
`Delay`	0 s to 999 min	This is the minimum time the idle run start is active. *

NOTE

* The minimum period can be overridden by pressing **Start** to cancel the idle run start period and increases to nominal speed.

9.3.2 Engine start flowchart

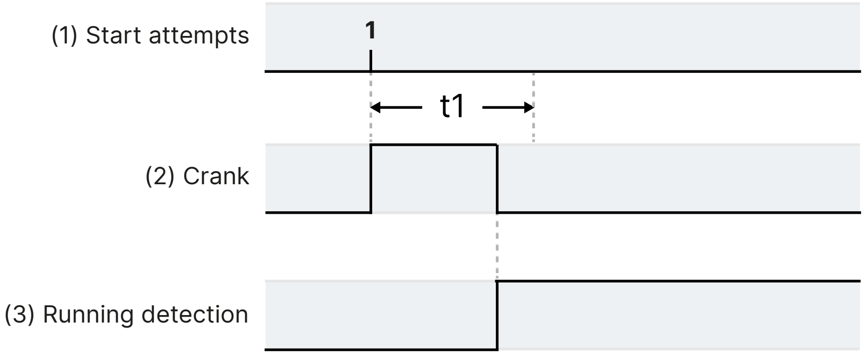
Both *Start prepare* and *Idle run start* functions are not included on this diagram.



1. **Command and mode match:** The controller checks that the command source and the controller mode match:
   - In AUTO mode, the power management system must send the command to start the genset. The controller ignores all other external commands.
   - In MANUAL mode, the command to start the genset can come from the following:
     - The operator can press **Start** on the display.
     - The operator can use PICUS to send a genset start command.
     - The command can come from an external source, for example, a relay output from a PLC.
2. **Start conditions OK:** The controller checks whether the start conditions are OK:
   - For a power management command, the controller is in AUTO mode.
   - If configured, the *Start enable* digital input is activated.
   - There are no active or unacknowledged alarms to prevent the genset start. These alarm actions prevent a genset start:
     - *Block*
     - *PMS-controlled stop*
     - *Trip generator breaker and stop engine*
     - *Trip generator breaker and shutdown engine*
3. **Activate crank output:** If all the start conditions are OK, the controller activates the *Crank* output and a timer.
4. **Crank on timer expired:** If *Running detection* is OFF after the *Crank on* timer runs out, the controller checks the number of start attempts:
   - If the maximum number of start attempts has not been reached, the controller attempts to start the genset again.
   - If the maximum number of start attempts has been reached, the controller activates the *Start failure* alarm and stops the engine.
5. **Running detection ON:** While the start timer runs, the controller checks whether *Running detection* is ON.
   - When the controller detects that the genset is running, the genset start is complete.
6. **Maximum start attempts:** The controller checks the number of start attempts:
   - If the maximum number of start attempts has not been reached, the controller attempts to start the genset again.
   - If the maximum number of start attempts has been reached, the controller activates the *Start failure* alarm and stops the engine.

9.3.3 Engine start sequence

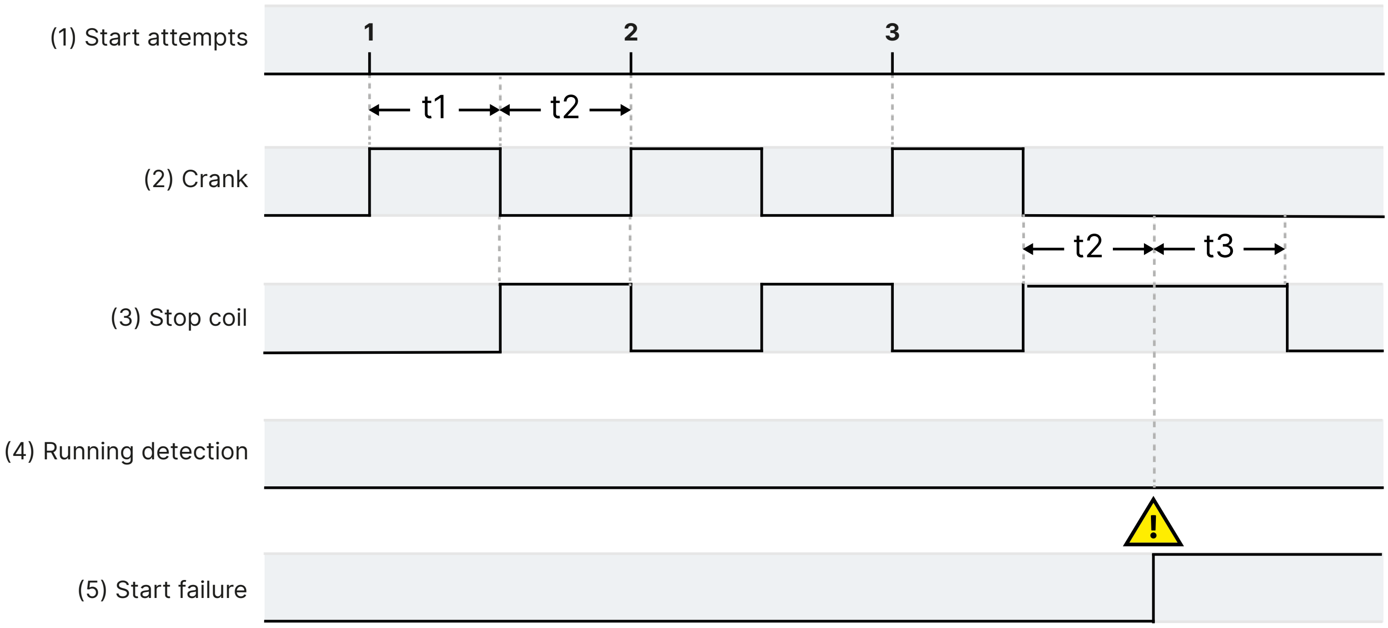
Successful engine start sequence for a stop coil system



t1 = Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)

1. **Start attempts**: The engine starts during the first start attempt.
2. **Crank**: `Engine > Controls > Crank` (digital output). The controller activates the *Crank* output. If *Running detection* changes from OFF to ON, cranking stops.
3. **Running detection**. The engine is regarded as started when *Running detection* is ON.

Failure of engine start sequence for a stop coil system



t1	Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)
t2	Crank off (`Parameters > Engine > Start sequence > Crank > Crank off`)
t3	Extended stop (`Parameters > Engine > Stop sequence > Extended stop`) (optional)

Failure of engine start sequence for a stop coil system:

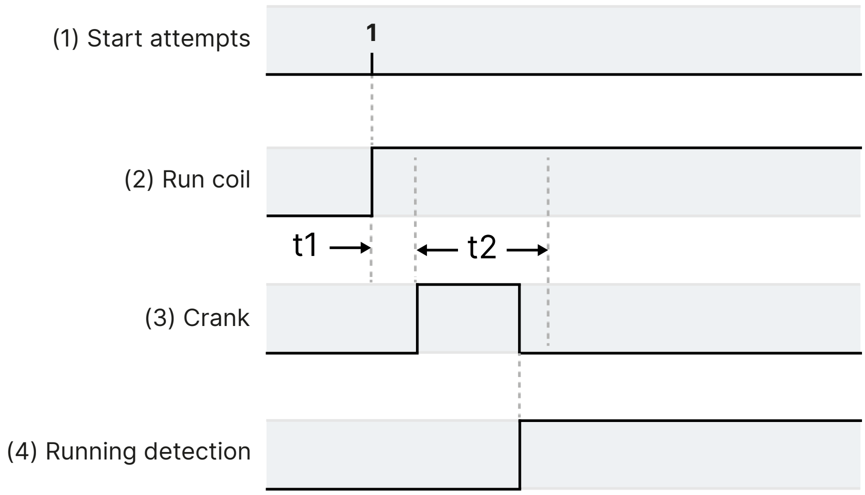
1. **Start attempts**: `Parameters > Engine > Start sequence > Start attempts > Normal` = 3.
2. **Crank**: `Engine > Crank` (digital output). The controller activates the *Crank* output for the *Crank on* time, and deactivates it for *Crank off* time.
3. **Stop coil**: *Engine > Stop coil* (digital output). If *Running detection* is OFF after the *Crank on* time, then the controller activates the *Stop coil* for the time in the *Crank off* parameter. If all start attempts fail, the controller also activates the *Stop coil* for the time in *Extended stop > Stop coil activated*. This ensures that the engine is stopped if the engine start was not detected. The engine cannot be started during the *Extended stop > Stop coil activated* time.

4. **Running detection**. There is no running detection.
5. **Start failure**. The controller activates the *Start failure* alarm after the last unsuccessful start attempt.

Engine start sequence for a run coil system

In this example, the `Engine > Start sequence > Run coil > During start attempts` parameter is set to *Follow crank*. The engine speed (RPM measurement) and/or the *Remove start (release crank relay)* digital input do not disengage the crank before there is *Running detection*.

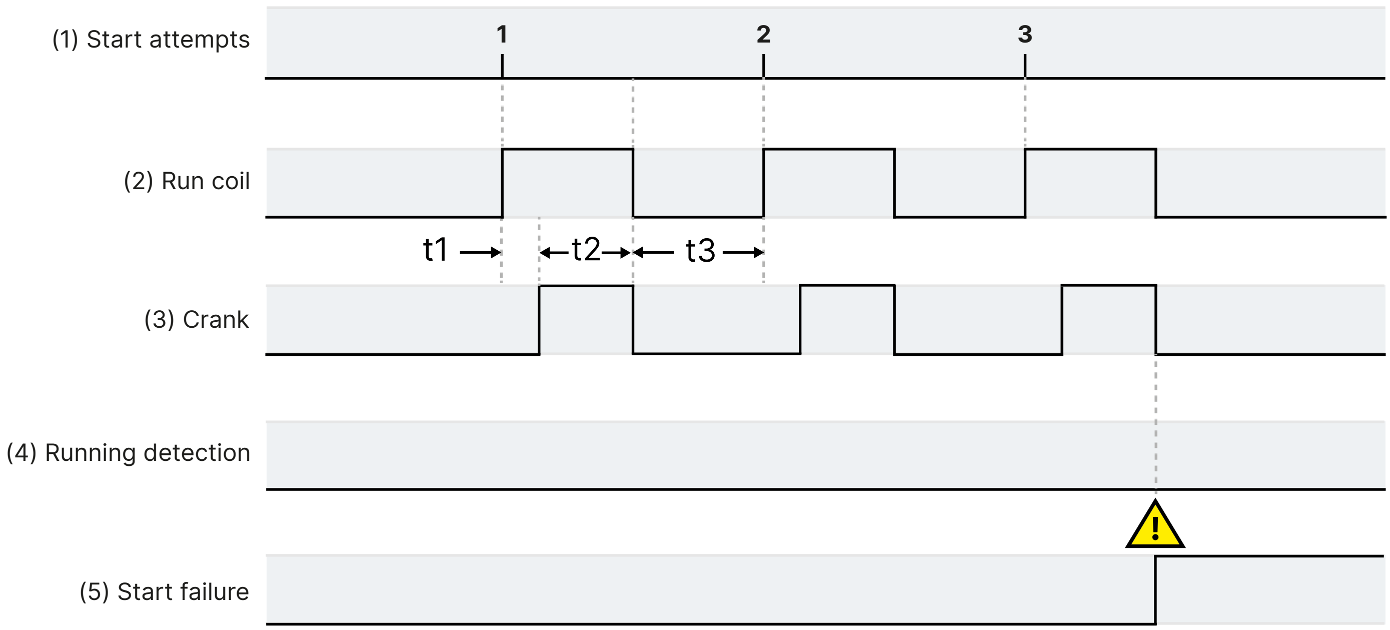
Successful engine start sequence for a run coil system



t1 = Run coil before crank (optional)
t2 = Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)

1. **Start attempts**: The engine starts during the first start attempt.
2. **Run coil**: `Engine > Run coil` (digital output). The controller activates the *Run coil* at the time in the *Run coil before crank* parameter. If *Running detection* is ON, the engine is regarded as started, and the *Run coil* remains activated.
3. **Crank**: `Engine > Crank` (digital output). The controller activates the *Crank* output. If *Running detection* changes from OFF to ON, cranking stops.
4. **Running detection**. The engine is regarded as started when *Running detection* is ON.

Failure of engine start sequence for a run coil system



t1	Run coil before crank (optional)
t2	Crank on (`Parameters > Engine > Start sequence > Crank > Crank on`)
t3	Crank off (`Parameters > Engine > Start sequence > Crank > Crank off`)

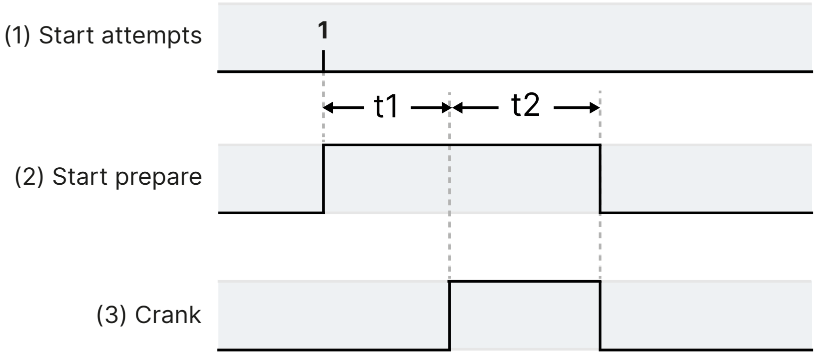
1. **Start attempts**: `Parameters > Engine > Start sequence > Start attempts > Normal` = 3.

2. **Run coil**: `Engine > Controls > Run coil` (digital output). The controller activates the *Run coil* at the time in the *Run coil before crank* parameter. If *Running detection* is still OFF after cranking, the controller deactivates the *Run coil* for the time in the *Crank off* parameter. This ensures that the engine is stopped if the engine start was not detected. The engine cannot be started during the *Crank off* time.
3. **Crank**: `Engine > Controls > Crank` (digital output). The controller activates the *Crank* output for the *Crank on* time, and deactivates it for *Crank off* time.
4. **Running detection**. There is no running detection.
5. **Start failure**. The controller activates the *Start failure* alarm after the last unsuccessful start attempt.

Optional start prepare

You can use the optional `Engine > Controls > Start prepare` digital output with a stop coil or a run coil system.

Successful engine start sequence with start prepare



t1 = Start prepare (`Parameters > Engine > Start sequence > Start prepare > Start prepare`)

t2 = Extended start prepare (`Parameters > Engine > Start sequence > Start prepare > Extended start prepare`)

1. **Start attempts**
2. **Start prepare**: `Engine > Controls > Start prepare` (digital output) (optional).
   a. At the start of each start sequence, the controller activates the *Start prepare* output for the time in the *Start prepare* parameter (**t1**). All other engine start outputs (that is, *Stop coil*, *Crank*) are not activated during this time.
   b. If there is an *Extended start prepare* time (**t2**), then the *Start prepare* output remains activated for this time during cranking. If cranking stops before the extended start prepare timer stops, then the controller deactivates the *Start prepare* output.
3. **Crank**: `Engine > Controls > Crank` (digital output). After the *Start prepare* time, the controller activates the *Crank* output.

9.3.4 Interruption of the start sequence

These actions interrupt the engine start sequence:

- The *Emergency stop* digital input is activated (for example, from the operator, or a PLC)
- When the controller is in MANUAL mode, there is a *Stop engine* command. For example: The operator pushes the push-button **Stop**  on the display unit.
- The following alarm actions:
  - *PMS-controlled stop*
  - *Trip generator breaker and stop engine*
  - *Trip generator breaker and shutdown engine*

When the start sequence is interrupted, the controller does the following:

- Deactivates the *Crank* output.
- Deactivates the *Run coil* output (if present).

- Activates the *Stop coil* output (if present).
- Deactivates the *Start prepare* output (if present).

There is no cooldown period when the engine start sequence is interrupted.

NOTE If *Running detection* is ON, the controller regards the engine as started. When the engine has started, the actions listed here do not interrupt the engine start sequence, but result in a engine stop instead. The engine stop normally includes the cooldown period configured in the controller. However, for a shutdown, there is no cooldown period.

9.4 Engine stop

9.4.1 Engine stop function

For a normal genset stop, the controller ensures that the genset runs for a cooldown period before stopping. If a shutdown alarm action shuts down the genset, there is no cooldown period. You can also configure an idle run stop period before the engine shuts down.

The controller software includes pre-programmed genset stop sequences. For the engine's stop function, you must configure these inputs and outputs, and parameters.

Parameters that need a hardware function are not visible until the function is assigned to an input or output.

Optional inputs and outputs

Function	I/O	Type	Details
`Engine > Command > De-load genset`	Digital input	Pulse	Optional. After the input is activated, the controller starts to de-load the genset.
`Engine > Command > Stop engine`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to stop the engine.
`Engine > Controls > Idle run`	Digital output	Continuous	Optional. Connect this output to the engine idle run if supported. Not all engines support this feature. This digital output is needed to use either idle run start and/or idle run stop.
`Engine > Command > Open generator breaker and stop engine`	Digital input	Pulse	Optional. The operator or another system can activate this input to request the controller to de-load and open the breaker, and then stop the engine.
`Engine > Command > Cooldown abort`	Digital input	Pulse	Optional. After the input is activated, the controller aborts the cooldown.

Parameters

`Engine > Stop sequence > Cooldown`

Parameter	Range	Comment
`Cooldown time` *	0 s to 165 min	This is the cooldown time if the digital input `Alarm system > Additional functions > Suppress alarm action` is not active. After the engine stop signal or command, the engine runs for this period before the controller activates the *Stop coil* (or deactivates the *Run coil*).

NOTE * If the digital input `Alarm system > Additional functions > Suppress alarm action` is active, the *Suppress alarm action* value is used instead of the *Cooldown time* value.

`Engine > Stop sequence > Extended stop`

Parameter	Range	Comment
`Extended stop`	1.0 to 99.0 s	The *Stop coil* remains activated for this period after *Running detection* is OFF. During this period a new start attempt is not possible.

Optional idle run stop

You can optionally configure an idle run stop period for the engine, allowing the engine to cool-down after taking load.

If this is configured, the controller will activate the digital output `Engine > Controls > Idle run` before stopping the engine. The controller then waits for one of the engine conditions (coolant temperature, oil temperature, external input condition, or the maximum timer) to be fulfilled before stopping the engine.

During the idle run stop period, the operator can override the period and press **Stop** on the display, the controller then cancels the idle run stop period and stops the engine.

Additionally, during the idle run stop period, the operator can press **Start** to abort the engine stop sequence and run the engine start sequence.

Optional. You must configure the `Engine > Controls > Idle run` digital output to see these parameters.

Optional parameters

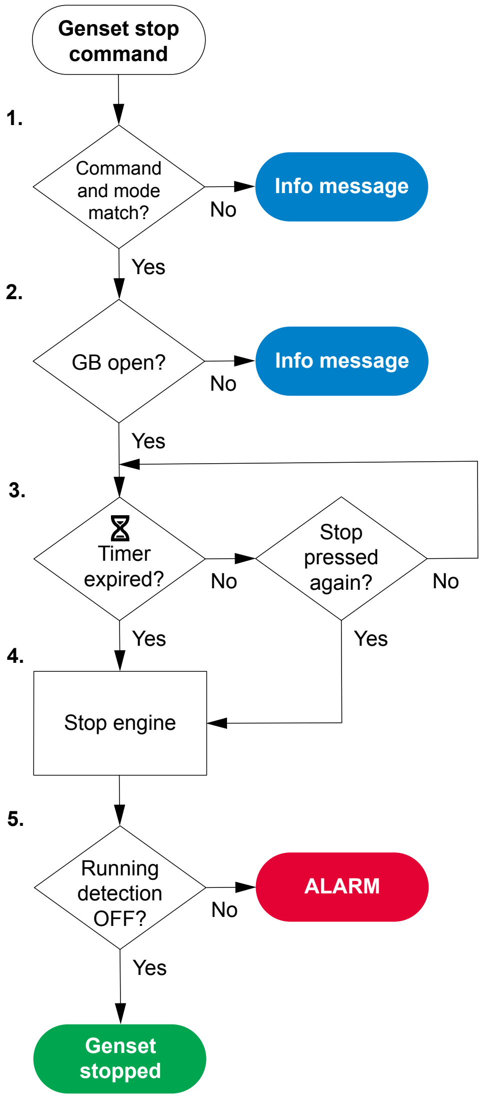
`Engine > Idle run stop > Minimum`

Parameter	Range	Comment
`Use`	Not enabled, Enabled	Uses minimum set point to determine if the engine is ready to stop.
`Delay`	0 s to 999 min	This is the minimum time the idle run stop is active.

9.4.2 Engine stop flowchart

The following flowchart shows how the controller normally stops a genset. An engine shutdown is described later.

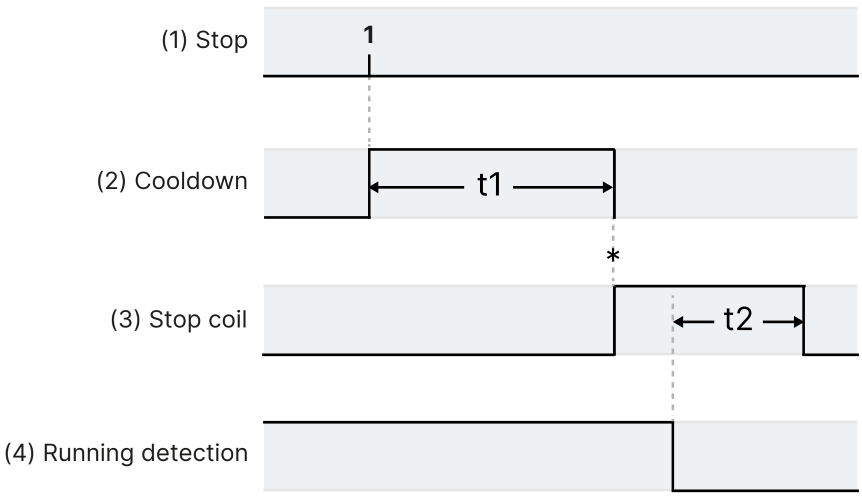
Idle run stop function is not included on this diagram.



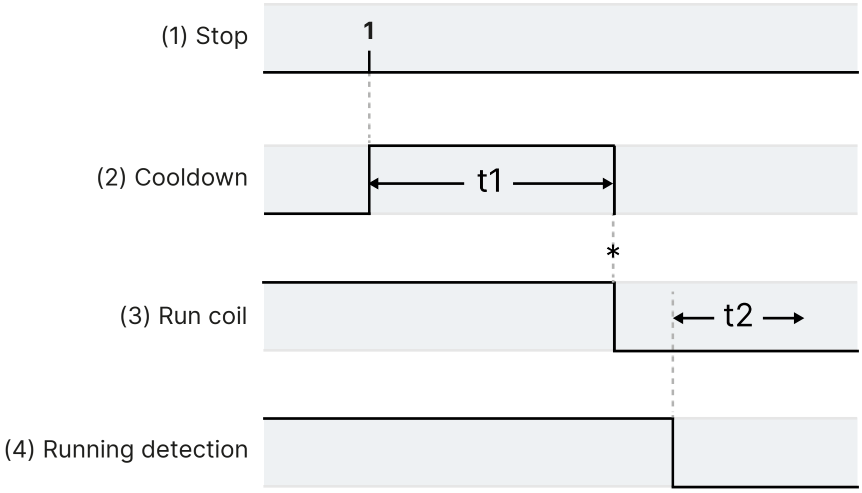
1. **Command and mode match:** The controller checks that the command source and the controller mode match:
   - In AUTO mode, the power management system must send the command to stop the genset. The controller ignores all other external commands.
   - In MANUAL mode, the command to stop the genset can come from the following:
     - The operator can press **Stop** on the display unit.
     - The operator can use PICUS to send an engine stop command.
     - The command can come from an external source, like a PLC.
2. **GB open:** The controller checks whether the genset breaker is open. If the genset breaker is not open, the controller cancels the stop sequence and the display unit shows an info message.
3. **Cooldown timer expired:** The genset runs without load for the cooldown time. The controller checks whether the cooldown timer has expired or the stop button was pressed again.
   - If the cooldown timer has not expired, but the engine stop button is pressed again, the controller stops the cooldown.
4. **Stop engine:** To stop the engine:
   - Stop coil system: The controller activates the *Stop coil* output.
   - Run coil system: The controller deactivates the *Run coil* output.
5. **Running detection OFF:** The controller checks whether the engine has stopped.
   - If *Running detection* is ON, the controller activates an alarm.
   - If *Running detection* is OFF, the engine has stopped and the stop sequence has been completed successfully.

9.4.3 Engine stop sequence

Engine stop sequence for a stop coil system



Engine stop sequence for a run coil system



t1	Cooldown (`Parameters > Engine > Stop sequence > Cooldown > Cooldown time`)
t2	Extended stop (`Parameters > Engine > Stop sequence > Extended stop > Extended stop`)
*	Up to this point, the engine can be restarted immediately, without completing the stop sequence.

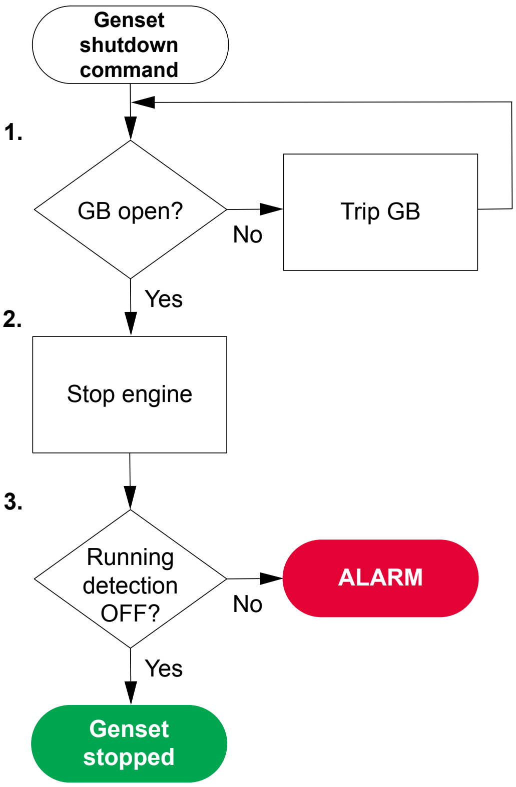
1. **Stop**. The stop command can come from the controller, an operator, or an external source. See Engine stop flowchart.
2. **Cooldown** (optional). The controller allows the genset to run for the time configured. There is no cooldown for shutdowns, an emergency stop, or an operator stop by pressing the engine stop push-button again. Temperature-dependent cooldown is also possible (see below).
3. **Stop engine**:
   - **Stop coil**: `Engine > Controls > Stop coil` (digital output). The controller activates the stop coil digital output until running feedback is OFF. The controller then keeps the stop coil activated for the time in the (optional) *Extended stop* parameter.
   - **Run coil**: `Engine > Controls > Run coil` (digital output). The controller deactivates the run coil digital output after the cooldown period. The genset cannot restart during the time in the (optional) *Extended stop* parameter.
4. **Running detection**. When the running detection is OFF, the controller regards the engine as stopped.

9.4.4 Engine shutdown flowchart

The engine is shut down for the following alarm action:
- Trip generator breaker and shutdown engine

The engine is also shutdown if the controller's *Emergency stop* input is deactivated.

Engine shutdown flowchart



1. **GB open**: The controller checks whether the generator breaker is open. If not, the controller trips the generator breaker.
2. **Stop engine**: The controller shuts down the engine:
   - Stop coil system: The controller activates the *Stop coil* output.
   - Run coil system: The controller deactivates the *Run coil* output.
3. **Running detection OFF**: If *Running detection* is still ON after the time allowed, the controller activates the *Stop failure* alarm.

NOTE The controller does not require the engine stop conditions to be met for an engine shutdown. Similarly, there is no cooldown time for an engine shutdown.

9.5 Generator breaker

9.5.1 How it works

The generator breaker (GB) connects the genset to the busbar. The genset must be running, and synchronised with the busbar, for the generator breaker to close. The generator breaker is an important part of the system safety, and trips to protect the genset from problems on the busbar. The generator breaker also trips to stop genset problems from disturbing the busbar.

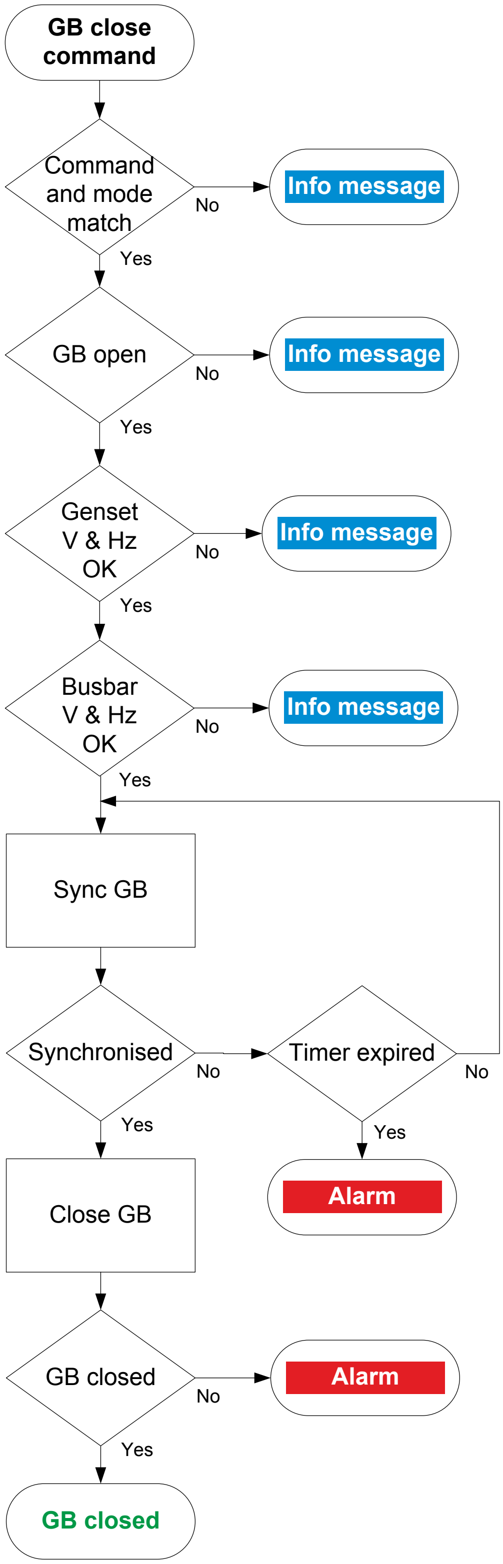
General breaker information

More information
See Breakers, synchronisation and de-loading for how synchronisation and breakers work. This includes the inputs and output functions and the parameters to configure.

[Breaker] refers to *Generator breaker*. The breaker abbreviation (*[*B]*) is *GB*.

9.5.2 Generator breaker close flowchart

More information
See Generator breaker blackout close flowchart for how to allow the genset to connect to a dead busbar.



1. **Command and mode match:** The controller checks that the command source and the controller mode match:
   - In AUTO mode, the power management system must send the command to close the generator breaker. The controller ignores all other external commands.
   - In MANUAL mode, the command to close the generator breaker can come from the following:
     - The operator can press the push-button **Close breaker** on the display unit.
     - The operator can use PICUS to send a close breaker command.
     - An external source, like a PLC.
2. **GB open:** The controller checks whether the generator breaker is open. If the generator breaker is already closed, the sequence stops, and an info message is shown.
3. **Genset V & Hz OK:** The controller checks whether the voltage and frequency from the genset are within the allowed range*. If these are not in the range, then the controller cancels the close command and displays an info message.
4. **Busbar V & Hz OK:** The controller checks whether the voltage and frequency on the busbar are within range*. If these are not in the range, then the controller cancels the close command and displays an info message.
5. **Sync GB:** The controller tries to synchronise the genset to the busbar.
   - When the genset and busbar are synchronised, the controller activates the *Breakers > Generator breaker > Controls > GB Close* output to close the breaker.
   - If the genset and busbar do not synchronise within the time allowed, the controller activates a *GB synchronisation failure* alarm.
6. **GB closed:** The controller checks whether the generator breaker has closed.
   - If the generator breaker has closed, the generator breaker close sequence has been completed successfully.
   - If the generator breaker has not closed, the controller activates the *GB closing failure* alarm.

NOTE * See `Parameters > [A-side] / [B-side] AC setup > Voltage and frequency OK` for these ranges.

9.5.3 Generator breaker blackout close flowchart

The power management system can automatically close the generator breaker as part of the blackout response.

More information
See Blackout in Power management for more information.

Manual blackout close not possible

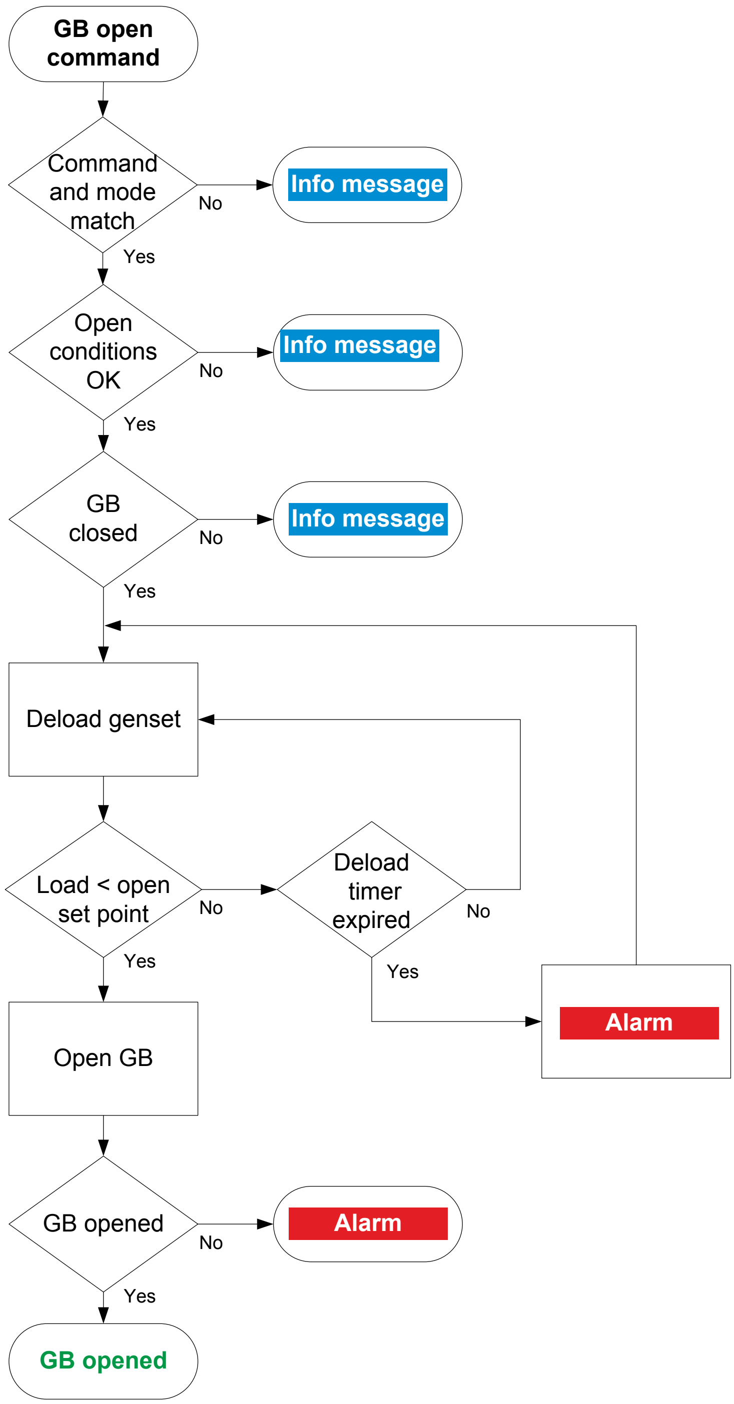
During a blackout, the **GENSET** controller is forced into AUTO mode. Since the **GENSET** controller is not in MANUAL mode, the operator cannot close the breaker by pushing **Close breaker** on the display.

9.5.4 Generator breaker open flowchart

The flowchart shows the sequence that the controller normally uses to open the generator breaker. This sequence is also used for the alarm action *PMS-controlled stop*.

The alarm action *Block* does not open a closed breaker, although it stops an open breaker from closing. If the controller or an operator sends a GB open command while *Block* is active, the controller uses this sequence.

The sequence to trip the generator breaker is described in another flowchart.



1. **Command and mode match:** The controller checks that the command source and the controller mode match:
   - In AUTO mode, the power management system must send the command to open the generator breaker. The controller ignores all other external commands.
   - In MANUAL mode, the command to open the genset breaker can come from the following:
     - The operator can press **Open breaker** on the display unit.
     - The operator can use PICUS to send an open breaker command.
     - The command can come from an external source, like a PLC.
2. **Open conditions OK:** The controller checks whether the open conditions are OK. The following conditions must be met:
   - The system must have at least one other source of power running and connected to the busbar (for example, another genset, a shaft generator or a shore controller).
   - The remaining gensets must not be overloaded after the breaker opens.
3. **GB closed:** The controller checks whether the generator breaker is closed. If the generator breaker is open, the sequence ends.
4. **Deload genset:** The power management system de-loads the genset:
   - When the load is less than the set point for the breaker to open, the controller activates the *Breakers > Generator breaker > Controls > GB open* output.
   - If the controller cannot de-load the breaker before the de-load timer expires, the controller activates the *GB de-load failure* alarm. The controller continues to try to de-load the breaker.
   - In MANUAL mode the de-loading of the genset can be stopped by sending a ‘GB Close’ command.
     - The de-loading sequence will stop and the breaker will remain closed.

- An info message will show GB Open cancelled.
- The system returns to the state before the ‘GB Open’ command.

5. **GB opened:** The controller checks whether the generator breaker has opened:
   - If the generator breaker has opened, the generator breaker open sequence has been completed successfully.
   - If the generator breaker has not opened, the controller activates the *GB opening failure* alarm.

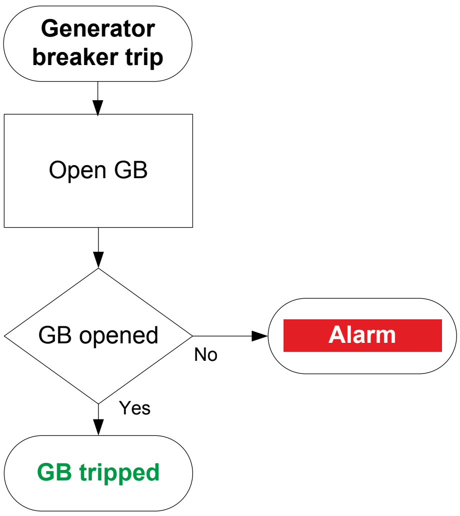
9.5.5 Generator breaker trip flowchart

The controller automatically trips the generator breaker (GB) for these alarm actions:

- Trip generator breaker
- Trip generator breaker and stop engine
- Trip generator breaker and shutdown engine

The generator breaker also trips if the controller's *Emergency stop* input is deactivated.

The controller does not require the genset stop conditions to be met for a breaker trip. Similarly, the breaker is not de-loaded for a trip.



1. **Open GB**: When a trip is required, the controller activates the `Breakers > Generator breaker > Controls > GB open` output to open the breaker.
2. **GB opened**: The controller checks whether the breaker has opened:
   - If the breaker has opened, the trip is successful.
   - If the breaker has not opened, the controller activates the *GB opening failure* alarm.

9.6 Close before excitation

You can configure the controllers to start up the gensets with the excitation switched off. When the genset(s) are started up, the breakers are closed and the excitation is started. Alternatively, you can close the breaker before the engine is started. This function is called Close Before Excitation (CBE).

For close before excitation, the gensets can be ready for the load very quickly. All of the gensets are connected to the busbar as soon as they are started. As soon as the excitation is switched on, the gensets are ready for operation. This is faster than the normal synchronising (where the breakers are not closed until the generators are synchronised, which takes some time to achieve).

The close before excitation function can also be used if the load requires a soft start. For example, when the gensets connect to a transformer.

As soon as the excitation is activated, the generators equalise the voltage and frequency. When the excitation is activated, the controller regulators are switched on after an adjustable delay. The excitation must be increased slowly when this function is used. You can only use CBE with a magnetic pick-up or J1939 speed signal.

9.6.1 Genset start

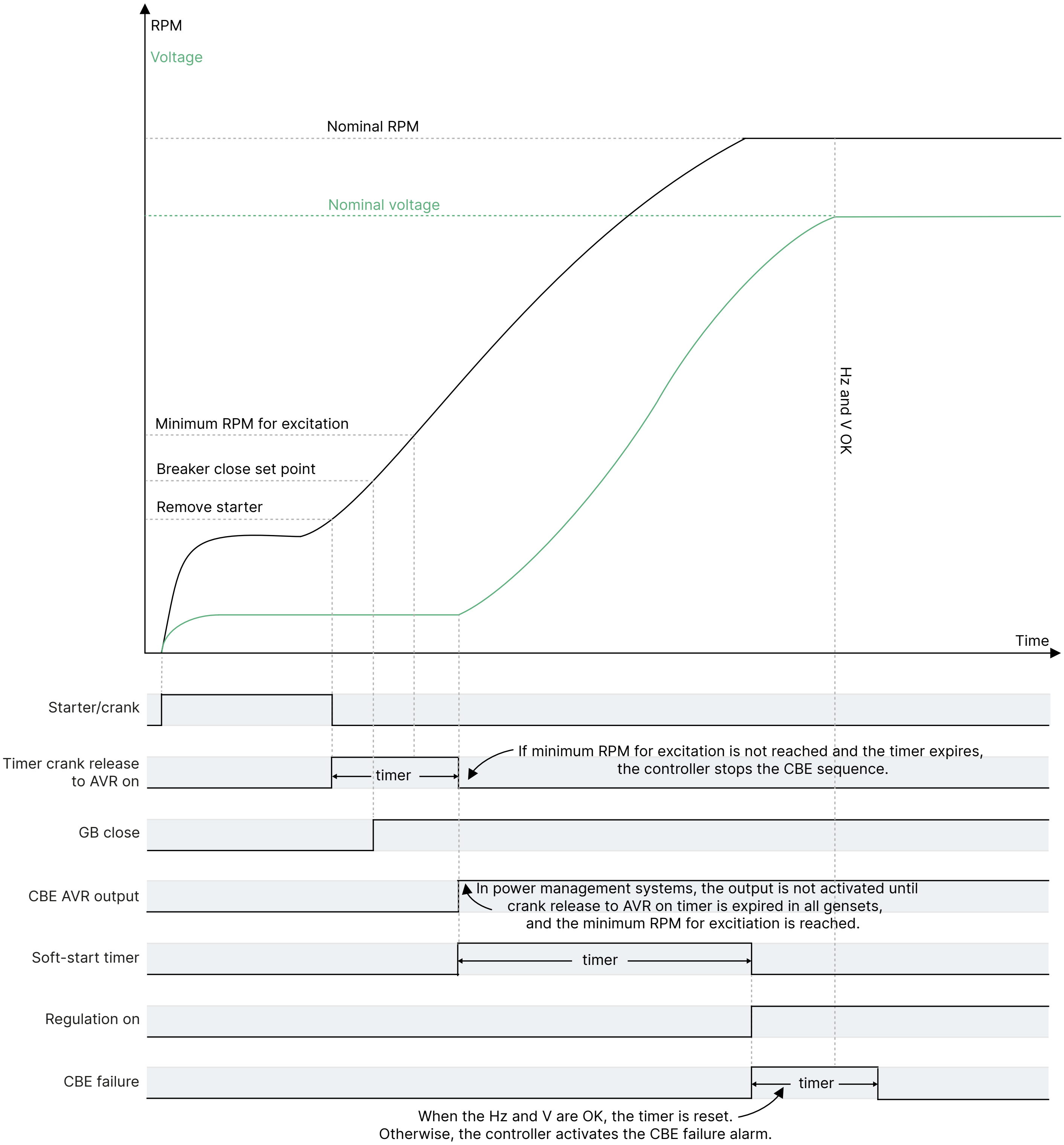
Output

Function	I/O	Type	Details
Auxiliary > Close before excitation > CBE AVR relay	Digital output	Continuous	The controller activates this output to start excitation.

Breakers > Close before excitation > Configuration

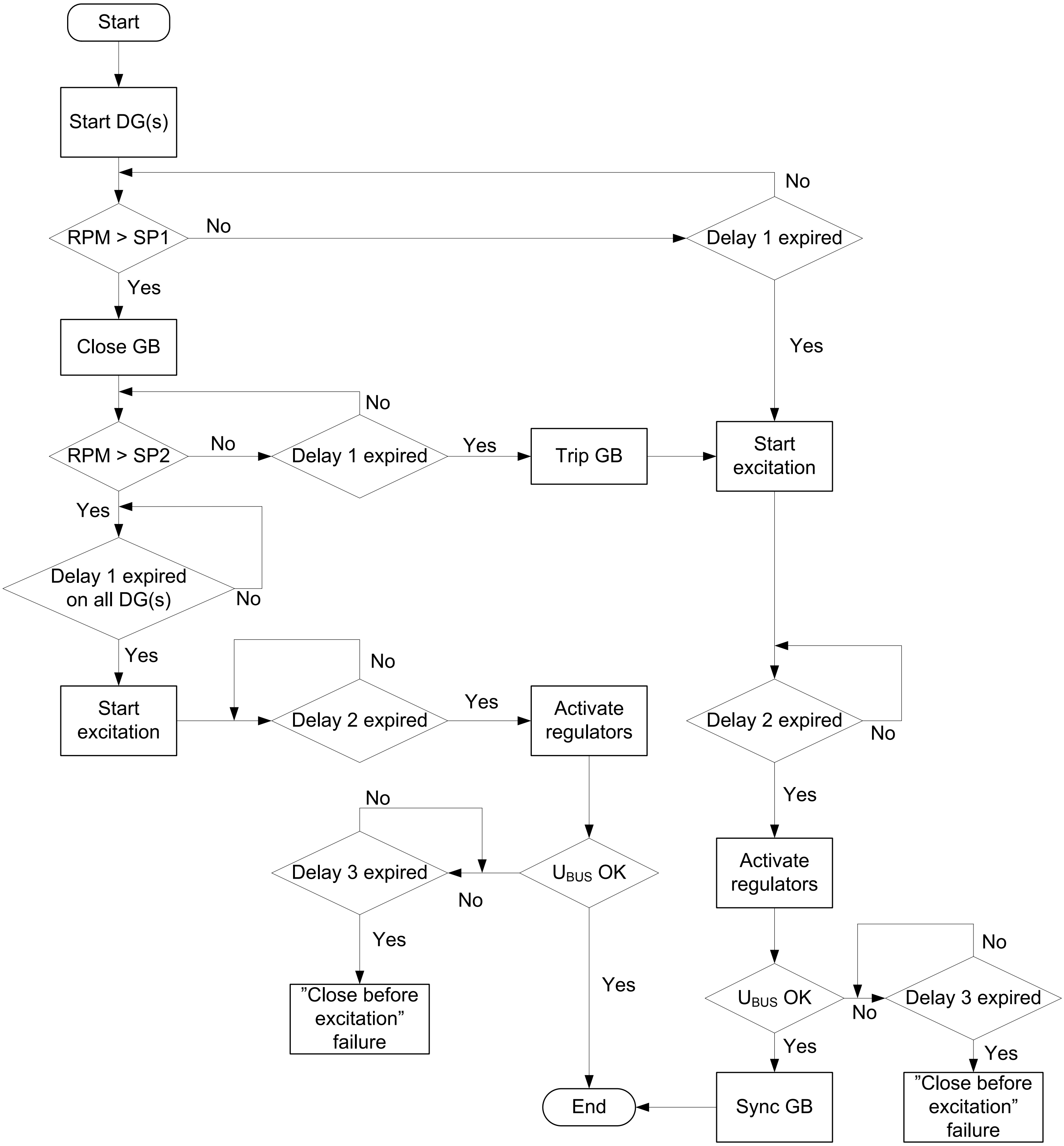
Parameter	Range	Details
Breaker close set point	0 to 4000 RPM	If 0, the breaker is closed when the start command is given.
Enable	Not enabled, Enabled	Enable CBE.
Timer crank release to AVR on	0.0 to 999.0 s	The genset must reach the breaker close set point within this time. If the RPM is at or above the set point after the timer runs out, the controller starts the excitation. If the RPM is below the set point, the controller trips the GB.
Breakers to close	Close GB, Close GB and TB	**Close GB**: See **CBE generator breaker flowchart**. **Close GB and TB**: If a tie breaker is present in a power management application, you can select *Close GB and TB*. See **CBE tie breaker flowchart**.
Soft-start timer	0.0 to 999.0 s	The period from when the excitation is started, until the regulation is activated. Alarms with the inhibit *Engine not running* can be activated after this timer runs out.
Minimum RPM for excitation	0 to 4000 RPM	The minimum RPM for the excitation to start.

Close before excitation sequence diagram



9.6.2 CBE generator breaker flowchart

Generator breaker handling

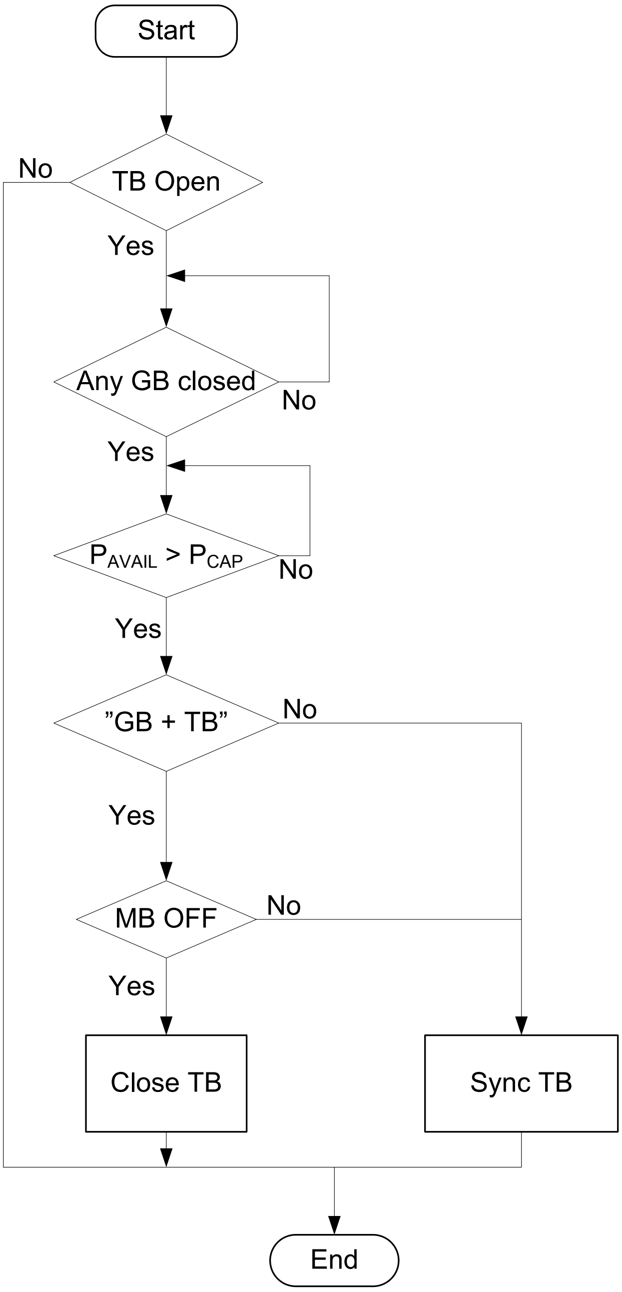


Abbreviations

- **SP1** = `Breaker close set point`
- **SP2** = `Minimum RPM for excitation`
- **Delay 1** = `Timer crank release to AVR on`
- **Delay 2** = `Soft-start timer`
- **Delay 3** = `CBE failure > Delay`

9.6.3 CBE tie breaker flowchart

Tie breaker handling



This flowchart applies in a power management system where there is a MAINS controllers that controls a tie breaker, and `Breakers to close` is *Close GB and TB*.

9.6.4 Excitation during cooldown

You can select how the controller should react during cooldown.

`Breakers > Close before excitation > Configuration`

Parameter	Range	Details
`Excitation control during cooldown`	Excitation follow U busbar, Excitation constant ON, Excitation OFF	See below. The parameter is not shared between gensets.

- **Excitation follow U busbar**: If there is voltage on the busbar during the genset cooldown, the excitation is ON. If the voltage on the busbar disappears, the excitation is shut OFF.

- **Excitation constant ON**: The excitation is ON until the genset stops or a new start request comes. This can be useful if the genset voltage drives the genset fans.
- **Excitation OFF**: The excitation is switched OFF as soon as the GB is open during cooldown. This can be useful if the genset mechanically pulls the genset fans. The genset can then rerun faster.

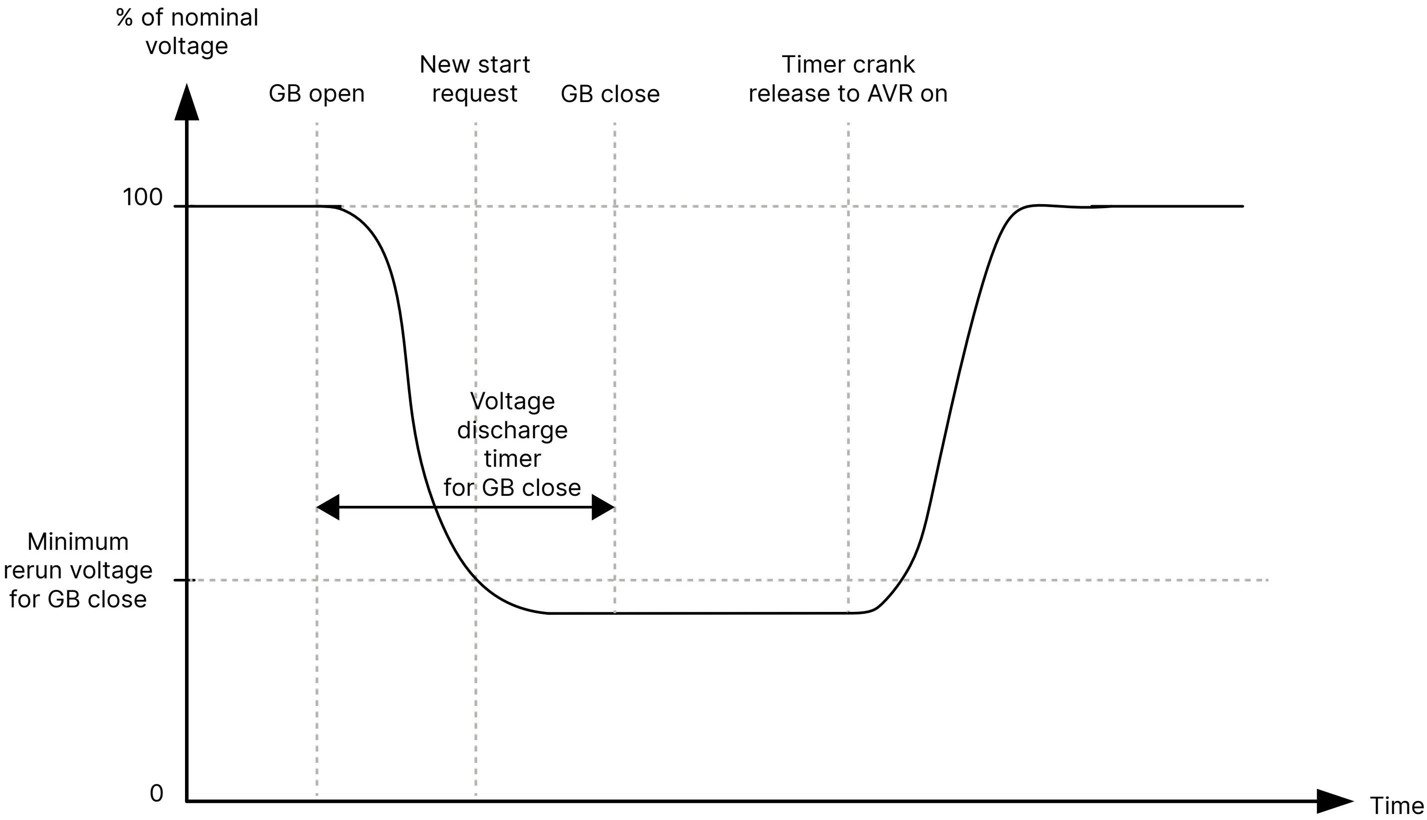
9.6.5 Voltage rerun

You can select what the controller should do during cooldown. If a new start request comes during cooldown (rerun), the genset(s) can do the CBE sequence again without stopping the genset(s) if the voltage has fallen enough.

`Breakers > Close before excitation > Configuration`

Parameter	Range	Details
`Voltage discharge timer for GB close`	1.0 to 20.0 s	This timer determines the minimum time required from when the excitation is removed until a voltage rerun. The delay allows the voltage of the generator to discharge, so that only remanence voltage is present when the GB is closed. The timer is restarted by a new start request or when the generator breaker opens.
`Maximum rerun voltage for GB close`	30 to 100 % of nominal voltage	Select how low the voltage must be, before the controller can close the breaker during the rerun. If the voltage is not below the voltage rerun level before the voltage discharge timer has expired, the genset is excluded from the CBE rerun sequence. The parameter is not shared between gensets.

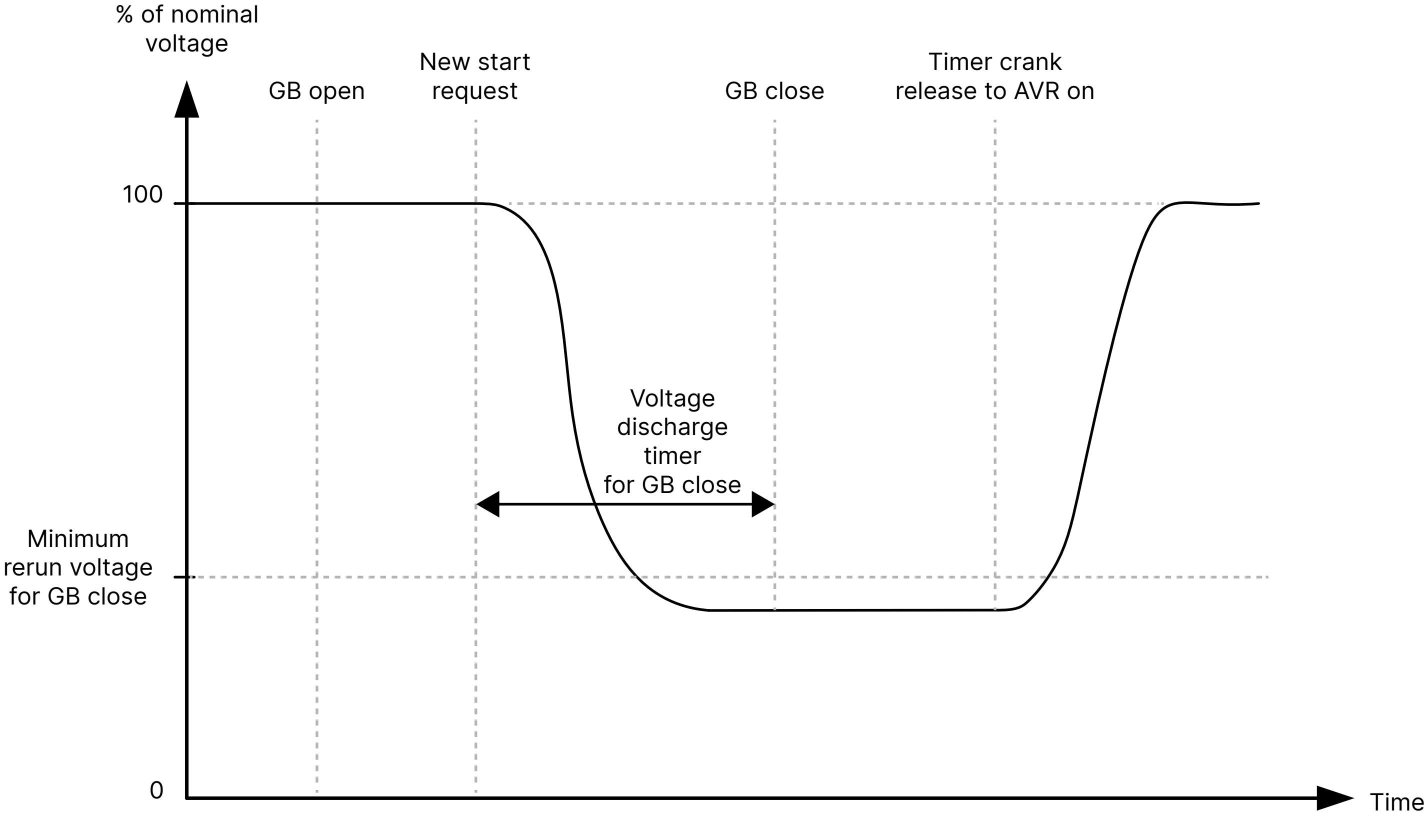
Example: Excitation is shut off as soon as the breaker is opened



The excitation is shut off as soon as the breaker is opened. Soon after the breaker is opened, a new start request appears. The controller delays closing the GB until the voltage discharge timer has expired.

This example is the fastest, because the excitation is already off when the start request appears. If the new start request appeared a little later, the voltage discharge timer could already have expired. This means that the generator breaker could close very shortly after the new start request.

Example: Excitation is on during cooldown



The excitation is on during cooldown. When a new start request is made, the excitation is shut off. When the excitation is shut off, the voltage discharge timer starts.

9.6.6 CBE alarms

`Breakers > Close before excitation > CBE failure`

Parameter	Range
`Delay`	0.0 to 999.0 s

If the genset start fails, the controller activates the alarm. To use close before excitation when the genset controller does not control the voltage, disable this alarm.

`Breakers > Close before excitation > CBE rerun failure`

Parameter	Range
`Delay`	0.0 to 999.0 s

If the rerun does not succeed within the configured time, the controller activates the alarm.

9.7 Digital AVR

The controller can work with a digital AVR (see the **Data sheet** for details). Select the DAVR and configure the source address on the **Fieldbus configuration** page in PICUS.

More information
See **Fieldbus configuration** in the **PICUS manual**.

You can then use the following parameters in the controller to configure the digital AVR.

Generator > Digital AVR > AC setup > Selection

Parameter	Range
AC configuration	Use the controller AC settings, 2-phase (W-U), 2-phase (V-W), 3-phase (U-V-W)

Generator > Digital AVR > AC setup > Voltage transformer

Parameter	Range
Enable VT	Not enabled, Enabled

Generator > Digital AVR > AC setup > Generator

Parameter	Range
Primary	400.0 to 32000.0 V
Secondary	50.0 to 600.0 V

Generator > Digital AVR > AC setup > Busbar

Parameter	Range
Primary	400.0 to 32000.0 V
Secondary	50.0 to 600.0 V

Generator > Digital AVR > Settings > Start on threshold

Parameter	Range
Start on threshold PWM	0.0 to 100.0 %
Start on threshold activation	0.0 to 100.0 %

Generator > Digital AVR > Settings > Soft start

Parameter	Range
Soft-start ramp	0.1 to 120.0 s

Generator > Digital AVR > Settings > Reset soft start

Parameter	Range
Minimum frequency threshold	6.0 to 500.0 Hz
Minimum VBus threshold	0.0 to 450.0 V

Generator > Digital AVR > Settings > Dry alternator

Parameter	Range
Excitation reference for dry alternator	0.0 to 20.0 A

Generator > Digital AVR > Settings > Bias

Parameter	Range
Bias scale	1.0 to 50.0 %
Analogue bias input type	0 to 10 V, +- 10 V, 4 to 20 mA
Regulation selection	Analogue, CAN bias

Generator > Digital AVR > Settings > PID

Parameter	Range
PID gain factor	1.0 to 200.0

Generator > Digital AVR > Settings > Droop

Parameter	Range
Reactive droop compensation	0.0 to 10.0 %
Voltage droop compensation	0.0 to 10.0 %
Droop type	Off, Reactive droop compensation, Voltage line droop compensation

Generator > Digital AVR > Settings > Controls

Parameter	Range
Write all settings	Not selected, Selected
Controls	Not enabled, Enabled
Reset all DVC alarms	Not selected, Selected
Digital AVR modes	Genset mode, Dry alternator, Ventilator mode

Generator > Digital AVR > Current limitation > Selection

Parameter	Range
Current limitation type	Off, Magnetisation, Inductive motor

Generator > Digital AVR > Current limitation > Magnetisation

Parameter	Range
Current limitation transformer	0.0 to 300.0 %

Generator > Digital AVR > Current limitation > Inductive motor starting

Parameter	Range
Current limitation induction motor	0.0 to 300.0 %

Generator > Digital AVR > Operation modes > Selection

Parameter	Range
SVR and LAM configuration	Off, SVR, SVR + LAM

Generator > Digital AVR > Operation modes > U/f variable slope

Parameter	Range
Knee set point	70.0 to 100.0 %
U/f variable slope	0.5 to 5.0

Generator > Digital AVR > Operation modes > Load acceptance module

Parameter	Range
Adjust LAM	70.0 to 100.0 %
LAM duration	0.0 to 10000.0 ms

Generator > Digital AVR > Operation modes > Soft voltage recovery

Parameter	Range
Soft voltage recovery	0.01 to 3.00 s/%

9.7.1 Digital AVR outputs

The controller analogue outputs can be configured to show a range of digital AVR values. See the functions available under Generator > Digital AVR > LED and Generator > Digital AVR > Measurements.

9.7.2 Digital AVR alarms

You can enable the following alarms. They are based on operating values from the digital AVR.

Generator > Digital AVR > Alarms > Over-voltage

Generator > Digital AVR > Alarms > Under-voltage

Generator > Digital AVR > Alarms > Over-frequency

Generator > Digital AVR > Alarms > Under-frequency

Generator > Digital AVR > Alarms > Open diode

Generator > Digital AVR > Alarms > Shorted diode

Generator > Digital AVR > Alarms > Reverse kW

Generator > Digital AVR > Alarms > Reverse kvar

Generator > Digital AVR > Alarms > Pt100 # alarm *

NOTE * # is 1 to 5.

Generator > Digital AVR > Alarms > Pt100 # fault *

NOTE * # is 1 to 5.

Generator > Digital AVR > Alarms > PTC # fault *

NOTE * # is 1 to 5.

Generator > Digital AVR > Alarms > Sensing lost

Generator > Digital AVR > Alarms > Unbalanced voltage

Generator > Digital AVR > Alarms > Unbalanced current

Generator > Digital AVR > Alarms > Short circuit

Generator > Digital AVR > Alarms > IGBT overheat

Generator > Digital AVR > Alarms > Motor start

Generator > Digital AVR > Alarms > PWR bridge overload

Generator > Digital AVR > Alarms > Power supply

Generator > Digital AVR > Alarms > CAN supply

Generator > Digital AVR > Alarms > Pt100 # open short fault status *

NOTE * # is 1 to 5.

Generator > Digital AVR > Alarms > AIN # wire break fault status *

NOTE * # is 1 to 5.

Generator > Digital AVR > Alarms > AOUT # overload wire break fault status *

NOTE * # is 1 to 5.

`Generator > Digital AVR > Alarms > DOUT overload fault status`

9.8 Other GENSET controller functions

9.8.1 Engine communication

The controller supports J1939 communication with engines, as well as some proprietary protocols.

More information
See **iE 250 ML 300 Engine interface communication** for the details for each engine type.

Inputs and outputs

You can use controller inputs and outputs for the ECU.

Function	I/O	Type	Details
`Engine > ECU > Measurement list filter - available`	Digital input	Pulse	
`Engine > ECU > Measurement list filter - clear`	Digital input	Pulse	
`Engine > ECU > Log request (DM2)`	Digital input	Pulse	After this input is activated, the controller requests the DM2 log from the ECU.
`Engine > ECU > Log clear (DM2)`	Digital input	Pulse	After this input is activated, the controller requests the ECU to clear the DM2 log.
`Engine > ECU > ECU reset input`	Digital input	Pulse	After this input is activated, the controller requests the ECU to reset.
`Engine > Controls > ECU power`	Digital output	Continuous	You can use this output so that the ECU is only powered on when the engine needs to run.
`Engine > ECU > ...`	Analogue outputs	Various	Over 100 ECU outputs are available as analogue outputs. These can be connected to switchboard instruments for troubleshooting.

Parameters for controls

`Engine > ECU > Controls > Speed control (TSC1 / Custom)`

Parameter	Range	Notes
`Enable`	Not enabled, Enabled	**Enable**: Enable writing commands to the ECU.
`Source address`	0 to 255	EIC speed/Torque control source address.
`Use nominal RPM as reference`	Not enabled, Enabled	**Enabled**: Use the nominal RPM as the reference for the ECU.

`Engine > ECU > Controls > Cab message (CM1 / Custom)`

Parameter	Range	Notes
`Source address`	0 to 255	Selection of EIC J1939 CAB message 1 source address. The controller telegrams for DPF regeneration use this source address.

`Engine > ECU > Controls > CAN controls`

Parameter	Range	Notes
`Enable`	Not enabled, Enabled	**Enable**: Enable writing commands to the ECU.

`Engine > ECU > Controls > Droop`

Parameter	Range	Notes
`Droop settings`	None, Engine Control Unit (ECU), Emulated droop	**None**: The controller does not use droop. **Engine control unit (ECU)**: The controller sends the specified droop value to the ECU. **Emulated droop**: The controller emulates the specified droop.
`Droop value`	0.0 to 25.0 %	The specified droop.

`Engine > ECU > Controls > Reset`

Parameter	Range	Notes
`Power off timer`	1 to 300 s	The controller uses this timer with the digital output `Engine > Controls > ECU power`. This can be wired to turn the ECU power off.

Parameters for diagnostic alarms

`Engine > ECU > Diagnostic alarms > ECU Red stop lamp`

`Engine > ECU > Diagnostic alarms > ECU Amber warning lamp`

`Engine > ECU > Diagnostic alarms > ECU Protect lamp`

`Engine > ECU > Diagnostic alarms > ECU Malfunction indicator lamp`

Parameters for DPF controls

`Engine > ECU > DPF controls > Controls`

Parameter	Range	Notes
`Aftertreatment Regeneration Inhibit Switch`	Not enabled, Enabled	**Enabled**: The regeneration is inhibited.
`Aftertreatment Regeneration Force Switch`	Automatic, Forced	**Automatic**: The ECU automatically regenerates the DPF filter as required. **Forced**: Forces the regeneration of the DPF filter.

Parameters for specific manufacturers

`Engine > ECU > Manufacture specific`

Parameter	Range	Notes
`Shutdown override > Enable`	Not enabled, Enabled	
`Parameters > Speed control`	Standard J1939, [Manufacturer specific]	If the manufacturer has a proprietary speed control, you can select it here.

9.8.2 Short-time parallel

You can uses these parameters to limit the time that the genset is parallel to the mains.

`Breakers > Short-time parallel > Configuration`

Parameter	Range
`Overlap`	Off, On
`Overlap`	0.10 to 99.90 s

9.8.3 Temperature-dependent power derating

The temperature-dependent power derating function reduces the genset nominal load by reducing the genset nominal power used by load sharing. The derating function can be configured for up to three temperature measurements.

Input and output

Function	I/O	Type	Details
`Engine > Power derate > Temperature > Derate # temperature [C]` *	Analogue input	The measurement must be in °C.	This can measure any temperature, for example, the engine cooling water.
`Engine > Power derate > Temperature > Derate # temperature [C]` *	Analogue output	-	Optional. You can connect this output to a switchboard instrument to monitor the analogue input.

NOTE * # is 1 to 3.

Parameters

`Engine > Power derate > Temperature > Derate #` *

The analogue input(s) must be configured to see the power derate parameter and curve.

Parameter	Range	Comment
`Enable derate`	Not enabled, Enabled	**Not enabled**: The load sharing uses the genset nominal power, no matter what the derate temperature is. **Enabled**: The controller uses the power derating curve to derate the power for load sharing within the configured range. See **How it works**.
`Setup`		Use this section to set up the power derate curve.

NOTE * # is 1 to 3.

How it works

By default, the genset nominal power is 100 % for temperatures up to 90 °C. If there is a *Derate temperature* input, then the power is derated linearly to 80 % at 130 °C. However, you can create a customised curve for each temperature input.

Power derate affects load sharing, since load sharing is based on a percentage of nominal power.

The derating does **not** affect the alarms.

Temperature-dependent power derating example

There are two 1000 kW gensets in the system. For genset A, the power derate curve is 100 % until 80 °C, then linearly down to 70 % at 100 °C. Genset B does not have power derating.

The genset A temperature is 90 °C. The system load is 1480 kW.

The derated nominal power for genset A is 85 % of the nominal power, that is, 850 kW. The total genset nominal power is 1850 kW.

For equal load sharing, each genset runs at 1480 kW / 1850 kW × 100 % = 80 % of their nominal load. Genset A runs at 680 kW, and genset B runs at 800 kW.

9.8.4 Percentage-dependent power derating

The percentage-dependent power derating function reduces the genset nominal load by reducing the genset nominal power used by load sharing.

Input and output

Function	I/O	Type	Details
`Engine > Power derate > Percentage > Derate percentage [%]`	Analogue input	The measurement must be in %.	
`Engine > Power derate > Percentage > Derate percentage [%]`	Analogue output	-	Optional. You can connect this output to a switchboard instrument to monitor the analogue input.

Parameters

`Engine > Power derate > Percentage`

The analogue input must be configured to see the power derate parameter.

Parameter	Range	Default	Comment
`Enable derate`	Not enabled, Enabled	Not enabled	**Not enabled**: The load sharing uses the genset nominal power, no matter what the derate percentage is. **Enabled**: The controller uses the analogue input to derate the power for load sharing.

9.8.5 Fuel pump

The fuel pump logic is used to start and stop the fuel supply pump to keep the fuel in the service tank at the required level. To see the fuel pump parameters, you must first configure the fuel pump digital output and the fuel level analogue input.

Inputs and outputs

Function	I/O	Type	Details
`Auxiliary > Fuel pump > Fuel pump`	Digital output	Continuous	Controller output to activate the fuel pump when the fuel level is below the start limit, until the fuel level is above the stop limit.
`Auxiliary > Fuel pump > Fuel level [%]`	Analogue input	-	The level in the fuel tank.
`Auxiliary > Fuel pump > Activate fuel pump logic`	Digital input	Pulse	Optional. External signal to activate the controller's fuel pump function. If this function is not assigned to a digital input, the fuel pump function is always active.
`Auxiliary > Fuel pump > Deactivate fuel pump logic`	Digital input	Pulse	Optional. External signal to deactivate the controller's fuel pump function.
`Auxiliary > Fuel pump > Fuel level [%]`	Analogue output	-	Optional. You can connect this to a switchboard instrument for troubleshooting.
`Auxiliary > Fuel pump > Analogue input > Fuel level [%]`	Analogue output	-	Optional. You can connect this to a switchboard instrument for troubleshooting.

`Auxiliary > Fuel pump > Fuel pump settings`

Name	Range	Details
`Pump ON set point`	0 to 100 %	Fuel level to activate the output, to start the fuel transfer pump.
`Pump ON delay`	0.0 s to 1 h	The fuel level must be below the pump on set point for this time before the controller activates the output to start the pump.

Name	Range	Details
`Pump OFF set point`	0 to 100 %	Fuel level to deactivate the output, to stop the fuel transfer pump.
`Pump OFF delay`	0.0 s to 1 h	The fuel level must be above the pump off set point for this time before the controller deactivates the output to stop the pump.

`Auxiliary > Fuel pump > Fuel fill alarm`

Name	Range	Details
`Delay`	1 s to 5 min	When the fuel pump is running, the fuel level must increase by 2 % within this delay, otherwise the controller activates the alarm.

9.8.6 Engine operating values as analogue inputs

In addition to analogue inputs described previously, you can use these analogue inputs to communicate engine operating values to the controller.

Analogue inputs

Function	I/O
`Engine > Measurements > Coolant > Engine coolant temperature [°C]`	Analogue input
`Engine > Measurements > Coolant > Engine coolant level [%]`	Analogue input
`Engine > Measurements > Lube oil > Engine oil temperature [°C]`	Analogue input
`Engine > Measurements > Lube oil > Engine oil pressure [bar]`	Analogue input

9.8.7 Engine operating values as analogue outputs

You can configure an analogue output with a function for an engine operating value from the ECU, the analogue input, or the MPU. The controller then adjusts the analogue output to reflect the engine operating value. For a list of the engine operating values, see the `Engine` analogue output functions in the controller.

Applications

An analogue output with an engine operating value may be wired to a switchboard instrument, to help the operator with troubleshooting. For example, the engine speed measured by the MPU can be displayed.

9.8.8 Engine states as digital outputs

You can configure a digital output with a function for an engine state. The controller activates the digital output if the engine state is present. These can be useful for troubleshooting.

Digital outputs

Function	I/O	Type	Details
`Engine > State > Start prepare completed`	Digital output	Continuous	Activated when the start prepare is completed.
`Engine > State > Running`	Digital output	Continuous	Activated if there is running detection for the engine.
`Engine > State > Not running`	Digital output	Continuous	Activated if there is no running detection for the engine.

9.8.9 Counters

You can view, edit and reset all the counters on the display unit under `Configure > Counters`.

The counters include:

- Start attempts
- Total running hours and minutes
- Trip running hours and minutes
- Generator breaker operations and trips
- Energy export (active and reactive)

Running hours trip works like a car trip meter. For example, you can use this counter to track the running hours since the last maintenance.

Energy counter outputs

For each energy counter, you can configure a digital output to send a pulse every time a certain amount of energy is transferred.

Digital outputs

You must configure the digital output function to see the parameters.

Function	I/O	Type
`Generator > Production counters > Active energy export pulse`	Digital output	Pulse
`Generator > Production counters > Reactive energy export pulse`	Digital output	Pulse

Parameters

`Generator > Production counters > Active energy export`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Generator > Production counters > Reactive energy export`

Parameter	Range	Comment
Pulse every	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
Pulse length	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Energy counter function and corresponding parameter full names

[Counter pulse]	[Counter]
Active energy export pulse 1	Active energy export
Reactive energy export pulse 1	Reactive energy export

Application example for an energy counter output

1. Connect the digital output to an external counter.
2. Configure the digital output using the display unit or PICUS to *Active energy export pulse 1*.
3. Configure the *Pulse every* parameter to the value where you would like to send a pulse. For example, 100 kWh.
4. Configure the *Pulse length* to the required length of the pulse for your external counter. For example, 1 second.

With the example setup the controller sends a 1 second pulse to the external counter for each 100 kWh the controller logs.

9.9 GENSET controller alarms

9.9.1 GENSET controller alarms

These alarms are in addition to the AC protections and general alarms for iE 250 controllers.

Alarms for the GENSET controller

	Alarms
Engine	Emergency stop
	Overspeed (2 alarms)
	Under-speed (2 alarms)
	Governor regulation error
	Power ramp up error
	Power ramp down error
	Crank failure
	Primary running feedback failure
	Start failure
	Stop failure
	Engine stop (external)
	Engine start (external)
	Start enable removed during start
	Total running hours notification
	Trip running hours notification
	Magnetic pickup wire break
Generator	Voltage or frequency not OK
	AVR regulation error
Load sharing	P load sharing failure
	Q load sharing failure
Regulator configuration	GOV output selection failure
	GOV output setup failure
	GOV relay setup incomplete
	AVR output selection failure
	AVR output setup failure
	AVR relay setup incomplete
Advanced blackout prevention	P load sharing failure (low frequency)
	P load sharing failure (high frequency)
	Q load sharing failure (low voltage)
	Q load sharing failure (high voltage)

9.9.2 Alarm actions

The controller has the following alarm actions:

- Warning

- Block generator breaker
- PMS-controlled stop
- Trip generator breaker
- Trip generator breaker and stop engine
- Trip generator breaker and shutdown engine
- Controlled stop

9.9.3 Inhibits

Inhibit	Disables the alarm when ...
Engine running	*Digital running detection* is ON.
Engine not running	*Digital running detection* is OFF.
Generator breaker closed	The `Breakers > Generator breaker > Feedback > GB closed` digital input is activated.
Generator breaker open	The `Breakers > Generator breaker > Feedback > GB open` digital input is activated.
Generator voltage present	The generator voltage is above 10 % of the nominal voltage.
No generator voltage	The generator voltage is below 10 % of the nominal voltage.
Mains in parallel	The mains is connected.
ACM wire break	All these conditions are met: • The generator breaker is closed • Voltage is detected by one set of ACM voltage measurements • No voltage is detected on a phase, or on all three phases for the other set of ACM voltage measurements
Inhibit 1	The `Alarm system > Inhibits > Activate inhibit 1` digital input is activated.
Inhibit 2	The `Alarm systems > Inhibits > Activate inhibit 2` digital input is activated.
Inhibit 3	The `Alarm systems > Inhibits > Activate inhibit 3` digital input is activated.

9.9.4 Breaker alarms

More information
See Breakers, synchronisation and de-loading for breaker handling and alarms in general.

GENSET alarm	Parameters	General name
GB synchronisation failure	`Breakers > Generator breaker monitoring > Synchronisation failure`	Breaker synchronisation failure
GB de-load failure	`Breakers > Generator breaker monitoring > De-load failure`	Breaker de-load failure
Vector mismatch	`Breakers > Generator breaker monitoring > Vector mismatch`	Vector mismatch
GB opening failure	`Breakers > Generator breaker monitoring > Opening failure`	Breaker opening failure
GB closing failure	`Breakers > Generator breaker monitoring > Closing failure`	Breaker closing failure
GB position failure	`Breakers > Generator breaker monitoring > Position failure`	Breaker position failure
GB trip (external)	`Breakers > Generator breaker monitoring > Tripped (external)`	Breaker trip (external)

GENSET alarm	Parameters	General name
GB short circuit	`Breakers > Generator breaker monitoring > Short circuit`	Breaker short circuit
GB configuration failure	-	Breaker configuration failure
Generator phase sequence error	`Generator > AC setup > Phase sequence error`	Phase sequence error
Busbar phase sequence error	`Busbar > AC setup > Phase sequence error`	Phase sequence error

9.9.5 AC alarms

More information
See AC configuration and nominal settings for information about the AC alarms in general.

Generator AC alarm names for GENSET controller

Controller alarm	Parameters	General name
Generator over-voltage [1 to 3]	`Generator > Voltage protections > Over-voltage [1 to 3]`	Over-voltage
Generator under-voltage [1 to 4]	`Generator > Voltage protections > Under-voltage [1 to 4]`	Under-voltage
Generator voltage unbalance	`Generator > Voltage protections > Voltage unbalance`	Voltage unbalance
Negative sequence voltage	`Generator > Voltage protections > Negative sequence voltage`	Negative sequence voltage
Positive sequence under-voltage	`Generator > Voltage protections > Positive sequence under-voltage`	Positive sequence under-voltage
Zero sequence voltage	`Generator > Voltage protections > Zero sequence voltage`	Zero sequence voltage
Generator over-current [1 to 4]	`Generator > Current protections > Over-current [1 to 4]`	Over-current
Fast over-current [1 to 2]	`Generator > Current protections > Fast over-current [1 to 2]`	Fast over-current
Current unbalance (average calc.)	`Generator > Current protections > Current unbalance (average calc.)`	Current unbalance (average calc.)
Current unbalance (nominal calc.)	`Generator > Current protections > Current unbalance (nominal calc.)`	Current unbalance (nominal calc.)
Directional over-current [1 to 2]	`Generator > Current protections > Directional over-current [1 to 2]`	Directional over-current
Inverse time over-current	`Generator > Current protections > Inverse time over-current`	Inverse time over-current
Negative sequence current	`Generator > Current protections > Negative sequence current`	Negative sequence current
Zero sequence current	`Generator > Current protections > Zero sequence current`	Zero sequence current
Generator over-frequency [1 to 3]	`Generator > Frequency protections > Over-frequency [1 to 3]`	Over-frequency
Generator under-frequency [1 to 3]	`Generator > Frequency protections > Under-frequency [1 to 3]`	Under-frequency

Controller alarm	Parameters	General name
Overload [1 to 5]	`Generator > Power protections > Overload [1 to 5]`	Overload
Reverse power 1 or 2	`Generator > Power protections > Reverse power 1 or 2`	Reverse power
Reactive power export [1 to 2]	`Generator > Reactive power protections > Reactive power export [1 to 2]`	Reactive power export
Reactive power import [1 to 2]	`Generator > Reactive power protections > Reactive power import [1 to 2]`	Reactive power import

Busbar AC alarm names for GENSET controller

Controller alarm	Parameters	General name
Busbar over-voltage [1 to 3]	`Busbar > Voltage protections > Over-voltage [1 to 3]`	Busbar over-voltage
Busbar under-voltage [1 to 2]	`Busbar > Voltage protections > Under-voltage [1 to 2]`	Busbar under-voltage
Busbar voltage unbalance	`Busbar > Voltage protections > Voltage unbalance`	Busbar voltage unbalance
Busbar over-frequency [1 to 4]	`Busbar > Frequency protections > Over-frequency [1 to 4]`	Busbar over-frequency
Busbar under-frequency [1 to 2]	`Busbar > Frequency protections > Under-frequency [1 to 2]`	Busbar under-frequency
Negative sequence voltage	`Busbar > Voltage protections > Negative sequence voltage`	Negative sequence voltage
Positive sequence under-voltage	`Busbar > Voltage protections > Positive sequence under-voltage`	Positive sequence under-voltage
Zero sequence voltage	`Busbar > Voltage protections > Zero sequence voltage`	Zero sequence voltage

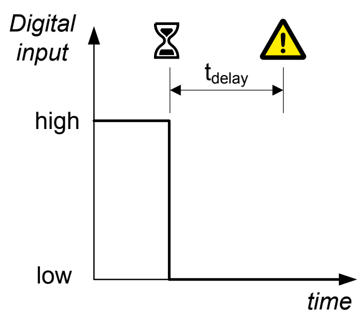
Additional protections for GENSET controller

Controller alarm	Parameters	General name
Vector shift	`Busbar > Additional protections > Vector shift`	Vector shift
ROCOF (df/dt)	`Busbar > Additional protections > ROCOF (df/dt)`	ROCOF (df/dt)

9.9.6 Emergency stop

You can configure one of the controller's digital inputs as the emergency stop.

The alarm action is *Trip generator breaker and shutdown engine*, latch enabled.



Function	I/O	Type	Details
`Alarm system > Additional functions > Emergency stop`	Digital input	Continuous	Wire the emergency stop digital input so that it is normally activated. If the emergency stop digital input is not activated, then controller activates the *Emergency stop* alarm.

CAUTION

The Emergency stop is part of the safety chain

The *Emergency stop* is part of the safety chain, and this digital input function should only be used to inform the controller of the emergency stop. However, the controller's emergency stop input cannot be used as the system's only emergency stop. For example, if the controller is unpowered, it cannot respond to the emergency stop digital input.

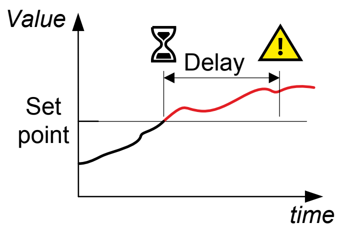
`Engine > Emergency stop > Emergency stop`

Parameter	Range
`Delay`	0.0 s to 1 min

9.9.7 Overspeed

These two alarms are for overspeed protection.

The alarm response is based on the genset speed, as measured by the MPU/W/NPN/PNP input.



`Engine > Protections > Speed > Overspeed # *`

In addition to these overspeed alarms, one of the controller's digital inputs can be connected to hardware that detects overspeed. A customised alarm for overspeed can then be configured on that digital input.

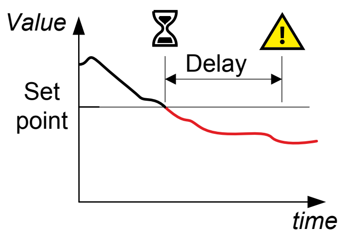
Parameter	Range
`Set point`	10.0 to 150.0 % of nominal speed
`Delay`	0.0 s to 3 min

NOTE * # is 1 or 2.

9.9.8 Underspeed

This alarm alerts the operator that a genset is running too slowly.

The alarm response is based on the engine speed as a percentage of the nominal speed. If the engine speed drops below the set point for the delay time, then the alarm is activated.



Engine > Protections > Speed > Under-speed # *

Parameter	Range
Set point (lower than)	0.0 to 100.0 % of nominal speed
Delay	0.0 s to 3 min

NOTE * # is 1 or 2.

9.9.9 Oil pressure

This alarm is activated if the oil pressure exceeds the set point.

Engine > Protections > Pressure > Oil pressure # *

Parameter	Range
Set point	0.0 to 10.0 bar
Delay	0.0 s to 3 min

NOTE * # is 1 or 2.

9.9.10 Oil temperature

This alarm is activated if the oil temperature exceeds the set point.

Engine > Protections > Temperature > Oil temperature # *

Parameter	Range
Set point	0.0 to 200.0 °C
Delay	0.0 s to 3 min

NOTE * # is 1 or 2.

9.9.11 Coolant temperature

This alarm is activated if the coolant temperature exceeds the set point.

Engine > Protections > Temperature > Coolant temperature # *

Parameter	Range
Set point	0.0 to 200.0 °C
Delay	0.0 s to 3 min

NOTE * # is 1 or 3.

9.9.12 Coolant level

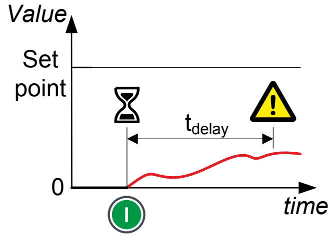
This alarm is activated if the coolant level is under the set point.

Engine > Protections > Level > Coolant level # *

Parameter	Range
Set point	0.0 to 100.0 %
Delay	0.0 s to 3 min

NOTE * # is 1 or 3.

9.9.13 Crank failure



The alarm response is based on the MPU/W/NPN/PNP input. This alarm is only available if the magnetic pickup (MPU) has been chosen as the primary running feedback.

The timer starts when cranking starts (that is, when the *Crank* output is activated). The alarm is activated if the set point has not been reached within the delay time.

`Engine > Start sequence > Crank failure`

Parameter	Range
`Set point` (lower than)	1 to 400 RPM
`Delay`	0.0 to 20.0 s

9.9.14 Running detection not reached

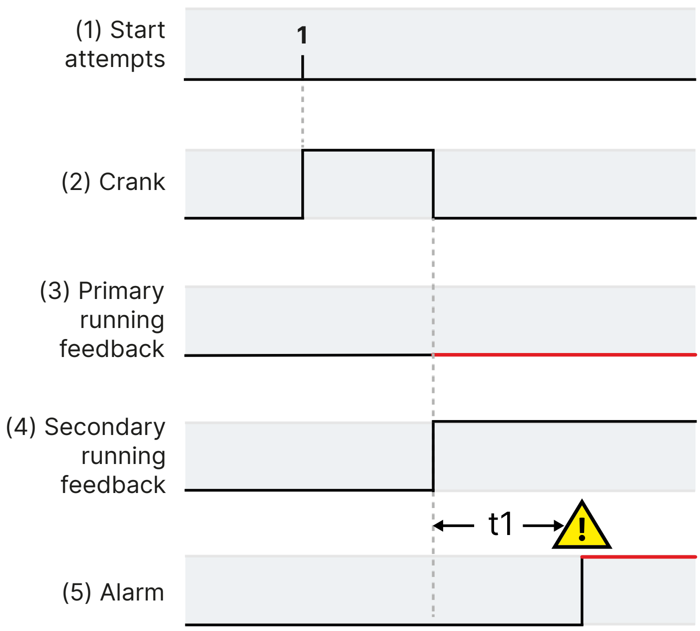
This alarm is activated if the running detection level is not reached.

`Engine > Start sequence > Running detection not reached`

Parameter	Range
`Run detection not reached`	1 s to 20 min

9.9.15 Primary running feedback failure

This alarm is for genset running feedback failure. This alarm is only available if more than one running feedback is present. The alarm is activated if running is detected on any of the secondary running feedbacks but not on the primary running feedback.



The sequence diagram on the right shows how the primary running feedback failure alarm works.

1. **Start attempt**: The controller gets a start signal.
2. **Crank**: The controller activates the *Crank* output.
3. **Primary running feedback**: If the primary running feedback has failed, it does not detect the genset start.
4. **Secondary running feedback**: The secondary running feedback detects the genset start. The crank stops after running is detected. The alarm timer starts when running is detected on the secondary running feedback, but not on the primary running feedback.
5. **Alarm**: If the primary running feedback does not detect that the genset has started within the delay time (t1), the *Primary running feedback failure* alarm is activated.

`Engine > Running detection > Primary running feedback failure`

This alarm is always *Enabled*.

Parameter	Range
`Delay`	0.0 s to 3 min

9.9.16 Magnetic pickup wire break

This alarm is activated if there is a magnetic pickup wire break.

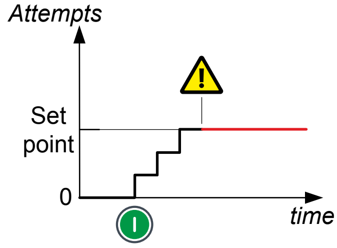
`Engine > Running detection > Magnetic pickup wire break`

Parameter	Range
`Delay`	1 s to 1 h

9.9.17 Start failure

This alarm is for genset start failure.

If the genset has not started after the maximum number of start attempts are completed, the controller activates this alarm.

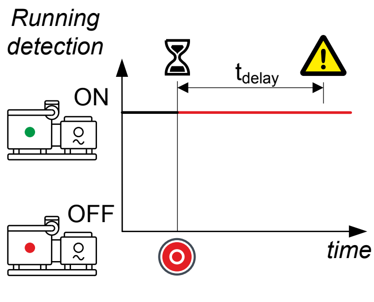


`Engine > Start sequence > Start failure`

9.9.18 Stop failure

This alarm is for genset stop failure.

The controller attempts to stop the genset by activating the *Stop coil* output (if present) or alternatively, by deactivating the *Run coil* output (if present). If *Running detection* is still ON after the delay time, the controller activates this alarm.



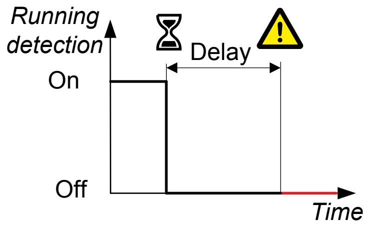
`Engine > Stop sequence > Stop failure`

Parameter	Range
`Delay`	10.0 s to 2 min

9.9.19 Engine stopped (external)

This alarm alerts the operator to an externally-initiated engine stop.

The alarm is activated if the controller did not initiate an engine stop, but *Running detection* shows that the engine has stopped.



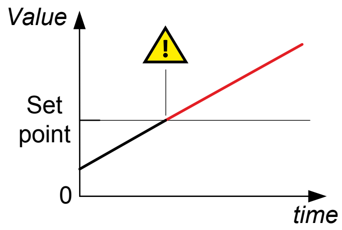
Engine > Stop sequence > Externally stopped

Parameter	Range
`Delay`	1 to 1200 s

9.9.20 Running hours notification

This alarm notifies the operator when the total running hours exceeds the set point.

The alarm response is based on the *Total running hours* counter.



Engine > Maintenance > Service timer > Service timer # *

Parameter	Range
`Set point`	0 to 9000 h

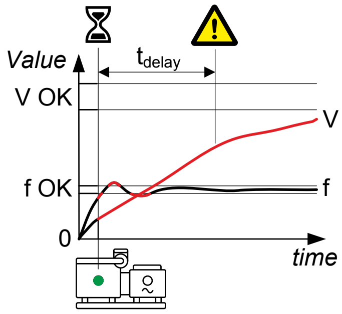
NOTE * # is 1 to 4.

9.9.21 Voltage or frequency not OK

This alarm alerts the operator that the voltage or frequency is not in the required operation range within a specified time after running detection is active.

A delay timer starts when running detection activates. If the voltage and frequency are not in the required operation ranges when the delay timer expires the alarm activates.

The alarm response is based on the voltage and frequency from the A-side.



[A-side] > AC setup > Voltage or frequency not OK

The alarm action is always *Block*.

Parameter	Range
`Delay`	1 s to 1 h

10. MAINS controller

10.1 About the MAINS controller

A **MAINS** controller controls a mains breaker (MB) to a mains connection, with or without a tie breaker (TB) to a load point.

10.1.1 MAINS controller functions

	Functions
Synchronisation and de-loading	• Broadcast sychronisation/de-loading information for GENSET controllers
Mains	• Configurable supervision
4th current	• Measure mains power or neutral current, and can also be used for protections
Counters	• Display unit counters, to edit or reset ∘ Breaker operations and trips ∘ External breaker operations ∘ Energy export to mains (active and reactive) ∘ Energy import from mains (active and reactive) ∘ Energy differential (active and reactive) • Energy counters with configurable digital outputs (for external counters) ∘ Energy export to mains (active and reactive) ∘ Energy import from mains (active and reactive) ∘ Energy differential (active and reactive)

10.2 MAINS controller principles

10.2.1 Plant mode

You must select the plant mode in the mains controller(s). If there are no BTBs, you only need to set the plant mode in one mains controller. If there are BTBs, set the plant mode in a mains controller in each section. In addition, each mains controller should be in AUTO mode. If a controller is not in AUTO mode, it will not automatically respond to the power management requirements.

`Power management rules > Plant/genset mode > Modes`

Name	Range	Details
`Plant mode`	Island operation Auto mains failure Peak shaving Fixed power Mains power export Load take over	Select the plant mode.
`Mode shift`	Off, On	**Off** **On**

Starting and stopping power management of the MAINS controller

Function	I/O	Type	Details
`Mains > Command > Start`	Digital input	Pulse	Start power management of the mains.
`Mains > Command > Stop`	Digital input	Pulse	Stop power management of the mains.

More information
See **Auto start/stop** in the **Power management** chapter for how to enable automatic power management of the mains.

10.2.2 MAINS controller nominal settings

`Mains > Nominal settings > Nominal settings # *`

Nominal setting	Range	Notes
`Voltage (V)`	100.0 V to 25 kV	The phase-to-phase** nominal voltage for the **MAINS** controller.
`Current (I)`	1.0 A to 9 kA	The maximum current flow in one phase (that is, L1, L2 or L3) during normal operation.
`Frequency (f)`	45.00 to 62.00 Hz	The system nominal frequency. All the controllers in the system should have the same nominal frequency.
`Power (P)`	10.0 kW to 20 MW	Configure the value according to the mains connection. Set the value to ensure the mains connection over-power protection is triggered at the correct time.
`Apparent power (S)`	12.5 kVA to 25 MVA	Mains connection apparent power.
`Power factor (PF)`	0.8000 to 1.0000	Mains connection power factor.

NOTE * # is 1 to 4.
NOTE ** In a single-phase set up the nominal AC voltage is phase-to-neutral.

The controller uses the nominal settings to calculate the nominal reactive power (nominal Q) for the mains connection. The controller can be configured to calculate the nominal active power (nominal P) or the nominal apparent power (nominal S). In this case, the controller uses the calculated values, and ignores any entered values.

More information
See Nominal power calculations.

10.2.3 Mains synchronisation controls

The mains controller parameters and breaker positions determine whether the power management system will synchronise across a breaker.

NOTE These parameters are also in genset controllers. When there is a mains controller, the power management ignores the genset controller settings.

`Local power management rules > Mains configuration > Controls`

Name	Range	Details
`Back synchronisation`	Not enabled, Enabled	**Not enabled**: Power management will not synchronise across the MB to the busbar. The MB can however close if the TB is open, since no synchronisation is required. If gensets are connected to the busbar, the TB cannot close if the MB is closed, since that would require back synchronisation. **Enabled**: Power management can synchronise across the MB to the busbar. If the MB is closed, power management can also synchronise across the TB to the busbar.
`Synchronisation to mains`	Not enabled, Enabled	**Not enabled**: Power management will not synchronise across the GB to the mains. The GB can however close if the MB is open,since no synchronisation is required. **Enabled**: Power management can synchronise across the GB to the mains.

10.2.4 Voltage and frequency OK

Use these parameters to configure the voltage and frequency OK range. You can use digital outputs to monitor the voltage and frequency OK status.

Digital outputs

Function	I/O	Type	Details
`Mains > State > Voltage and frequency OK`	Digital output	Continuous	The controller activates this output when the mains side voltage and frequency are okay.
`Mains > State > No voltage and frequency`	Digital output	Continuous	The controller activates this output when the mains side has no voltage and frequency.
`Busbar > State > Voltage and frequency OK`	Digital output	Continuous	The controller activates this output when the busbar side voltage and frequency are okay.
`Busbar > State > No voltage and frequency`	Digital output	Continuous	The controller activates this output when the busbar side has no voltage and frequency.

`Local power management > Mains configuration > Voltage and frequency OK`

Name	Range	Details
`Low voltage hysteresis`	0 to 70 % of nominal voltage	If the voltage has been below the low voltage set point, the voltage has to rise above the set point by the hysteresis voltage before the controller can treat the voltage as okay.
`High voltage hysteresis`	0 to 20 % of nominal voltage	If the voltage has been above the high voltage set point, the voltage has to drop below the set point by the hysteresis voltage before the controller can treat the voltage as okay.
`Low frequency hysteresis`	0.0 to 20.0 % of nominal frequency	If the frequency has been below the low frequency set point, the frequency has to rise by the hysteresis frequency before the controller can treat the frequency as okay.
`High frequency hysteresis`	0.0 to 20.0 % of nominal frequency	If the frequency has been above the high frequency set point, the frequency has to drop by the hysteresis frequency before the controller can treat the frequency as okay.
`Voltage failure delay`	0.5 s to 16.5 min	The voltage failure sequence is activated if the voltage stays outside the required range for the duration of this timer.
`Voltage OK delay`	2 s to 165 min	The voltage must stay inside the required range for the duration of this timer before the controller can treat the voltage as okay.
`Low voltage`	30 to 100 % of nominal voltage	The low set point for the voltage okay range.
`High voltage`	100 to 130 % of nominal voltage	The high set point for the voltage okay range.
`Voltage failure sequence`	Start engine and open MB, Start engine	**Start engine and open MB**: If there is a voltage failure, the power management starts a genset and opens the mains breaker. **Start engine**: If there is a voltage failure, the power management starts a genset.
`Unbalance voltage`	2 to 100 %	The voltage unbalance must be below this set point before the controller can treat the voltage as okay. The voltage unbalance protection calculation is used.
`Frequency failure delay`	0.5 s to 16.5 min	The frequency failure alarm is activated if the frequency stays outside the required range for the duration of this timer.
`Frequency OK delay`	2 s to 165 min	The frequency must stay inside the required range for the duration of this timer before the controller can treat the frequency as okay.

Name	Range	Details
`Low frequency`	80.0 to 100.0 % of nominal frequency	The low set point for the frequency okay range.
`High frequency`	100.0 to 120.0 % of nominal frequency	The high set point for the frequency okay range.

10.2.5 Multiple mains

The controller can be used in an application with multiple mains connection. Each connection must have its own MAINS controller.

`Local power management > Mains configuration > Controls`

Name	Range	Details
`Parallel`	Not enabled, Enabled	**Not enabled**: The mains connection cannot run in parallel with mains connections. That is, the mains breaker cannot close if any other mains breakers are closed. If the tie breakers (TBs) in the section are normally closed, then only one of the tie breakers can be closed. The system tries to keep the TB closed for the *ID to run*. If *ID to run* does not have a TB configured as a normally closed breaker, or if it fails to close it, then, for the mains controller with the lowest ID without TB failures present, the system closes the TB. **Enabled**: The mains connection can run in parallel with mains connections.
`No break transfer`	Not enabled, Enabled	**Not enabled**: The controllers use a blackout change-over to switch between mains connections. **Enabled**: The controllers use a synchronised change-over to switch between mains connections.
`Auto switch`	Off, Static section, Dynamic section, All section	This parameter determines whether a mains controller detecting a mains failure tries to get the connected load supplied by sources in its own busbar section, or all sections. Busbar sections are created by bus tie breakers (BTBs). If no BTBs are installed, then there is no difference between selecting static, dynamic, and all section. **Off**: A mains failure does not specifically activate an automatic power source switch. **Static section**: The back-up power must come from the power sources in the same static section as the controller. **Dynamic section**: The back-up power must come from the same dynamic section as the controller. The application never tries to synchronise/close a BTB to get help in an AMF situation. Note: If *Dynamic section* is selected, one mains controller can be requested to carry the whole load of the dynamic section, without any help from the gensets. The mains connection(s) must therefore be able to carry the load from the entire section. **All section**: The back-up power can come from all available sections.
`Run type`	Run one mains, Run all mains	**Run one mains**: Only one mains breaker in the section can be closed at a time. If other TBs in the section are closed, they will be tripped so that only the TB of *ID to run* is closed. If no TB is available in the section, the MB will be tripped (causing a blackout). **Run all mains**: All mains breakers can be closed at the same time. If the *Run type* is changed during operation, then the *Parallel* setting determines whether there is a blackout or a synchronised change-over.
`ID to run`	1 to 32	The mains to connect when the *Run type* is *Run one mains*.
`MB failure start`	Not enabled, Enabled	**Not enabled**: A mains breaker close failure does not specifically activate genset start(s). **Enabled**: The system must start genset(s) if there is a mains breaker close failure. Mode shift is also automatically enabled.
`Exclude run all`	Not enabled, Enabled	**Not enabled**: If the *Run type* is *Run all mains*, this controller's mains breaker can be closed. **Enabled**: If the *Run type* is *Run all mains*, this controller's mains breaker cannot be closed.

10.2.6 External regulation of the mains

You can use parameters configure the mains regulation settings in the mains controller. You can use an analogue input for external regulation of the mains, as well as digital inputs to activate or deactivate different regulation.

Inputs and outputs

Function	I/O	Type	Details
`Mains > External set points > Power set point [%]`	Analogue input	-	If external power is activated, the controller calculates the external set point by using this input to multiply the *Mains power* set point.
`Mains > External set points > Activate external power`	Digital input	Pulse	After this input is activated, the controller uses the analogue input to regulate the mains power set point.
`Mains > External set points > Deactivate external power`	Digital input	Pulse	After this input is activated, the controller does not use the analogue input to regulated the mains power set point.
`Mains > Set point offsets > Active power > Activate offset [1 to 3]`	Digital input	Continuous	When input [1 to 3] is activated, the controller subtracts the active power offset [1 to 3] from the power set point.
`Mains > Set point offsets > Cos phi > Activate offset [1 to 3]`	Digital input	Continuous	When input [1 to 3] is activated, the controller adds cos phi offset [1 to 3] to the cos phi set point.

`Power management rules > Mains power > External set points`

Name	Range	Details
`Mains power`	-20 000 kW to 20 000 kW	Mains power set point. Use positive values for power from the mains connection.
`Mains power`	-100 to 100 % of nominal power	Mains power set point. Use positive values for power from the mains connection.
`Mains power`	In percent, In kW	**In percent**: The value configured in percent is used. **In kW**: The value configured in kW is used.

`Power management rules > Mains power > Settings`

Name	Range	Details
`Controller settings cos phi`	0.700 to 1.000	The cos phi set point.
`Controller settings cos phi`	Inductive, Capacitive	**Inductive**: The cos phi set point is inductive. **Capacitive**: The cos phi set point is inductive.
`Controller settings cos phi`	• Off • Fixed for DG(s) • Fixed for import/ export	**Off**: Power management ignores the cos phi set point. **Fixed for DG(s)**: Power management makes the gensets use the cos phi set point in the mains controller. **Fixed for import/export**: Power management regulates the gensets so that the mains export/import cos phi meets the set point in the mains controller.

`Power management rules > Mains power > Active power`

Name	Range	Details
`Offset [1 to 3]`	-100.0 to 100.0 % of nominal power	The controller offsets the mains power external set point by this amount.

`Power management rules > Mains power > Fixed cos phi offset`

Name	Range	Details
`Offset [1 to 3]`	0.0000 to 1.0000	The controller offsets the mains cos phi set point by this amount.
`Offset [1 to 3]`	Inductive, Capacitive	**Inductive**: The cos phi offset is inductive. **Capacitive**: The cos phi offset is inductive.

10.2.7 Mains test

The test mode is activated by activating a digital input. The test stops automatically when the test timer runs out.

Digital input

Function	I/O	Type
`Local > Mode > Test`	Digital input	Pulse

`Power management rules > Mains power > Mains test`

Name	Range	Details
`Test`	1 to 20000 kW	The power from the mains during the test.
`Test`	0 s to 999 min	The test duration.
`Test type`	Simple test, Load test, Full test	**Simple test**: The power management system starts a genset and runs it at nominal frequency with the generator breaker open. The test runs until the timer expires. **Load test**: If the mains breaker is open, the controllers synchronise to the mains, and close the mains breaker. The system runs at the specified power from the mains for the test duration. To run the load test, synchronisation to mains must be enabled. **Full test**: If the mains breaker is open, the controllers synchronise to the mains and close the mains breaker. The power management controls the power from the mains for the test duration. To run the load test, synchronisation to mains must be enabled.
`Return mode`	Manual, Auto, No mode change	The MAINS controller mode after the test.

10.3 Mains breaker

10.3.1 How it works

The mains breaker (MB) connects the mains to the busbar. The mains breaker is an important part of the system safety, and trips to protect the busbar from mains problems. The mains breaker also trips to stop busbar problems from disturbing the mains.

For the **MAINS** controller, the breaker abbreviation (*[*B]*) is *MB*. *[Breaker]* refers to *Mains breaker*.

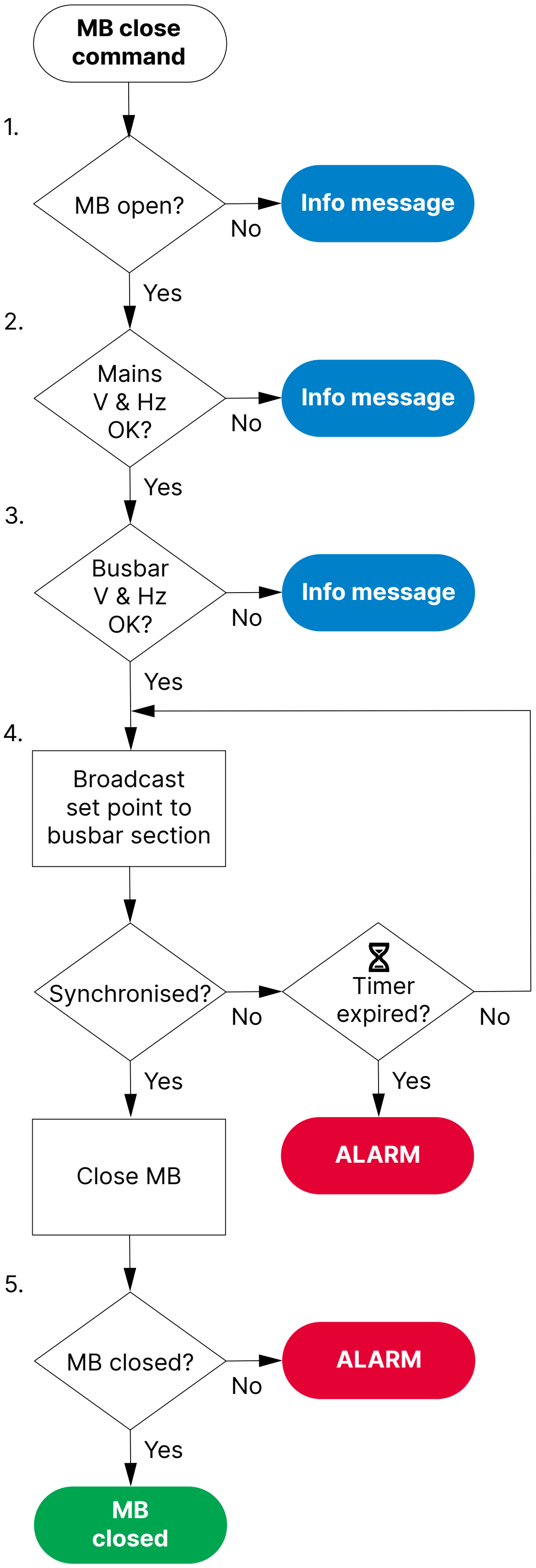
10.3.2 Mains breaker synchronisation

When the breaker close button is pressed, the **MAINS** controller tries to synchronise and close the breaker.

Regardless of the regulation, if the synchronisation requirements are met (within the time available for synchronisation), the controller automatically closes the breaker.

More information
See Breakers, synchronisation and de-loading for synchronisation and breakers. This includes the inputs and output functions and the parameters to configure.

10.3.3 Mains breaker close flowchart



1. **MB open**: The controller checks whether the breaker is open. If the breaker is already closed, the sequence stops, and an info message is shown.
2. **Mains V & Hz OK**: The controller checks whether the voltage and frequency are within the allowed range*. If these are not in the range, then the controller cancels the close command and displays an info message.
3. **Busbar V & Hz OK**:
   - The controller checks whether the voltage and frequency on the busbar are within range*. If these are not in the range, then the controller cancels the close command and displays an information message.
   - See Mains breaker blackout close flowchart for more information.
4. **Broadcast set point to busbar section**: The controller broadcasts the required set point on the busbar section.
   - If the mains and busbar are synchronised, the controller activates the `Breakers > Mains breaker > Controls > MB close` output to close the breaker.
   - If the mains and busbar do not synchronise within the time allowed, the controller activates an *MB synchronisation failure* alarm.
5. **MB closed**: The controller checks whether the breaker has closed.
   - If the breaker has closed, the breaker close sequence has been completed successfully.
   - If the breaker has not closed, the controller activates the *MB closing failure* alarm.

NOTE * See `Local power management / Mains configuration > Voltage and frequency OK` and `Busbar > AC setup > Voltage and frequency OK` for these ranges.

More information
See Mains breaker blackout close flowchart for information about how to allow the **MAINS** controller to connect to a dead busbar.

10.3.4 Mains breaker de-loading

When the breaker open button is pressed, the **MAINS** controller checks whether regulation is possible in the busbar section connected to the mains breaker. If regulation is not possible, the controller trips the breaker (without de-loading).

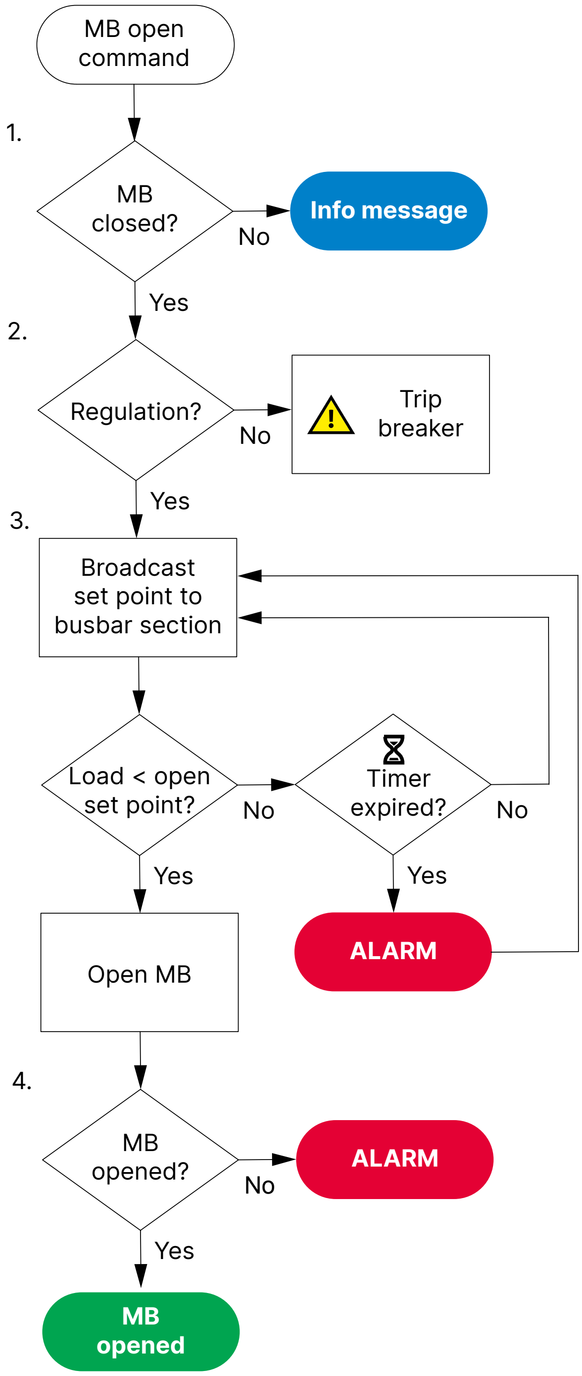
If regulation is possible, the **MAINS** controller tries to de-load and open the breaker.

The **MAINS** controller broadcasts the de-loading set points for the **GENSET** controllers in the busbar section connected to the mains breaker. The **GENSET** controller(s) with active regulation modes automatically respond to de-loading set points from the **MAINS** controller. When the mains breaker is open, the **GENSET** controllers return to their previous regulation modes.

The set points from the **MAINS** controller are ignored by **GENSET** controllers in these cases:
- The **GENSET** controller is in fixed power mode, with set point adjustment locked.
- The **GENSET** controller regulation is off.
- The **GENSET** controller is under *Manual regulation*. However, the mains breaker can be de-loaded manually.

10.3.5 Mains breaker open flowchart

The alarm action *Block* does not open a closed breaker, although it stops an open breaker from closing. If the controller or an operator sends an MB open command while *Block* is active, the controller uses this sequence.



1. **MB closed**: The controller checks whether the breaker is closed. If the breaker is open, the sequence ends.
2. **Regulation**: The controller checks whether regulation is possible in the sections connected to the bus tie breaker.
   - If regulation is not possible, the controller trips the breaker.
   - If regulation is possible, the controller tries to de-load the breaker.
3. **Broadcast set point to busbar section**: The controller broadcasts the required set point on the busbar section.
   - When the load is less than the set point for the breaker to open, the controller activates the `Breakers > Mains breaker > Controls > MB open` output.
   - If the controller cannot de-load the breaker before the de-load timer expires, the controller activates the *MB de-load failure* alarm. The controller continues to try to de-load the breaker.
4. **MB opened**: The controller checks whether the breaker has opened:
   - If the breaker has opened, the mains breaker open sequence has been completed successfully.
   - If the breaker has not opened, the controller activates the *MB opening failure* alarm.

CAUTION

Possible blackout

Opening the mains breaker may cause a blackout.

10.3.6 Mains breaker blackout close flowchart

Blackout conditions

A blackout is present if the phase-to-phase voltage is less than 10 % of the nominal voltage (V_{L-L} < 10 % of V_{nom}). This percentage is fixed.

Conditions that prevent blackout close

If any of the following conditions are present, the controller will not start the blackout close:

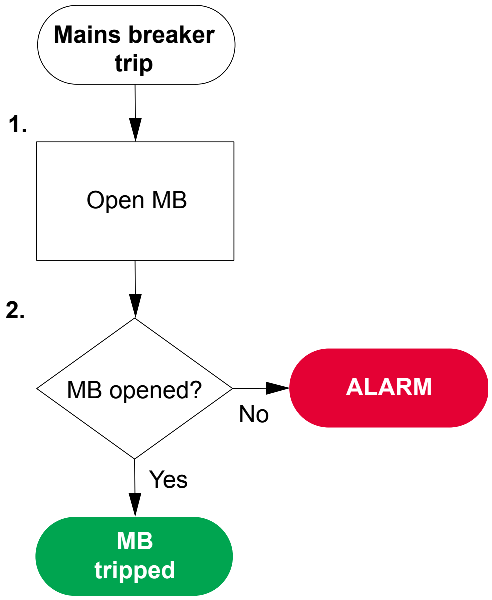
- The breaker position is unknown.
- There is a short circuit.
  - A digital input with the function `Breakers > Mains breaker > Feedback > MB short circuit` was activated.
- There is a blocking alarm.
  - The alarm action determines whether the alarm is a blocking alarm.
- The busbar AC measurements are not OK.
  - A measurement failure is detected on one or more of the phases of the busbar.
- The `Busbar > AC setup > Blackout detection > Blackout delay` timer has not expired.

10.3.7 Mains breaker trip flowchart

The controller automatically trips the mains breaker (MB) for this alarm action:

- Trip mains breaker

The breaker is not de-loaded for a trip.



1. **Open MB**: When a trip is required, the controller activates the `Breakers > Mains breaker > Controls > MB open` output to open the breaker.
2. **MB opened**: The controller checks whether the breaker has opened:
   - If the breaker has opened, the trip is successful.
   - If the breaker has not opened, the controller activates the *MB opening failure* alarm.

10.4 Tie breaker

10.4.1 How it works

The tie breaker (TB) connects a load point to the busbar. The tie breaker is an important part of the system safety, and trips to protects both busbars from problems. The tie breaker also trips to stop busbar problems from disturbing the other busbar.

For the **MAINS** controller, the breaker abbreviation (*[*B]*) is *TB*. *[Breaker]* refers to *Tie breaker*.

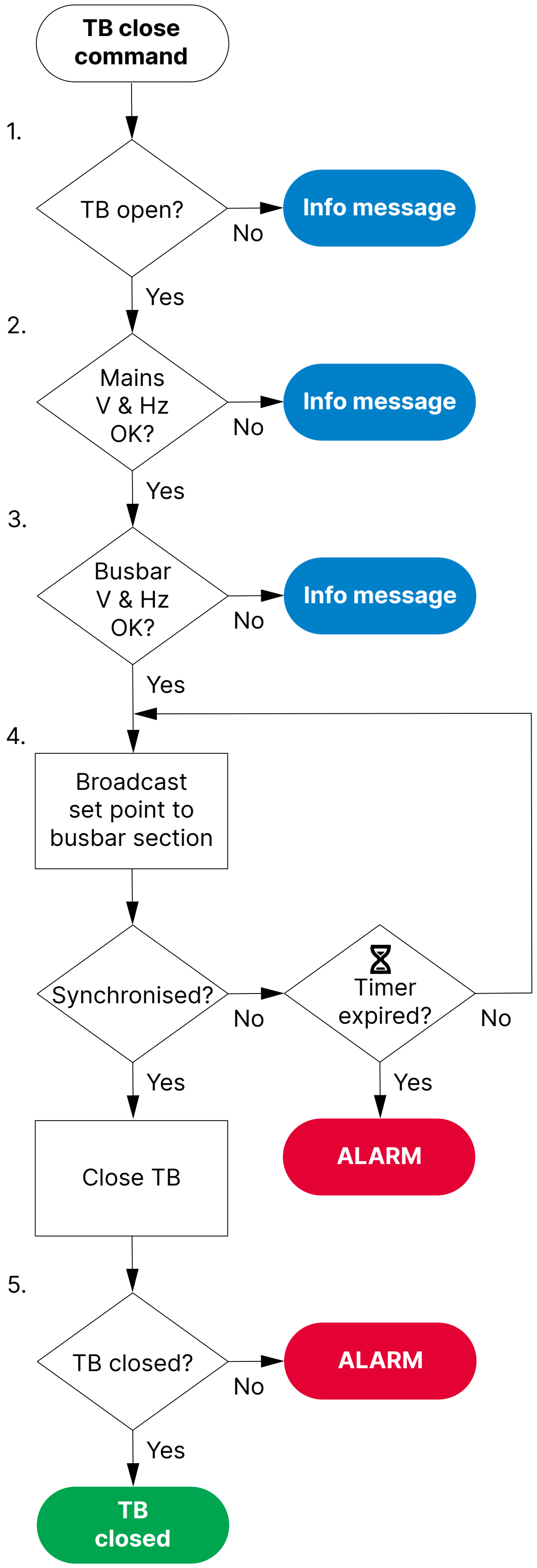
10.4.2 Tie breaker synchronisation

When the tie breaker close button is pressed, the **MAINS** controller tries to synchronise and close the tie breaker.

Regardless of the regulation, if the synchronisation requirements are met (within the time available for synchronisation), the controller automatically closes the breaker.

More information
See Breakers, synchronisation and de-loading for synchronisation and breakers. This includes the inputs and output functions and the parameters to configure.

10.4.3 Tie breaker close flowchart



1. **TB open**: The controller checks whether the breaker is open. If the breaker is already closed, the sequence stops, and an info message is shown.
2. **Mains V & Hz OK**: The controller checks whether the voltage and frequency are within the allowed range*. If these are not in the range, then the controller cancels the close command and displays an info message.
3. **Busbar V & Hz OK**: Subject to the *Blackout close* parameter:
   - The controller checks whether the voltage and frequency on the busbar are within range*. If these are not in the range, then the controller cancels the close command and displays an information message.
4. **Broadcast set point to busbar section**: The controller broadcasts the required set point on the busbar section.
   - If busbar A and busbar B are synchronised, the controller activates the `Breakers > Tie breaker > Control > TB close` output to close the breaker.
   - If busbar A and busbar B do not synchronise within the time allowed, the controller activates an *TB synchronisation failure* alarm.
5. **TB closed**: The controller checks whether the breaker has closed.
   - If the breaker has closed, the breaker close sequence has been completed successfully.
   - If the breaker has not closed, the controller activates the *TB closing failure* alarm.

NOTE * See `Local power management / Mains configuration > Voltage and frequency OK` and `Busbar > AC setup > Voltage and frequency OK` for these ranges.

10.4.4 Tie breaker de-loading

When the tie breaker open button is pressed, the **MAINS** controller checks whether regulation is possible in the busbar sections connected to the tie breaker. If regulation is not possible, the controller trips the breaker (without de-loading).

If regulation is possible, the **MAINS** controller tries to de-load and open the breaker.

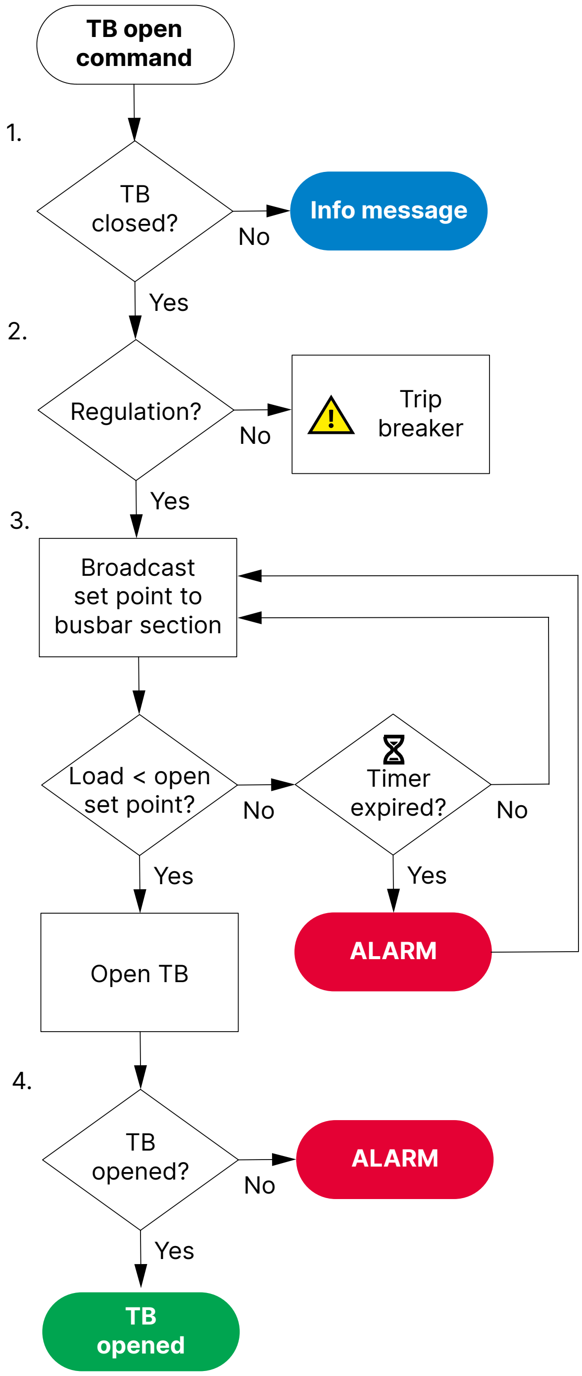
The **MAINS** controller broadcasts de-loading set points for the **GENSET** controllers in the busbar sections connected to the tie breaker. The **GENSET** controller(s) with active regulation modes ignore their regulation modes and automatically respond to de-loading set points from the **MAINS** controller. When the tie breaker is open, the **GENSET** controllers return to their previous regulation modes.

The set points from the **MAINS** controller are ignored by **GENSET** controllers in these cases:

- The **GENSET** controller is in fixed power mode, with set point adjustment locked.
- The **GENSET** controller regulation is off.
- The **GENSET** controller is under *Manual regulation*. However, the bus tie breaker can be de-loaded manually.

10.4.5 Tie breaker open flowchart

The alarm action *Block* does not open a closed breaker, although it stops an open breaker from closing. If the controller or an operator sends an TB open command while *Block* is active, the controller uses this sequence.



1. **TB closed**: The controller checks whether the tie breaker is closed. If the tie breaker is open, the sequence ends.
2. **Regulation**: The controller checks whether regulation is possible in the sections connected to the tie breaker.
   - If regulation is not possible, the controller trips the tie breaker.
   - If regulation is possible, the controller tries to de-load the tie breaker.
3. **Broadcast set point to busbar section**: The controller broadcasts the required set point on the busbar section.
   - When the load is less than the set point for the tie breaker to open, the controller activates the `Breakers > Tie breaker > Controls > TB open` output.
   - If the controller cannot de-load the tie breaker before the de-load timer expires, the controller activates the *TB de-load failure* alarm. The controller continues to try to de-load the tie breaker.
4. **TB opened**: The controller checks whether the tie breaker has opened:
   - If the tie breaker has opened, the mains breaker open sequence has been completed successfully.
   - If the tie breaker has not opened, the controller activates the *TB opening failure* alarm.

CAUTION

Possible blackout

Opening the tie breaker may cause a blackout.

10.4.6 Tie breaker blackout close flowchart

DANGER!

Incorrect blackout close settings

Incorrect blackout close parameter settings can lead to equipment damage or loss of life.

Blackout conditions

A blackout is present if the phase-to-phase voltage is less than 10 % of the nominal voltage (V_{L-L} < 10 % of V_{nom}). This percentage is fixed.

Conditions that prevent blackout close

If any of the following conditions are present, the controller will not start the blackout close:

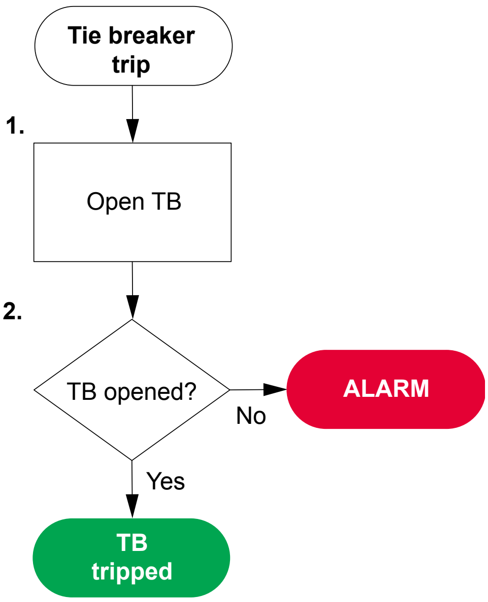
- The breaker position is unknown.
- There is a short circuit.
  - A digital input with the function `Breakers > Tie breaker > Feedback > TB short circuit` was activated.
- There is a blocking alarm.
  - The alarm action determines whether the alarm is a blocking alarm.
- The busbar AC measurements are not OK.
  - A measurement failure is detected on one or more of the phases of the busbar.
- The `Busbar > AC setup > Blackout detection > Blackout delay` timer has not expired.

10.4.7 Tie breaker trip flowchart

The controller automatically trips the tie breaker (TB) for this alarm action:

- Trip tie breaker

The breaker is not de-loaded for a trip.



1. **Open TB**: When a trip is required, the controller activates the `Breakers > Tie breaker > Controls > TB open` output to open the breaker.
2. **TB opened**: The controller checks whether the breaker has opened:
   - If the breaker has opened, the trip is successful.
   - If the breaker has not opened, the controller activates the *TB opening failure* alarm.

10.4.8 Tie breaker controls

In the *Application configuration*, you can configure the tie breaker as normally closed or normally open.

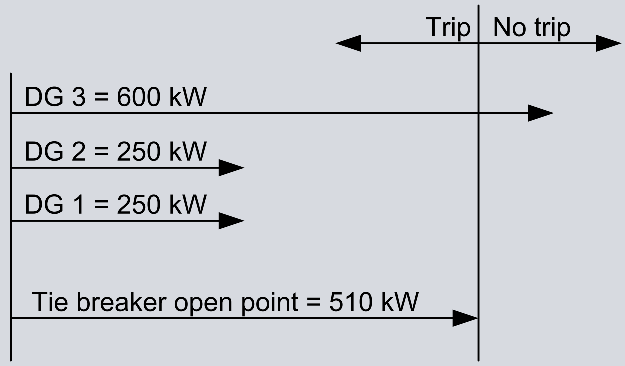
`Local power management > Mains configuration > Controls`

Name	Range	Details
`TB de-load before GB`	Not enabled, Enabled	**Not enabled**: The gensets are deloaded and the GB(s)open before the TB. **Enabled**: The tie breaker is deloaded and opens before the GB(s). This is also known as deload TB back synchronisation.
`TB open point`	0 to 20000 kW	If the gensets are running parallel to mains and the mains breaker trips, the controller might have to also trip the tie breaker. If the running gensets cannot supply the load

Name	Range	Details
		specified by *TB open point*, then the tie breaker opens. The tie breaker can close again when the *Power capacity* is reached. See the example below.
`Power capacity`	1 to 20000 kW	The *Power capacity* is used in AMF applications to determine how much power must be available, before the tie breaker can close. When the gensets are started, the generator breakers will close. When the power specified in *Power capacity* is available, then the tie breaker will be closed. If there is more than one tie breaker in the power management system, the tie breaker with the lowest power capacity is closed first.
`Power capacity overrule`	0.0 to 999.9 s	If some of the gensets fail to start and the power capacity set point is not reached, the tie breaker will never be closed. It is therefore possible to overrule the power capacity set point after the *Power capacity overrule* timer runs out. The timer starts after one of the gensets has a fault with a fail class that stops the genset from connecting to the busbar.
`Power capacity overrule`	Not enabled, Enabled	**Not enabled**: The power capacity set point cannot be overruled. **Enabled**: The power capacity set point can be overruled.

TB open point example

In the diagram below, the nominal powers of gensets DG 1, DG 2, and DG 3 are shown. The tie breaker trips if DG1 or DG2 is connected to the load, because the nominal power is less than 510 kW. If DG1 and DG2 are running together, the tie breaker also trips, because their combined nominal power is still less than 510 kW. If, however, DG3 is running alone or together with one of the two smaller DGs, then the tie breaker does not trip, because the total nominal power is more than 510 kW.



10.5 Other MAINS controller functions

10.5.1 Counters

You can view, edit and reset all the counters on the display unit under `Configure > Counters`. The counters include:

- Mains connection breaker operations and trips
- Active and reactive energy export (to grid)
- Active and reactive energy import (from grid)
- Active and reactive energy differential
- External breaker operations

Energy counter digital outputs

For each energy counter, you can configure a digital output to send a pulse every time a certain amount of energy is transferred.

Digital outputs

You must configure the digital output function to see the parameters.

Function	I/O	Type
`Mains > Production counters > Active energy export pulse`	Digital output	Pulse
`Mains > Production counters > Reactive energy export pulse`	Digital output	Pulse
`Mains > Production counters > Active energy import pulse`	Digital output	Pulse
`Mains > Production counters > Reactive energy import pulse`	Digital output	Pulse

Parameters

`Mains > Production counters > Active energy export`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Mains > Production counters > Reactive energy export`

Parameter	Range	Comment
`Pulse every`	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Mains > Production counters > Active energy import`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Mains > Production counters > Reactive energy import`

Parameter	Range	Comment
`Pulse every`	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Mains > Production counters > Active energy differential`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Mains > Production counters > Reactive energy differential`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Production counter function and corresponding parameter full names

[Counter pulse]	[Counter]
Active energy export pulse	Active energy export
Reactive energy export pulse	Reactive energy export
Active energy import pulse	Active energy import
Reactive energy import pulse	Reactive energy import
Active energy differential pulse	Active energy differential
Reactive energy differential pulse	Reactive energy differential

Application example for an energy counter output

1. Connect the digital output to an external counter.
2. Configure the digital output using the display unit or PICUS to *Active energy export pulse*.
3. Configure the *Pulse every* parameter to the value where you would like to send a pulse. For example, 100 kWh.
4. Configure the *Pulse length* to the required length of the pulse for your external counter. For example, 1 second.

With the example setup the controller sends a 1 second pulse to the external counter for each 100 kWh the controller logs.

10.5.2 Mains supervision

You can set up parameters for mains supervision. If there is a mains error (voltage or frequency outside the configured limits), then the controller can activate an alarm to open the breaker (to protect the asset). The controller can also show the mains status using digital outputs.

Parameters

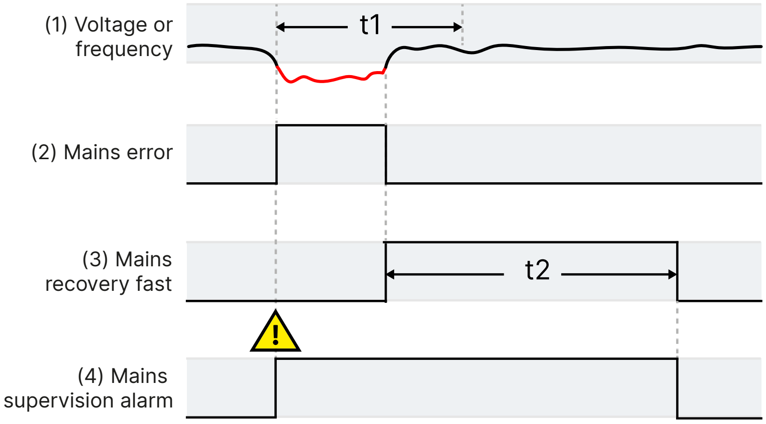
`Mains > AC setup > Supervision selector`

Parameter	Range	Notes
`Enable supervision`	Not enabled, Enabled	**Not enabled**: No mains supervision. **Enabled**: The controller can activate the mains supervision alarm. The mains supervision digital outputs show the mains supervision status.
`Recovery selector time`	0.1 s to 1 h	If the mains error lasts for less than this time, then *Recovery time fast* is used. If the error lasts for longer than this time, then *Recovery time slow* is used.
`Recovery time fast`	0.1 s to 1 h	This is used if the mains error stops within the *Recovery selector time*. The timer starts when the mains error stops.
`Recovery time slow`	0.1 s to 1 h	This is used if the mains error does not stop within the *Recovery selector time*. The timer starts when the mains error stops.
`Voltage low`	80.0 to 100.0 % of nominal voltage	There is a mains error if the mains voltage is below this level.
`Voltage high`	100.0 to 120.0 % of nominal voltage	There is a mains error if the mains voltage is above this level.
`Frequency low`	90.0 to 100.0 % of nominal frequency	There is a mains error if the mains frequency is below this level.
`Frequency high`	100.0 to 110.0 % of nominal frequency	There is a mains error if the mains frequency is above this level.

How it works

These sequence diagrams are examples of how mains supervision works.

Recovery time fast mains error

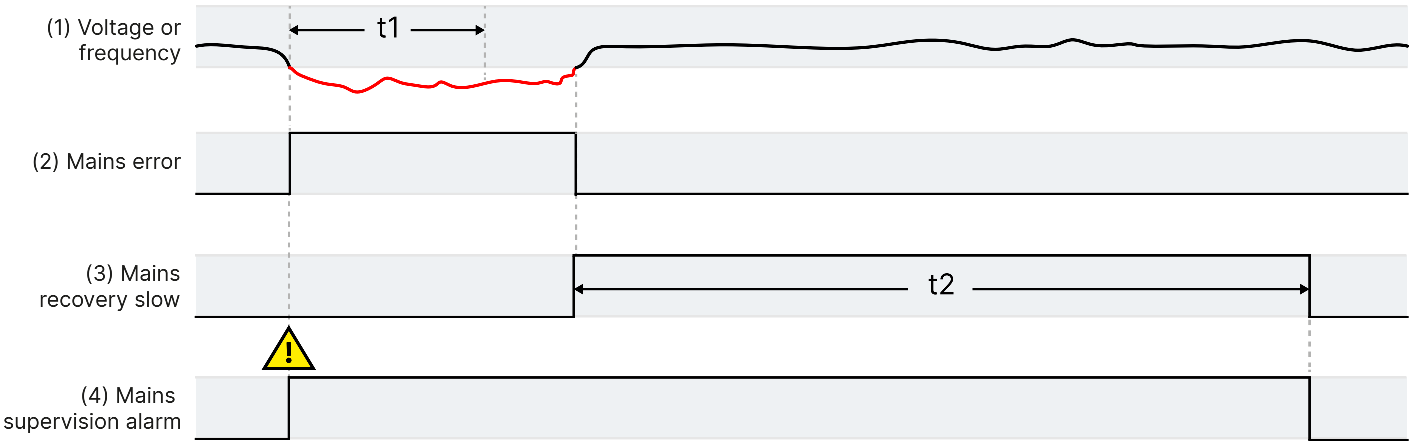


t1 = Recovery selector time (`Mains > AC setup > Supervision selector > Recovery selector time`)

t2 = Recovery time fast (`Mains > AC setup > Supervision selector > Recovery time fast`)

1. **Voltage or frequency**: The mains voltage or frequency is outside the configured limits for less than the *Recovery selector time*. The controller therefore uses the *Recovery time fast*.
2. **Mains error**: `Mains > Supervision > Mains error` (digital output) (optional). The controller activates this digital output while the mains voltage or frequency is outside the configured limits.
3. **Mains recovery fast**: `Mains > Supervision > Mains recovery fast` (digital output) (optional). The controller activates this digital output while the *Recovery time fast* timer is running.
4. **Mains supervision alarm**. The controller activates this alarm while there is a mains error, and while the recovery timer is running.

Recovery time slow mains error



t1 = Recovery selector time (`Mains > AC setup > Supervision selector > Recovery selector time`)

t2 = Recovery time slow (`Mains > AC setup > Supervision selector > Recovery time slow`)

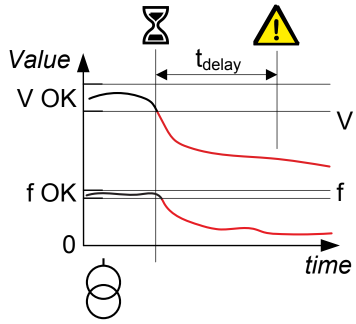
1. **Voltage or frequency**: The mains voltage or frequency is outside the configured limits for more than the *Recovery selector time*. The controller therefore uses the *Recovery time slow*.
2. **Mains error**: `Mains > Supervision > Mains error` (digital output) (optional). The controller activates this digital output while the mains voltage or frequency is outside the configured limits.

3. **Mains recovery slow:** `Mains > Supervision > Mains recovery slow` (digital output) (optional). The controller activates this digital output while the *Recovery time slow* timer is running.
4. **Mains supervision alarm**. The controller activates this alarm while there is a mains error, and while the recovery timer is running.

10.5.3 Mains supervision alarm

The controller activates this alarm if the mains voltage or frequency is outside the range configured under `Mains > AC setup > Supervision selector`.

The alarm remains activated for the recovery time.



`Mains > AC setup > Supervision alarm`

10.5.4 Mains supervision status as digital outputs

You can configure digital outputs with functions for the mains supervision status. The controller activates the digital output when the mains supervision state is activated. These outputs can be useful for troubleshooting.

Digital outputs

Function	I/O	Type	Details
`Mains > Supervision > Mains error`	Digital output	Continuous	Activated when there is a mains error.
`Mains > Supervision > Mains recovery fast`	Digital output	Continuous	Activated during the fast recovery period.
`Mains > Supervision > Mains recovery slow`	Digital output	Continuous	Activated during the slow recovery period.

10.5.5 Short-circuit limitation

Short-circuit limitation is a critical power function to protect a busbar (or busbar section) with multiple sources of power. When short-circuit limitation is active, the power management system does not allow additional sources of power to connect if this would exceed the configured limits. If the configured limits are exceeded, there is a warning alarm.

Short-circuit limitation is especially useful for applications in the low voltage range (400 V) where the short-circuit currents of the transformers and generators are high. These can easily exceed the rated values of the breakers.

`Power management rules > Short circuit > Short-circuit limitation`

Name	Range	Details
`Section P>`	0 kW to 30 GW	Set point for the nominal power allowed on busbar.
`Section P> factor`	1.0 to 25.5	Set point for the weighing of nominal power contribution to short-circuit calculation. This factor can be used if two transformers or generators have the same nominal power values, but different short-circuit values.
`Delay`	0.0 to 999.0 s	Alarm timer when the threshold is exceeded.

Short-circuit limitation example

	The application has four 1500 kW gensets. The *Section P> factor* for Genset 4 is 2.0. The factor for Gensets 1, 2 and 3 is 1.0. The short circuit limitation is 5 MW. Gensets 1, 2 and 3 can be connected simultaneously, since the total nominal power is 4.5 MW. However, if Genset 4 is connected, the weight factor makes its contribution to short-circuit limitation 3 MW. Therefore, to avoid exceeding the short circuit limitation, only one other genset can be connected.

10.5.6 Fuel pump

To keep the level in a tank in the required range, you can use the controller's inputs and outputs to control a pump.

More information
See **Fuel pump** in the **GENSET controller** chapter for details.

10.6 MAINS controller alarms and protections

10.6.1 Alarm actions

The controller has the following alarm actions:
- Warning
- Block
- Trip mains breaker
- Trip tie breaker *

NOTE * Tie breaker actions are only present in **MAINS** controller with mains breaker (MB) and tie breaker (TB).

10.6.2 Inhibits

The controller includes the following inhibits:

Inhibit	Disables the alarm when ...
`Mains breaker closed`	Based on the breaker feedbacks and validation, the mains breaker is closed. *
`Mains breaker open`	Based on the breaker feedbacks and validation, the mains breaker is open. *
`Tie breaker closed` **	Based on the breaker feedbacks and validation, the tie breaker is closed. *
`Tie breaker open` **	Based on the breaker feedbacks and validation, the tie breaker is open. *
`Mains voltage present`	The mains voltage is above 10% of the nominal voltage.
`No mains voltage`	The mains voltage is below 10% of the nominal voltage.
`Mains in parallel`	The busbar section is connected to at least one mains.
`Mains not in parallel`	There are no mains connected to the busbar section.
`Inhibit 1`	The `Alarm system > Inhibits > Activate inhibit 1` digital input is activated.
`Inhibit 2`	The `Alarm system > Inhibits > Activate inhibit 2` digital input is activated.
`Inhibit 3`	The`Alarm system > Inhibits > Activate inhibit 3` digital input is activated.

NOTE * There is no inhibit if there is breaker feedback failure.
NOTE ** Only on **MAINS** controller with mains breaker (MB) and tie breaker (TB).

10.6.3 Breaker alarms

[Breaker] is either **MB** for Mains breaker or **TB** for Tie breaker. *

MAINS alarm	Parameters	General name
[Breaker] synchronisation failure	`Breakers > [Breaker] breaker monitoring > Synchronisation failure`	Breaker synchronisation failure
[Breaker] de-load failure	`Breakers > [Breaker] breaker monitoring > De-load failure`	Breaker de-load failure
[Breaker] vector mismatch	`Breakers > [Breaker] breaker monitoring > Vector mismatch`	Vector mismatch
[Breaker] opening failure	`Breakers > [Breaker] breaker monitoring > Opening failure`	Breaker opening failure
[Breaker] closing failure	`Breakers > [Breaker] breaker monitoring > Closing failure`	Breaker closing failure
[Breaker] position failure	`Breakers > [Breaker] breaker monitoring > Position failure`	Breaker position failure
[Breaker] tripped (external)	`Breakers > [Breaker] breaker monitoring > Tripped (external)`	Breaker trip (external)
[Breaker] short circuit	`Breakers > [Breaker] breaker monitoring > Short circuit`	Breaker short circuit
[Breaker] configuration failure	-	Breaker configuration failure
Phase sequence error mains	`Mains > AC setup > Phase sequence error`	Phase sequence error
Phase sequence error busbar	`Busbar > AC setup > Phase sequence error`	Phase sequence error

NOTE * The Tie breaker (TB) alarms are only present on a **MAINS** controller with mains breaker (MB) and tie breaker (TB).

More information
The Breakers, synchronisation and de-loading for breaker handling and alarms in general.

10.6.4 AC alarms

More information
The **AC configuration and nominal settings** chapter describes AC alarms in general.

The following table shows where to configure these alarms for the **MAINS** controller, as well as which general alarm corresponds to each **MAINS** controller alarm.

Mains AC alarm names for the MAINS controller

MAINS controller alarm	Parameters	General name
Mains over-voltage [1 to 2]	`Mains > Voltage protections > Over-voltage [1 to 2]`	Over-voltage
Mains under-voltage [1 to 3]	`Mains > Voltage protections > Under-voltage [1 to 3]`	Under-voltage
Mains voltage unbalance	`Mains > Voltage protections > Voltage unbalance`	Voltage unbalance
Positive sequence under-voltage	`Mains > Voltage protections > Positive sequence under-voltage`	Positive sequence under-voltage

MAINS controller alarm	Parameters	General name
Negative sequence voltage	`Mains > Voltage protections > Negative sequence voltage`	Negative sequence voltage
Zero sequence voltage	`Mains > Voltage protections > Zero sequence voltage`	Zero sequence voltage
Over-current [1 to 4]	`Mains > Current protections > Over-current [1 to 4]`	Over-current
Fast over-current [1 to 2]	`Mains > Current protections > Fast over-current [1 to 2]`	Fast over-current
Current unbalance (average calc.)	`Mains > Current protections > Current unbalance (average calc.)`	Current unbalance (average calc.)
Current unbalance (nominal calc.)	`Mains > Current protections > Current unbalance (nominal calc.)`	Current unbalance (nominal calc.)
Directional over-current [1 to 2]	`Mains > Current protections > Directional overcurrent [1 to 2]`	Directional over-current
Inverse time over-current	`Mains > Current protections > Inverse time over-current`	Inverse time over-current
Negative sequence current	`Mains > Current protections > Negative sequence current`	Negative sequence current
Zero sequence current	`Mains > Current protections > Zero sequence voltage`	Zero sequence voltage
Mains over-frequency [1 to 3]	`Mains > Frequency protections > Over-frequency [1 to 3]`	Over-frequency
Mains under-frequency [1 to 3]	`Mains > Frequency protections > Under-frequency [1 to 3]`	Under-frequency
Overload [1 to 5]	`Mains > Power protections > Overload [1 to 5]`	Overload
Reverse power [1 to 2]	`Mains > Power protections > Reverse power [1 to 2]`	Reverse power
Reactive power export [1 to 2]	`Mains > Reactive power protections > Reactive power export [1 to 2]`	Reactive power export
Reactive power import [1 to 2]	`Mains > Reactive power protections > Reactive power import [1 to 2]`	Reactive power import

Busbar AC alarm names for the MAINS controller

MAINS controller alarm	Configure > Parameters >	General name
Busbar over-voltage [1 to 3]	`Busbar > Voltage protections > Over-voltage [1 to 3]`	Busbar over-voltage
Busbar under-voltage [1 to 4]	Busbar > Voltage protections > Under-voltage 1 [1 to 4]	Busbar under-voltage
Busbar voltage unbalance	`Busbar > Voltage protections > Voltage unbalance`	Busbar voltage unbalance
Positive sequence under-voltage	`Busbar > Voltage protections > Positive sequence under-voltage`	Busbar positive sequence under-voltage
Negative sequence voltage	`Busbar > Voltage protections > Negative sequence voltage`	Busbar negative sequence voltage
Zero sequence voltage	`Busbar > Voltage protections > Zero sequence voltage`	Busbar zero sequence voltage

MAINS controller alarm	Configure > Parameters >	General name
Busbar over-frequency [1 to 3]	`Busbar > Frequency protections > Over-frequency [1 to 3]`	Busbar over-frequency
Busbar under-frequency [1 to 4]	`Busbar > Frequency protections > Under-frequency [1 to 4]`	Busbar under-frequency

Other AC alarm names for the MAINS controller

MAINS controller alarm	Configure > Parameters >	General name
V< and Q< [1 to 2]	`Mains > Additional protections > V< and Q< [1 to 2]`	Low voltage low reactive power
Average over-voltage [1 to 2]	`Mains > Additional protections > Average over-voltage [1 to 2]`	Average over-voltage
Vector shift	`Busbar > Additional protections > Vector shift`	Vector shift
ROCOF (df/dt)	`Busbar > Additional protections > ROCOF (df/dt)`	Rate of change of frequency

11. BUS TIE breaker controller

11.1 About the BUS TIE breaker controller

Each **BUS TIE breaker** controller controls one bus tie breaker. Before closing the bus tie breaker, the power management system synchronises the busbar sections.

Before opening the bus tie breaker, the power management system de-loads the bus tie breaker. The power management system also ensures that enough power is available on each busbar section after the bus tie breaker opens.

There can be a ring busbar connection.

11.1.1 BUS TIE breaker controller functions

	Functions
Pre-programmed sequences	• Bus tie breaker open sequence (with de-loading), to split the busbar into sections • Bus tie breaker close sequence (with synchronisation), to connect the busbar sections
Busbar section management	• Busbar split and connection (configurable) • Busbar section management • Ring busbar connection

Counters	• Display unit counters, to edit or reset
	  ∘ Bus tie breaker operations and trips
	  ∘ Energy export (active and reactive) (to busbar B)
	  ∘ Energy import (active and reactive) (to busbar A)
	  ∘ Energy differential (active and reactive)
	  ∘ External breaker operations
	• Energy counters with configurable digital outputs (for external counters)
	  ∘ Energy export (active and reactive) (to busbar B)
	  ∘ Energy import (active and reactive) (to busbar A)
	  ∘ Energy differential (active and reactive)

Control types	• Power management system (PMS) control
	  ∘ Display unit push-buttons for breaker operations
	  ∘ Synchronisation, de-loading, and breaker control
	  ∘ Push-button functions also possible using inputs, PICUS, and/or Modbus
	• Manual control
	  ∘ Operator controls the system from the switchboard

11.2 BUS TIE breaker controller principles

11.2.1 Sections

By opening or closing, bus tie breakers create or join busbar sections in the application.

More information
See **Busbar sections** in the **Power management** chapter.

11.2.2 Configure a BUS TIE breaker controller

Configure each **BUS TIE breaker** controller on the single-line application drawing with PICUS.

The **BUS TIE breaker** controller measures the current and voltage on busbar A. The **BUS TIE breaker** controller also measures the voltage on busbar B. Busbar A for one **BUS TIE breaker** controller can be busbar B for the next **BUS TIE breaker** controller.

Each **BUS TIE breaker** controller creates a new busbar section.

More information
See Busbar sections in the **Power management** chapter for how the bus tie breakers create busbar sections.

11.2.3 BUS TIE breaker controller nominal settings

The controller nominal settings are used in a number of key functions. For example, many protection settings are based on a percentage of the nominal settings.

Busbar A nominal settings

`Busbar A > Nominal settings > Nominal settings #` *

Nominal setting	Range	Notes
`Voltage (V)`	10 V to 160 kV	The phase-to-phase ** nominal AC voltage for busbar A.
`Current (I)`	1 A to 9 kA	The maximum current flow in one phase (that is, L1, L2 or L3) in busbar A during normal operation.
`Frequency (f)`	48 to 62 Hz	The system nominal frequency, typically either 50 Hz or 60 Hz. All the controllers in the system should have the same nominal frequency.
`Power (P)`	1 kW to 900 MW	The nominal active power for the bus tie breaker. Ignored if *P nominal calculated* is selected.
`Apparent power (S)`	1 kVA to 1 GVA	The nominal apparent power for the bus tie breaker. Ignored if *S nominal calculated* is selected.
`Power factor (PF)`	0.6 to 1	The nominal power factor at the bus tie breaker.

NOTE * # is 1 to 4.
** In a single-phase set up the nominal AC voltage is phase-to-neutral.

`Busbar A > Nominal settings > Nominal settings # > Calculation method` *

Calculation method	Options
`Reactive power (Q) nominal`	Q nominal calculated Q nominal = P nominal Q nominal = S nominal
`P or S nominal`	No calculation P nominal calculated S nominal calculated

NOTE * # is 1 to 4.

More information
See **Nominal power calculations** for more information.

Busbar B nominal settings

`Busbar B > Nominal settings > Nominal settings #*`

Nominal setting	Range	Notes
`Voltage (V)`	10 V to 160 kV	The phase-to-phase nominal voltage for busbar B. If there is no transformer between busbar A and busbar B, the nominal voltage for busbar B is the same as the nominal voltage for busbar A.
`Frequency (f)`	48 to 62 Hz	The system nominal frequency, typically either 50 Hz or 60 Hz. All the controllers in the system should have the same nominal frequency.

NOTE * # is 1 to 4.

11.2.4 AC configuration

The following table shows how the general AC configuration description applies to the **BUS TIE breaker** controller.

BUS TIE breaker	General name
Busbar A	[A-side]
Busbar B	[B-side]

More information
The AC configuration and nominal settings chapter describes the AC configuration in general.

11.2.5 Breaker configuration

More information
See the Breakers, synchronisation and de-loading for synchronisation and breakers. This includes the inputs and output functions and the parameters to configure.

For the **BUS TIE breaker** controller, the breaker abbreviation (*[*B]*) is *BTB*. *[Breaker]* refers to *Bus tie breaker*.

11.2.6 BTB-specific configuration

Breakers > Bus tie breaker configuration > Configuration

Parameter	Range	Comment
`BTB supply`	AC voltage, DC voltage	**AC voltage**: An alternating current (AC) bus tie breaker is supplied from the busbar. The breaker can operate when either of the busbars is live. However, it cannot operate if there is a blackout on both busbars. If there is a blackout on both busbars and the operator tries to close the BTB, then the power management system will start a genset. **DC voltage**: A direct current (DC) bus tie breaker is supplied from the switchboard power supply. It can operate if there is a blackout.
`Tie breaker normally open/closed`	Normally open, Normally closed	**Normally open**: If there is no power, the BTB is open. **Normally closed**: If there is no power, the BTB is closed.

11.2.7 Plant mode

For a bus tie breaker controller, the plant mode defines when a mains controller can request help. That is, a mains controller can request that the BTB close if the plant mode is:

- Automatic Mains Failure
- Load take over

- Island operation

For these plant modes, a BTB will not close automatically, even if more power is needed:
- Fixed Power
- Peak shaving
- Mains Power Export

11.3 BUS TIE breaker controller sequences

11.3.1 Splitting the busbar

The busbar can be split into two busbar sections which operate independently by opening the bus tie breaker. The signal to open the bus tie breaker can come from:

- The operator can press the push-button **Open breaker** on the **BUS TIE breaker** controller display unit.
- The operator can use PICUS to send an open breaker command.
- A digital input with the `Breakers > Bus tie breaker > Command > BTB open` function.
- An external source, like a PLC.

The power management system then ensures that there is enough power available for each busbar section so that they can run independently. If there is enough power on each busbar section, the power management system de-loads the bus tie breaker. When the bus tie breaker is de-loaded, the **BUS TIE breaker** controller opens the bus tie breaker.

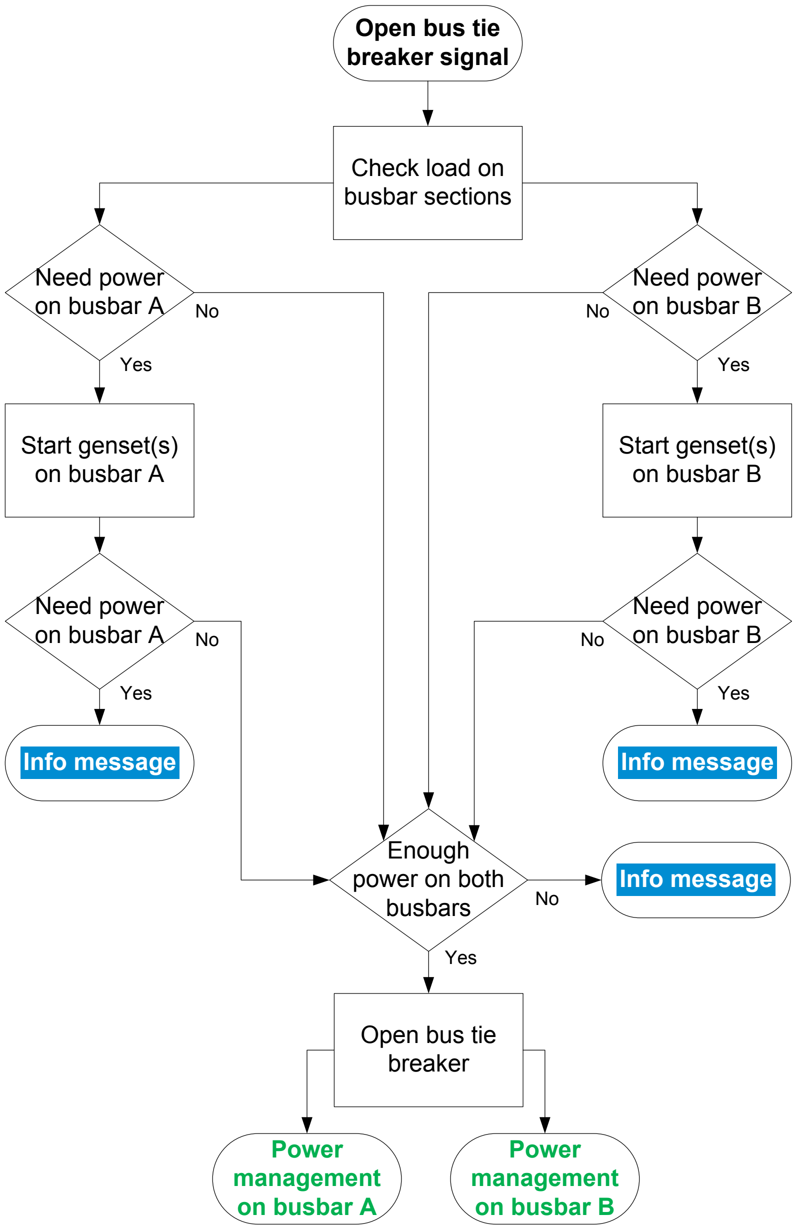
Requirements

The power management system can only split the busbar if:
- The following controllers are under PMS control:
  - **BUS TIE breaker** controller
  - All connected **GENSET** controller(s)
  - All connected **MAINS** controller(s)
- There are enough gensets available under PMS control to supply the required power to each busbar section.
  - If the required **GENSET** controllers are in MANUAL mode, then their gensets must be **connected**.
  - **GENSET** controllers in AUTO mode need not be connected. The power management system can start and connect them as necessary.
- If the only power supply to a busbar section is a mains connection, then that mains must be **connected**.

How it works

The following flowchart shows the sequence that the controller normally uses to open the bus tie breaker (BTB).

Splitting the busbar flowchart



1. **Open bus tie breaker signal:** The BUS TIE breaker controller gets a signal to open the bus tie breaker.
2. **Check load on busbar sections:** The **BUS TIE breaker** controller checks the load on the busbars that would be created if the bus tie breaker is opened.
3. **Need power on busbar #:** If more power is needed on a busbar, more gensets are started. If there is still not enough power, the **BUS TIE breaker** controller display unit shows the info message *Busbar split not possible*.
4. **Open bus tie breaker:** If there is enough power on both of the busbars, then the controller opens the bus tie breaker.
5. **Power management on busbar #:** After the bus tie breaker is opened, the busbar sections operate independently, with separate power management on each busbar section.

11.3.2 Connecting busbar sections

The busbar sections can be connected to form one busbar section by closing the bus tie breaker. The signal to close the bus tie breaker can come from:

- The operator can press the push-button **Close breaker** on the **BUS TIE breaker** controller display unit.
- The operator can use PICUS to send an close breaker command.
- A digital input with the `Breakers > Bus tie breaker > Command > BTB close` function.
- An external source, like a PLC.

The power management system then synchronises the busbar sections on either side of the breaker. When the busbars are synchronised, the controller closes the bus tie breaker.

When you close a bus tie breaker, then the two sections on either side of the bus tie breaker are joined into one section.

Requirements

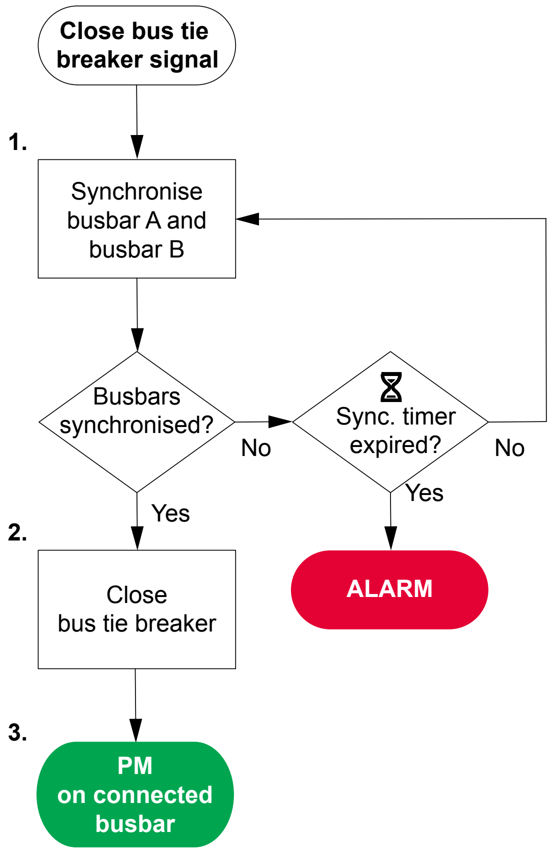
The power management system can only connect the busbar sections if, for at least one of the sections, all of the following controllers are in PMS control:

- **BUS TIE breaker** controller
- **MAINS** controller (if present and **connected**)
- **GENSET** controllers for the gensets that are **connected** to the busbar

The controller will not allow the bus tie breaker to close in any of these situations:
- In the sections to be joined, there are one or more unknown breaker positions.
- Mains connections are connected on both sides of the breaker, and *Multiple mains connections allowed* is *Not enabled*.

If only gensets are connected to both sections, the power management system can connect the sections.

How it works



1. **Synchronise busbar A and busbar B:** After getting the signal to close the bus tie breaker, the power management system regulates the gensets on either side of the bus tie breaker.
   - If mains connection is **connected** to one of the busbars, the power management system only regulates the gensets on the other busbar.
2. **Busbars synchronised:** When the busbars are synchronised, the power management system automatically closes the bus tie breaker. If the busbars do no synchronise within the time available, the controller activates a *BTB synchronisation failure* alarm.
3. **Power management on connected busbar:** The power management system controls the connected busbar sections as one busbar section.

11.3.3 Bus tie breaker blackout close flowchart

More information
See Blackout for the sequence that the controller uses to close the bus tie breaker if there is a blackout on one of the busbars.

Manual blackout close

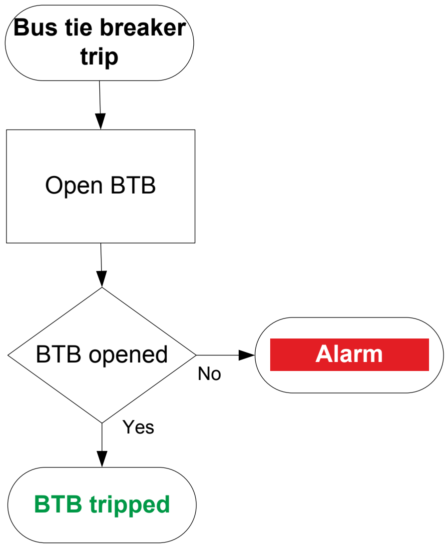
During a blackout, the operator can manually close the bus tie breaker by pushing the push button **Close breaker** on the display unit.

11.3.4 Bus tie breaker trip flowchart

The controller automatically trips the bus tie breaker (BTB) for this alarm action:
- Trip bus tie breaker

The controller does not require the bus tie breaker open conditions to be met for a breaker trip. Similarly, the bus tie breaker is not de-loaded for a trip.

Bus tie breaker trip flowchart



1. **Open BTB:** When a trip is required, the controller activates the *Breakers > Bus tie breaker > Control > BTB open* output to open the breaker.
2. **BTB opened:** The controller checks whether the breaker has opened:
   - If the breaker has opened, the trip is successful.
   - If the breaker has not opened, the controller activates the *BTB opening failure* alarm.

11.4 Other BUS TIE breaker controller functions

11.4.1 Counters

You can view, edit and reset all the counters on the display unit under `Configure > Counters`. The counters include:

- Bus tie breaker operations and trips
- Active and reactive energy export (to busbar B)
- Active and reactive energy import (to busbar A)
- Active and reactive energy difference (the difference between the energy export and import)

Energy counter outputs

For each energy counter, you can configure a digital output to send a pulse every time a certain amount of energy is transferred. You must configure the digital output function to see the parameters.

Configure the digital outputs under `Busbar A > Production counters > [Counter pulse]`.

Parameters

`Busbar A > Production counters > Active energy export`

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

`Busbar A > Production counters > Reactive energy export`

Parameter	Range	Comment
`Pulse every`	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Busbar A > Production counters > Active energy import

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Busbar A > Production counters > Reactive energy import

Parameter	Range	Comment
`Pulse every`	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Busbar A > Production counters > Active energy differential

Parameter	Range	Comment
`Pulse every`	1 kWh to 10 MWh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Busbar A > Production counters > Reactive energy differential

Parameter	Range	Comment
`Pulse every`	1 kvarh to 10 Mvarh	The value when a digital output sends a pulse.
`Pulse length`	0.1 s to 1 h	The length of the pulse that is sent. This value should be long enough so the pulse can be registered by the external counter.

Application example for an energy counter output

1. Connect the digital output to an external counter.
2. Configure the digital output using the display unit or PICUS to *Active energy export pulse*.
3. Configure the *Pulse every* parameter to the value where you would like to send a pulse. For example, 100 kWh.
4. Configure the *Pulse length* to the required length of the pulse for your external counter. For example, 1 second.

With the example setup the controller sends a 1 second pulse to the external counter for each 100 kWh the controller logs.

11.4.2 Mains unbalance voltage

Local power management > Mains configuration > Voltage and frequency OK

Parameter	Range	Comment
`Unbalance voltage`	2 to 100 % of nominal voltage	The mains voltage unbalance must be below this threshold for the mains voltage and frequency to be okay. This is a shared parameter.

11.4.3 Test mode

For a BTB controller, the BTB test response depends on the mains controller test mode. The BTB controller does not have a test mode.

For a bus tie breaker controller, a mains controller can request that the BTB close if the test mode is *Full test*.

For the *Simple test* and *Load test* mains controller test modes, a BTB will not close automatically, even if more power is needed.

11.4.4 Fuel pump

To keep the level in a tank in the required range, you can use the controller's inputs and outputs to control a pump.

More information
See **Fuel pump** in the **GENSET controller** chapter for details.

11.4.5 Digital outputs

The BTB controller supports the standard controller digital outputs, and also the output below.

Function	I/O	Type	Details
`Breakers > Bus tie breaker > State > BTB is preparing`	Digital output	Continuous	

11.5 BUS TIE breaker controller alarms and protections

11.5.1 Alarm actions

The controller has the following alarm actions:
- Warning
- Block bus tie breaker
- Trip bus tie breaker

11.5.2 Inhibits

Inhibit	Disables the alarm when ...
Bus tie breaker closed	The `Breakers > Bus tie breaker > Feedback > BTB Closed` digital input is activated.
Bus tie breaker open	The `Breakers > Bus tie breaker > Feedback > BTB Open` digital input is activated.
ACM wire break	All these conditions are met: • The bus tie breaker is closed • Voltage is detected by one set of ACM voltage measurements • No voltage is detected on a phase, or on all three phases for the other set of ACM voltage measurements
Inhibit 1	The `Alarm system > Inhibits > Activate inhibit 1` digital input is activated.
Inhibit 2	The `Alarm system > Inhibits > Activate inhibit 2` digital input is activated.
Inhibit 3	The `Alarm system > Inhibits > Activate inhibit 3` digital input is activated.

11.5.3 Breaker alarms

Breaker alarm names for the BUS TIE breaker controller

BUS TIE breaker alarm	Parameter	General name
BTB synchronisation failure	`Breakers > Bus tie breaker monitoring > Synchronisation failure`	Breaker synchronisation failure
BTB de-load failure	`Breakers > Bus tie breaker monitoring > De-load failure`	Breaker de-load failure

BUS TIE breaker alarm	Parameter	General name
Vector mismatch	Breakers > Bus tie breaker monitoring > Vector mismatch	Vector mismatch
BTB opening failure	Breakers > Bus tie breaker monitoring > Opening failure	Breaker opening failure
BTB closing failure	Breakers > Bus tie breaker monitoring > Closing failure	Breaker closing failure
BTB position failure	Breakers > Bus tie breaker monitoring > Position failure	Breaker position failure
BTB trip (external)	Breakers > Bus tie breaker monitoring > Tripped (external)	Breaker trip (external)
BTB short circuit	Breakers > Bus tie breaker monitoring > Short circuit	Breaker short circuit
BTB configuration failure	-	Breaker configuration failure
Busbar A phase sequence error	Busbar A > AC setup > Phase sequence error	Phase sequence error
Busbar B phase sequence error	Busbar B > AC setup > Phase sequence error	Phase sequence error

More information
See Breakers, synchronisation and de-loading for breaker handling and alarms in general.

11.5.4 AC alarms

Busbar A AC alarms for the BUS TIE breaker controller

BUS TIE breaker alarm	Parameters	General name
Busbar A over-voltage [1 to 2]	Busbar A > Voltage protections > Over-voltage [1 to 2]	Over-voltage
Busbar A under-voltage [1 to 3]	Busbar A > Voltage protections > Under-voltage [1 to 3]	Under-voltage
Busbar A voltage unbalance	Busbar A > Voltage protections > Voltage unbalance	Voltage unbalance
Positive sequence under-voltage	Busbar A > Voltage protections > Positive sequence under-voltage	Positive sequence under-voltage
Negative sequence voltage	Busbar A > Voltage protections > Negative sequence voltage	Negative sequence voltage
Zero sequence voltage	Busbar A > Voltage protections > Zero sequence voltage	Zero sequence voltage
Busbar A over-current [1 to 4]	Busbar A > Current protections > Over-current [1 to 4]	Over-current
Fast over-current [1 to 2]	Busbar A > Current protections > Fast over-current [1 to 2]	Fast over-current
Current unbalance (average calc.)	Busbar A > Current protections > Current unbalance (average calc.)	Current unbalance (average calc.)
Current unbalance (nominal calc.)	Busbar A > Current protections > Current unbalance (nominal calc.)	Current unbalance (nominal calc.)
Directional over-current [1 to 4]	Busbar A > Current protections > Directional over-current [1 to 4]	Directional over-current

BUS TIE breaker alarm	Parameters	General name
Inverse time over-current	Busbar A > Current protections > Inverse time over-current	Inverse time over-current
Negative sequence current	Busbar A > Current protections > Negative sequence current	Negative sequence current
Zero sequence current	Busbar A > Current protections > Zero sequence current	Zero sequence current
Busbar A over-frequency [1 to 3]	Busbar A > Frequency protections > Over-frequency [1 to 3]	Over-frequency
Busbar A under-frequency [1 to 3]	Busbar A > Frequency protections > Under-frequency [1 to 3]	Under-frequency
Power export [1 to 5]	Busbar A > Power protections > Power export [1 to 5]	Power export
Power import [1 to 2]	Busbar A > Power protections > Power import [1 to 2]	Power import
Reactive power export [1 to 2]	Busbar A > Reactive power protections > Reactive power export [1 to 2]	Reactive power export
Reactive power import [1 to 2]	Busbar A > Reactive power protections > Reactive power import [1 to 2]	Reactive power import
V< and Q< [1 to 2]	Busbar A > Additional protections > V< and Q< [1 to 2]	V< and Q<
Average over-voltage [1 to 2]	Busbar A > Additional protections > Average over-voltage [1 to 2]	Average over-voltage

Busbar B AC alarm names for the BUS TIE breaker controller

BUS TIE breaker alarm	Configure > Parameters >	General name
Busbar B over-voltage [1 to 3]	Busbar B > Voltage protections > Over-voltage [1 to 3]	Busbar over-voltage
Busbar B under-voltage [1 to 4]	Busbar B > Voltage protections > Under-voltage [1 to 4]	Busbar under-voltage
Busbar B voltage unbalance	Busbar B > Voltage protections > Voltage unbalance	Busbar voltage unbalance
Positive sequence under-voltage	Busbar B > Voltage protections > Positive sequence under-voltage	Positive sequence under-voltage
Negative sequence voltage	Busbar B > Voltage protections > Negative sequence voltage	Negative sequence voltage
Zero sequence voltage	Busbar B > Voltage protections > Zero sequence voltage	Zero sequence voltage
Busbar B over-frequency [1 to 3]	Busbar B > Frequency protections > Over-frequency [1 to 3]	Busbar over-frequency
Busbar B under-frequency [1 to 4]	Busbar B > Frequency protections > Under-frequency [1 to 4]	Busbar under-frequency
Vector shift	Busbar B > Additional protections > Vector shift	Vector shift
ROCOF (df/dt)	Busbar B > Additional protections > ROCOF (df/dt)	ROCOF (df/dt)

More information

See AC configuration and nominal settings for general information about the AC alarms.

12. Modbus

12.1 Modbus in the controller

12.1.1 How it works

Modbus is generally accepted as a standard communication protocol between intelligent industrial devices. This means that the Modbus protocol is used as a standard method to represent and communicate data in intelligent industrial devices.

The controller includes a built-in Modbus TCP/IP server. The Modbus TCP/IP server allows external devices to communicate with the controller using the Modbus TCP/IP communication protocol. For example:

- A PLC can request that specific data is read from the controller, such as the settings for the nominal AC configuration.
- A PLC can send commands to the controller using the Modbus TCP/IP protocol.

This document will only describe the information required to communicate with the controller using the Modbus TCP/IP protocol. For more information about Modbus in general and the Modbus TCP/IP protocol, refer to the documentation freely available at http://www.modbus.org.

Refer to the Modbus tables, available for download at www.deif.com, to see how the controller data is mapped to the Modbus addresses.

NOTE All values in this chapter are decimal values, unless specifically stated that a value is hexadecimal.

12.1.2 Warnings

DANGER!

Access to controller settings with Modbus TCP

All controller settings can be accessed and modified through Modbus TCP.

This includes disabling critical controller protections by changing settings and alarms. Use the Modbus tables provided by DEIF to ensure that you do not disable critical protections.

NOTICE

Modbus and Emulation

Modbus control remains active even during Emulation mode.

If Modbus is allowed to control sources, these will continue to be controlled even if the controller is in Emulation mode.

12.2 Modbus implementation in the controller

12.2.1 Modbus TCP protocol

The controller uses the Modbus TCP protocol to communicate with an external device over the Modbus network and through the internet. The communication protocol uses static IPv4 addresses to send information. Dynamic IPv4 addresses (created by a dynamic host configuration protocol server (DHCP server)) and IPv6 addresses are not supported by the controller for Modbus communication purposes.

More information
See the **Operator's manual** or the **PICUS manual** for how to configure the controller communication settings.

12.2.2 Modbus communication port

By default the controller uses port 502 (standard for Modbus TCP protocol) for TCP communication. Create a custom Modbus server to use a different communication port.

Each controller can process up to 10 communication requests at a single time.

12.2.3 Controller identifier

The Modbus TCP protocol will always use the controller IPv4 address to identify the controller that the client wants to communicate with. However, some Modbus communication tools will still require/automatically add a Modbus server ID, also known as a unit identifier, for the unit that the server is communicating with. For these cases the controller accepts Modbus server IDs from 1 to 247. This is the case for all controllers in the network that communicate using the Modbus TCP protocol.

If two Modbus servers are enabled at the same time that use the same communication port, then a unique Modbus Server ID must be configured for each server.

Specific controller identifiers can be selected for the controller when you configure a custom server.

12.2.4 Data handling

NOTICE

Check Modbus protocol address information

Check the Modbus protocol address information using PICUS to ensure that you are referencing the correct Modbus address for the function that you are executing.

NOTE Always document and store changes that you make to the way that the controller interprets Modbus data.

Data format (endian)

To ensure that the correct data is retrieved from the controller, the request from the Modbus client must match the data format of the selected address. The data format is configured in the Modbus server, and are applied to the *Holding register* and the *Input register*.

Sign

In general, the integer data (16-bit and 32-bit) that is accessed from the controller through Modbus TCP are signed integer values.

Conversion

Data in the *Holding register* and *Input register* of the Modbus table is converted according to the conversion template selected for that address. When data is read using Modbus, then the *Formula* is used to convert the Modbus data. When data is written using Modbus, then the *Reverse formula* is used to convert the data into a form that can be stored in the Modbus protocol.

Conversions can also be used to force unit conversions on specific addresses.
NOTE *Reverse formulas* are NOT automatically determined.

Modbus data conversion example

The parameter nominal power factor is assigned to an unused address in a custom Modbus protocol. The controller can process inputs to the forth decimal value (for example, 0.8002) for the nominal power factor. To read and write values correctly using Modbus a conversion template *X * 10000* is assigned to the address. The *Formula* equal to *x*10000* and a *Reverse formula* equal to *x*0.0001*.

	This means that when a value of 0.8002 is read from the controller, the displayed value is: Result = *Formula* ⇒ Result = x * 10000 ⇒ Result = 0.8002 * 10000 ⇒ Result = 8002 To write a value of 0.85 to the controller using Modbus, the value that should be written to the controller is: Result = *Reverse formula* ⇒ Result = x * 0.0001 ⇒ 0.85 = x * 0.0001 ⇒ x = 8500

Refresh rate

Data stored in the Modbus addresses is refreshed at the following maximum rates:

Data	Maximum refresh rate	Function group example
AC measurements	20 ms	A-side AC measurements
Values	40 ms	Alarm parameter: Enable

12.3 Modbus tables

12.3.1 Download Modbus tables

To download the Modbus tables, use this link:

https://www.deif.com/rtd/ie250/modbus

Or from you can download from the iE 250 documentation page, under **Communication**:

https://www.deif.com/documentation/ie250/

12.3.2 About the Modbus tables

The Modbus tables are stored in a Microsoft® Excel file that contains five spreadsheets with Modbus data. The table below gives a short description of each of the spreadsheets in the file.

Spreadsheet name	Description
Descriptions	This spreadsheet contains an overview of the other four spreadsheets. The information includes a description of each function group listed in the tables spreadsheets.
Discrete output coil	You can read or write information to the addresses that are listed in this spreadsheet. Use Modbus function code 01 to read whether a coil is on or off. Use Modbus function code 05 or 15 to toggle the coil value. Read-only addresses will return a 0 value if you try to write to them.
Discrete input contact	You can only read information from the addresses that are listed in this spreadsheet. Use Modbus function code 02 to read whether the contact is on or off.
Output holding register	You can read or write information to the addresses that are listed in this spreadsheet. Use Modbus function code 03 to read the information stored at the requested Modbus address(es). Use Modbus function code 06 or 16 to write information to the Modbus address(es). Read-only addresses will return a 0 value if you try to write to them.
Input register	You can only read information from the addresses that are listed in this spreadsheet. Use Modbus function code 04 to read the information stored at the requested Modbus address(es).
Controller text	This spreadsheet contains an overview of texts associated to Modbus output values. This association is only available for selected Modbus addresses.

12.4 Specific Modbus function groups

12.4.1 CustomLogic: Modbus signal

You can find the function group *CustomLogic: Modbus signal* in the Discrete output coil (01; 05; 15) and the Discrete input contact (02) sheets of the Modbus table. The function group allows you to interact with the CustomLogic of the controller using Modbus.

When you read a value from these addresses, the controller will return a value to show if the flag for the signal is active (true, 1) or not active (false, 0). When you write a value to the addresses in the Discrete output coil, the value stored in the address changes to the new value.

NOTE You cannot write values to Modbus signals that have been assigned to coils in CustomLogic.

More information
See **CustomLogic** in the **PICUS manual** for how to assign a Modbus signal to CustomLogic elements.

12.4.2 Breaker priority: Buffered value

How it works

You can find the function group *Breaker priority: Buffered value* in the Holding register of the Modbus table. The function group acts as a temporary storage area for the breaker priority values that will be written to the controller using the function group *Breaker priority: Write values*.

When you read a value from these addresses, the breaker priority that you want to assign to the breaker that is stored in the address is returned to you. When you write a value to these addresses, the value is stored and ready to be written to the controller when you activate *Breaker priority: Write values*.

CAUTION

Breaker priorities and the Modbus addresses

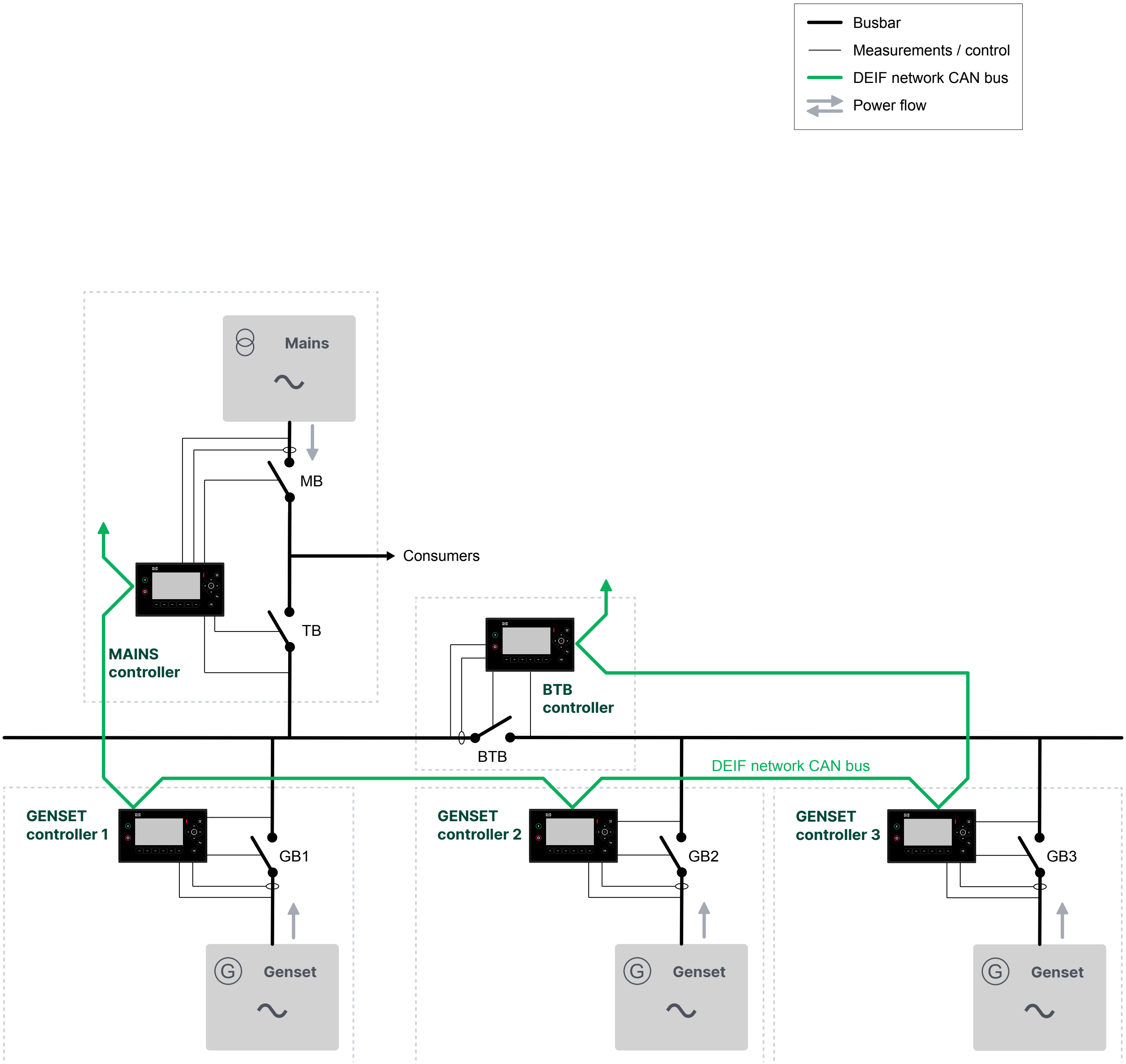
The breaker priorities and the Modbus address associated to a specific breaker is dependent on the **single-line application drawing**. If you change the **single-line application drawing**, you will change the associated Modbus addresses. If you add or remove GENSET controllers from the **single-line application drawing**, the breaker priorities can change.

Breaker priority allocation

These rules apply when breaker priorities are assigned:

- Only **GENSET** controllers receive a breaker priority value that is greater than zero (0).
- All other controller types receive a breaker value of zero (0).
- Breaker priorities are assigned to the first available breaker priority, according to the order in which controllers are added to the single-line application drawing.
- Breaker priority Modbus addresses are assigned to the first available breaker priority Modbus address, according to the order in which controllers are added to the single-line application drawing.

Example of how breaker priority works



In this example, it is assumed that the single-line application drawing was drawn by placing the components in the drawing in the following order:

1. Genset controller 1
2. Mains controller
3. Bus tie breaker controller
4. Genset controller 2
5. Genset controller 3

This means that the breakers were assigned the values and priorities:

Component	Modbus address (Holding register and input register)	Breaker priority: Buffered value	Breaker priority: Value
Genset controller 1	14001	0	1
Mains controller	14002	0	0

Component	Modbus address (Holding register and input register)	Breaker priority: Buffered value	Breaker priority: Value
Bus tie breaker	14003	0	0
Genset controller 2	14004	0	2
Genset controller 3	14005	0	3

The Modbus addresses are assigned to the breaker for the controller. The Modbus addresses are assigned to the components in the order that they were inserted into the single-line application drawing. The Modbus address(es) assigned to a component will not change when the controller ID changes.

Only genset breakers will be assigned a breaker priority value that is between 1 and 128. All other components and addresses which are unassigned (for example 14008 in the example above) have a breaker priority value of 0. Breakers with a breaker priority of 0 assigned to them, cannot be changed.

If a component is removed from the single-line application drawing, the Modbus address becomes free and can be reassigned. The breaker priorities are automatically reassigned for all the remaining components in the single-line application drawing.

For example if we remove Genset controller 1, and Genset controller 3 from the example above, the table will look as follows:

Updated breaker priority values and Modbus addresses after removing components

Component	Modbus address (Holding register and input register)	Breaker priority: Buffered value	Breaker priority: Value
-	14001	0	0
Mains controller	14002	0	0
Bus tie breaker	14003	0	0
Genset controller 2	14004	0	1
-	14005	0	0

If we add Genset controller 1 to the single-line application drawing and then add Genset controller 3, the table will look as follows:

Updated breaker priority values and Modbus addresses after adding components

Component	Modbus address (Holding register and input register)	Breaker priority: Buffered value	Breaker priority: Value
Genset controller 1	14001	0	2
Mains controller	14002	0	0
Bus tie breaker	14003	0	0
Genset controller 2	14004	0	1
Genset controller 3	14005	0	3

The table above shows that the breakers are assigned the first open Modbus address in the Modbus table. This means that it is possible for a genset controller to have its breakers assigned to Modbus addresses that do not follow directly on one another.

When you want to change the breaker priorities by using Modbus, write the desired priority value to the Modbus address in the function group *Breaker priority: Buffered value*. When you are satisfied with the breaker priorities, activate *Breaker priorities: Write values* to write the values to the controller. Only values between 1 and 128 are accepted inputs for breaker priorities. Breakers that already have a priority of 0 assigned to them, cannot be changed. You cannot write the breaker priorities to the controller if there are duplicate non-zero entries in *Breaker priority: Buffered value*. The tables below show the results after new breaker priorities were written to the buffered values, and after the buffered values were written to the controller.

12.5 Setting up Modbus

12.5.1 Setting up Modbus TCP/IP communication

In order to communicate with a controller through Modbus TCP, the following conditions must be met:

- The device interfacing with the controller must be connected to one of the following:
  - Any Ethernet connection on the controller.
  - Another controller in the DEIF network.
- The controller must have an IPv4 address.
- Modbus TCP communication software must be installed on the device communicating with the controller.

More information
See the **Installation instructions** for how to wire the Ethernet connection to the controller.

12.6 Modbus alarm

12.6.1 Modbus communication timeout

The controller activates this alarm if there are no Modbus requests within the delay time.

`Communication > Modbus > Modbus communication timeout`

Parameter	Range
`Delay`	0.1 s to 1 h

13. Hardware characteristics

13.1 General characteristics

Some terminal types are common to a number of different hardware modules.

The hardware includes digital bi-directional channels. These can be used as either digital outputs or digital inputs. In PICUS, under `Configure > Input/Output`, these terminals are named **DIO**. After selecting a DIO, you can select the IO type (*Digital input*, or *Digital output*) in PICUS.

The hardware includes analogue bi-directional channels. These can be used as either analogue outputs or analogue inputs. In PICUS, under `Configure > Input/Output`, these terminals are named **AIO**. After selecting an AIO, you can select the IO type (*Analog input*, or *Analog output*) in PICUS.

Technical specifications

More information
See the Data sheet for all of the technical specifications for the controller and modules.

13.1.1 Digital outputs

Configuration

All digital outputs are configurable.

You can assign a digital output function or an alarm to a digital output. Alternatively, you can create customised a digital output function using CustomLogic, and assign it to a digital output.

Controller types and application drawing

The controller type determines which digital output functions are available.

To see certain digital output functions, you must include the corresponding asset in the application drawing.

Configure output state

On the display or with PICUS, you can select a digital output channel and configure the output state. Under *Output state*, select **Close when active** (the output is closed while the function is active), or **Open when active** (the output is open while the function is active).

13.1.2 Digital inputs

The controller can use digital inputs for many purposes. Examples: Command buttons, breaker feedback, and alarms.

Polarity

The digital inputs use negative switching.

The controller activates the *Emergency stop* safety function for a LOW digital input. For all other digital input functions, the controller activates the function for a HIGH digital input.

Configuration

The digital inputs are configurable. That is, for each digital input, you can assign digital input function(s) and/or configure alarm(s).

You can also create responses to digital inputs using CustomLogic. You can also activate some digital input functions using a Modbus command.

Controller types and application drawing

The controller type determines which digital input functions are available.

To see certain digital input functions, you must include the corresponding equipment in the application drawing.

Controller operation

Some of the digital input functions are only applicable in certain controller modes. If the controller is in another mode, it ignores the digital input.

13.1.3 Analogue inputs

The controller can use an analogue input to receive operating data. The controller can also activate alarms based on the analogue input.

Analogue input function

Assigning a function to the analogue input is optional.

You can assign one (or more) of the controller's analogue input functions to the input. You can only select functions that use the same units.

Analogue input type

Under *Sensor value (x-axis)*, select the input type. You can also adjust the input range.

You can select from these input types:

- 0 to 20 mA
- 0 to 10 V
- 0 to 10000 ohm

Analogue input sensor setup

The sensor setup requires a curve. The curve allows the controller to convert the analogue input to the selected function's value.

Pre-configured curves may be available for the function. Alternatively, you can select a previously customised curve, or customise a curve.

Sensor failure

You can configure customised alarms for sensor failure. The *Below range alarm* is activated when the analogue input is below the specified value. Similarly, the *Above range alarm* is activated when the analogue input is above the specified value.

NOTICE
Use of sensor failure alarms Do not use the sensor failure alarms to respond to ordinary operating data. Configure customised analogue input alarms instead.

Analogue input alarms

You must complete the sensor setup before configuring any analogue input alarms.

You can configure any number of alarms for an analogue input. However, you cannot exceed 25 customised alarms for the controller.

13.1.4 Analogue outputs

An analogue output can be used to output operating data or values.

Analogue output function

Assign one function to the analogue output. You can adjust the *Function input (x)* range.

Analogue output type

After assigning a function, under *Output (y)*, select the output type. You can also adjust the output range.

The output types that can be selected depend on the hardware.

Module	Terminals	Output types
Controller	13, 14, 15 and 16	0 to 20 mA 0 to 10 V
MIO2.1	40-41 and 43-44	-10 to 10 V PWM

Analogue output curve

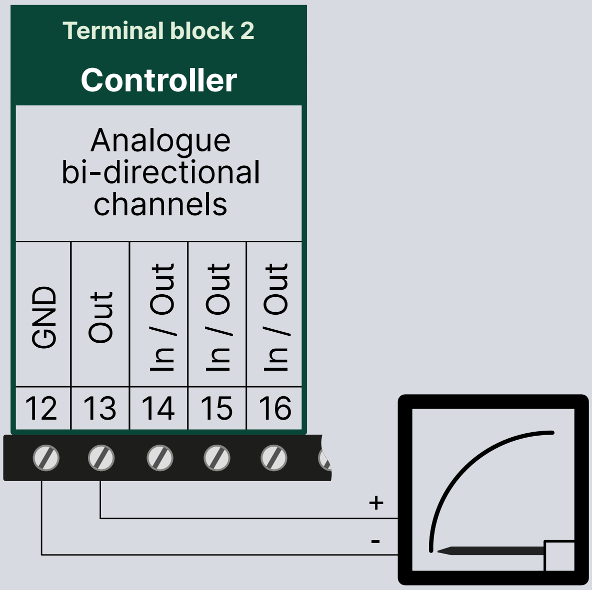
The output requires a curve. The curve allows the controller to convert the selected function's value to the analogue output.

Pre-configured curves may be available for the function. Alternatively, you can select a previously customised curve, or customise a curve.

Output for a switchboard instrument

Output *Generator power* example

The customer has a 1 MW genset, and wants to display the power from the genset on the switchboard. He uses a DEIF DQ-96x with a scale from -100 to 1500 kW.
The designer creates the following wiring for a `Generator > Power (P) > Generator | Total [kW]` analogue output:

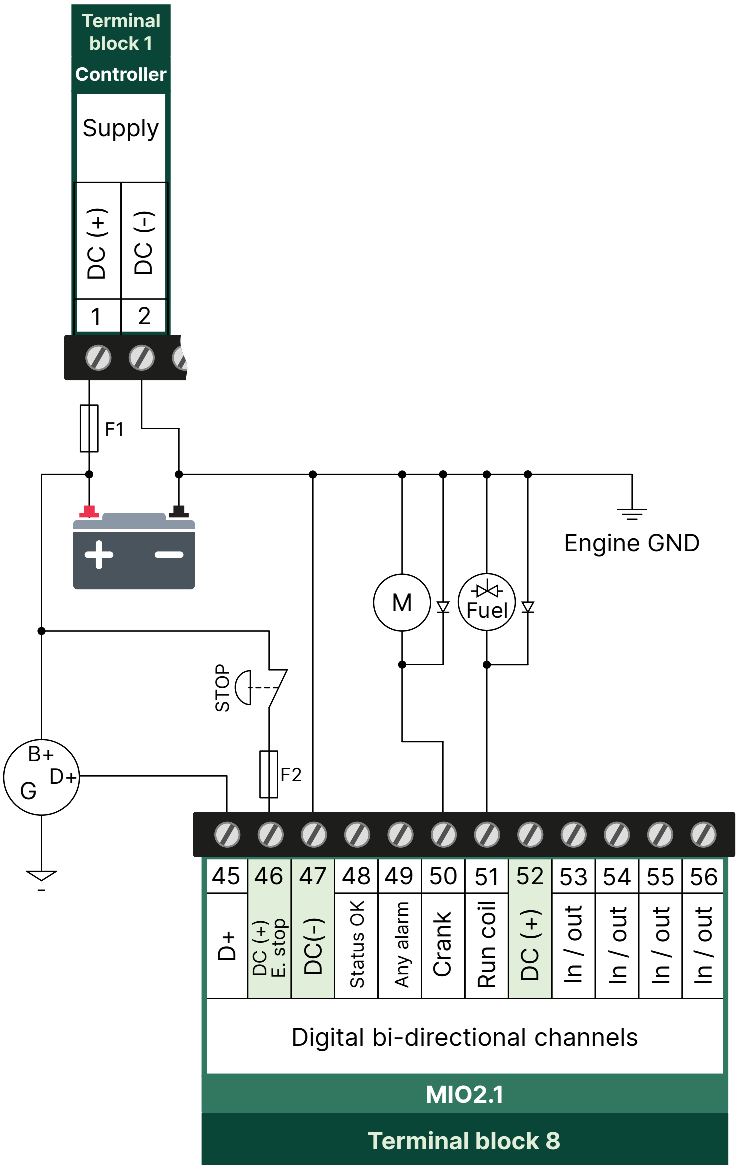


The designer selects 0 to 20 mA and configures a customised function curve with an output of 4 mA for -100 kW, and 20 mA for 1500 kW.

13.2 Controller

13.2.1 Power supply

The power supply is connected to terminals 1 and 2 on the controller.



Backup power

The DEIF controller does not contain a backup power supply. The power supply source must therefore include the power backup needed.

Start current

When the power supply is connected, the start current may briefly exceed the current that corresponds to the maximum power on the data sheet.

Battery-powered systems normally do not have a problem with start current.

For other types of power supply, for example, an AC-to-DC supply, the start current may be a problem. The minimum rating for the power supply current limiter is therefore included on the data sheet.

Reverse polarity

The power supply is protected against reverse polarity. That is, if the power supply terminals are switched, the DEIF controller will not be damaged. However, the DEIF controller will not be able to operate until the power supply has been connected correctly.

MIO2.1 Emergency stop

Terminal 46 is a hardware emergency stop. When the external emergency stop button is pressed, in the wiring shown above the power to the D+ terminal is broken. The power to terminals 48 to 51 is also broken. If required, you can wire terminal 46 so that it also breaks the power to DIO channels 9 to 12 (terminals 53 to 56).

NOTE The hardware emergency stop (terminal 46) is NOT related to the `Alarm system > Additional functions > Emergency stop` input, or the controller emergency stop alarm parameters (configured under `Engine > Emergency stop`).

Diode compensation

`Hardware > PCM2.1 > Diode compensation`

Parameter	Range	Notes
`Diode offset`	0 to 1 V DC	This corrects the power supply measurement values used for the supply voltage alarms. Use this to compensate for a small decrease in voltage over the diode.

Heat emission

For the heat emission from the controller, use the maximum power consumption for the power supply (or power supplies).

13.2.2 Controller CAN bus communication

The power management communication (that is, the DEIF network) uses CAN bus. The controllers are connected together with CAN bus cables. CAN bus is also uses for engine communication, and control of the DAVR.

Recommended CAN bus cable

CAN communication (Engine, DAVR, Power management) RS-485 communication (Modbus)
Belden 3105A or equivalent, 22 AWG (0.33 mm²) twisted pair, shielded, impedance 120 Ω (Ohm), < 40 mΩ/m, min. 95 % shield coverage.

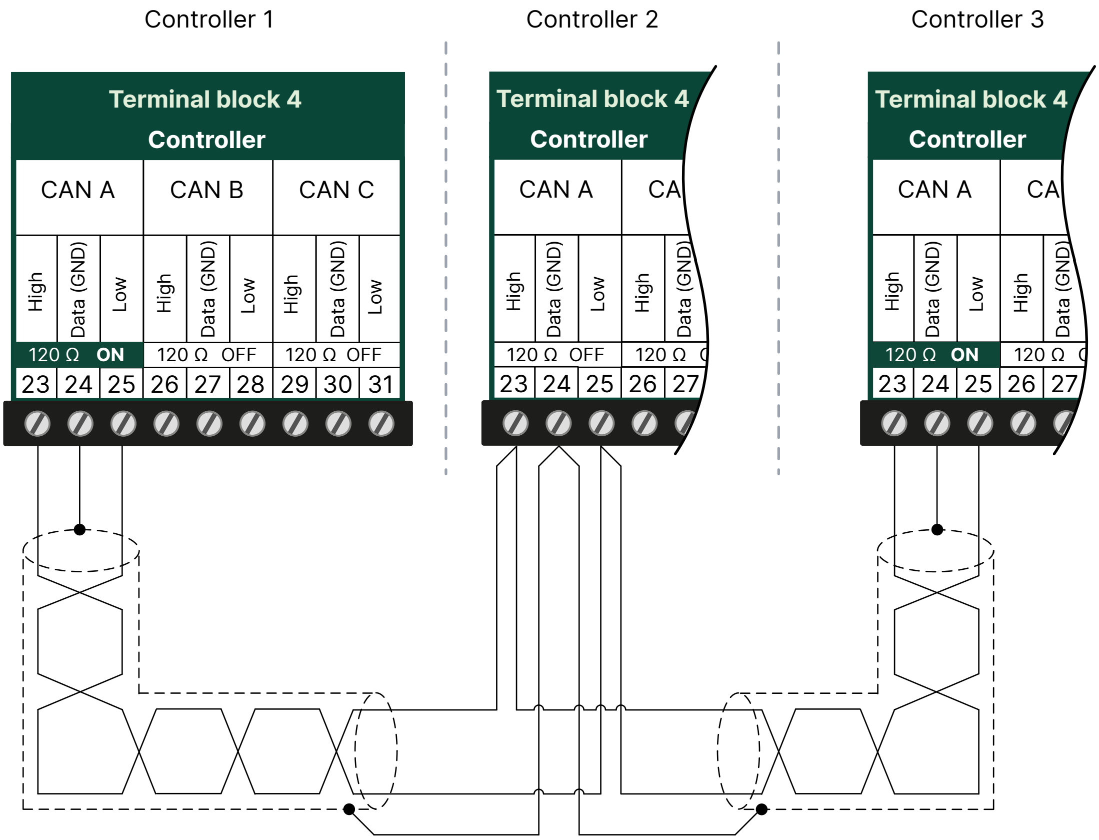
Controller ID

A new controller has a default **Controller ID** of **0** (zero). You must configure the controller ID (otherwise an alarm is activated). The controller ID must be the same as on the single-line application drawing.

You can use either the **Display** or **PICUS** to configure the Controller ID. If the controller type changes, the controller automatically restarts.

More information
See **Communication** in the **Operator's manual** or **PICUS manual** for how to configure the communication settings.

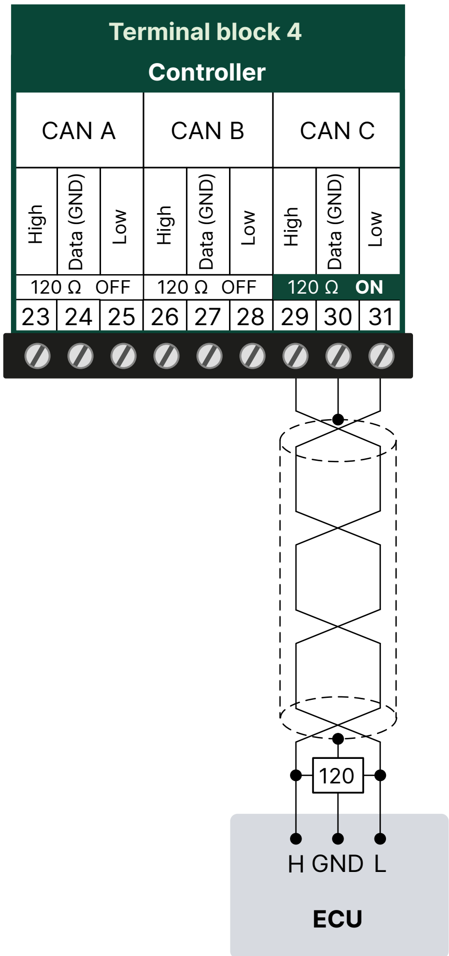
13.2.3 CAN bus DEIF network



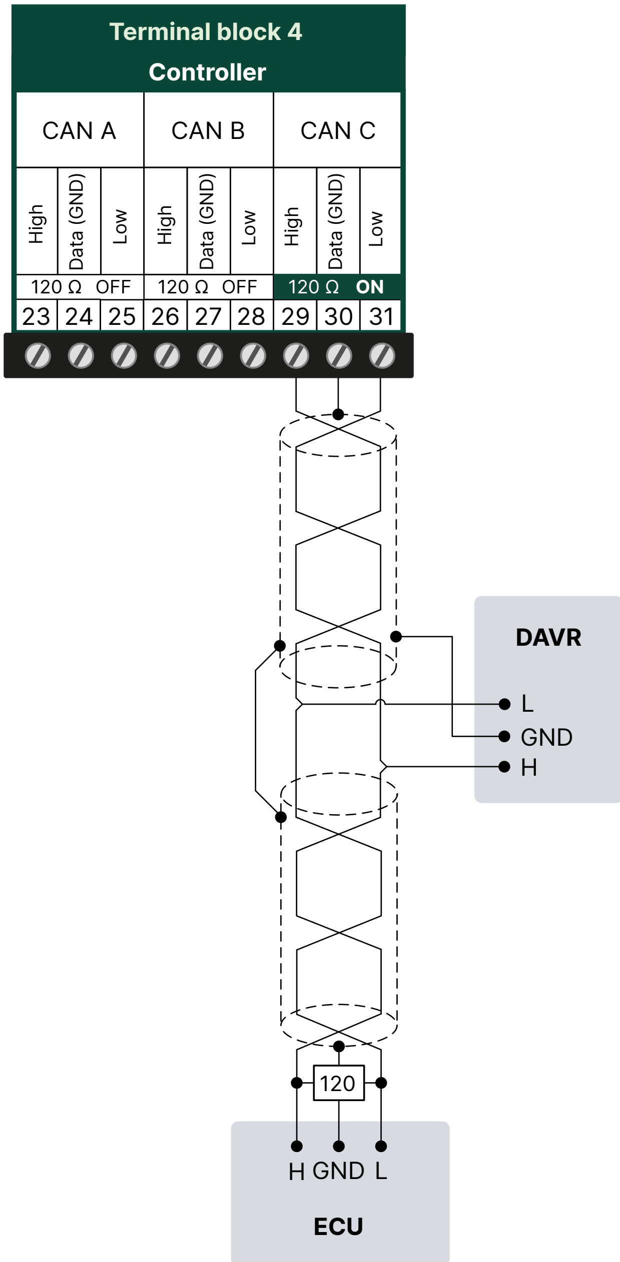
The controllers use CAN bus for the DEIF network (power management communication).

13.2.4 CAN bus engine communication

ECU only



DAVR and ECU on same CAN bus

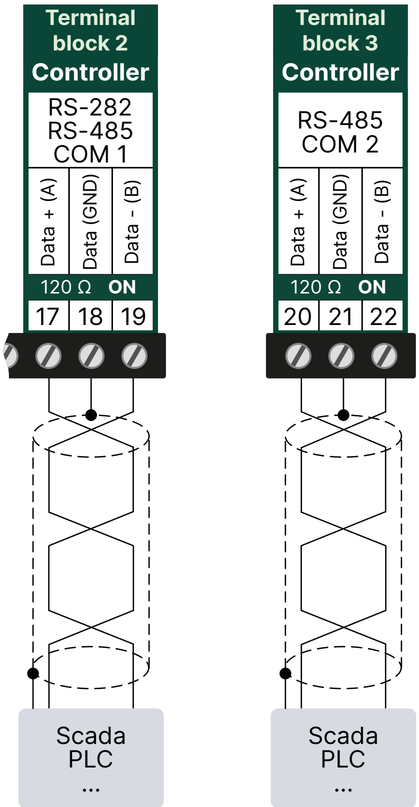


13.2.5 Serial communication COM 1 / COM 2

Can be used for example to Modbus RTU, SCADA systems, or PLCs.

2-wire connection

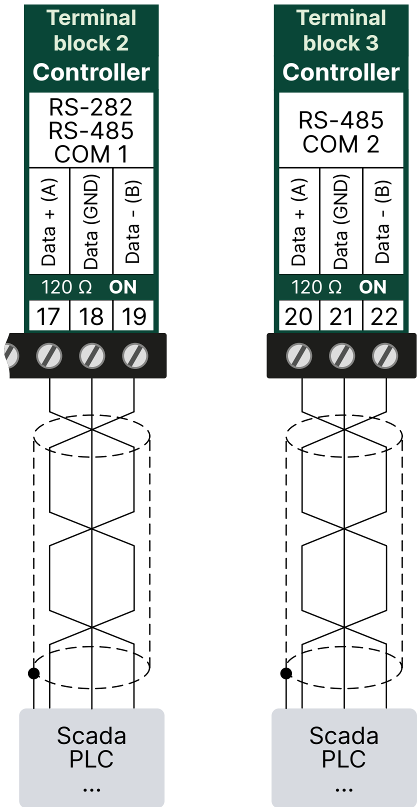
With 2-wires, connect the GND terminal to the cable shield. Only connect the shield to earth at one end.



Only COM 1 supports RS-282.

3-wire connection

Only connect the shield to earth at one end.



13.3 Measurement Input Output module MIO2.1

13.3.1 Voltage measurements

The MIO2.1 has two sets of terminals for voltage measurement. Terminals 78 to 81 measure the voltage on the A-side. Terminals 83 to 86 measure the voltage on the B-side.

The MIO uses the voltage measurements for synchronisation and protective functions. The measurements are shared with the controller for regulation, supervision, and logging. For power functions, the A-side voltage measurements are used combination with the relevant current measurements (terminals 72 to 77, or 70 to 71).

For 3-phase systems, to supervise phase-neutral or phase-earth voltages, you must also connect the neutral voltage measurements (terminal 78 on the A-side, and terminal 83 on the B-side).

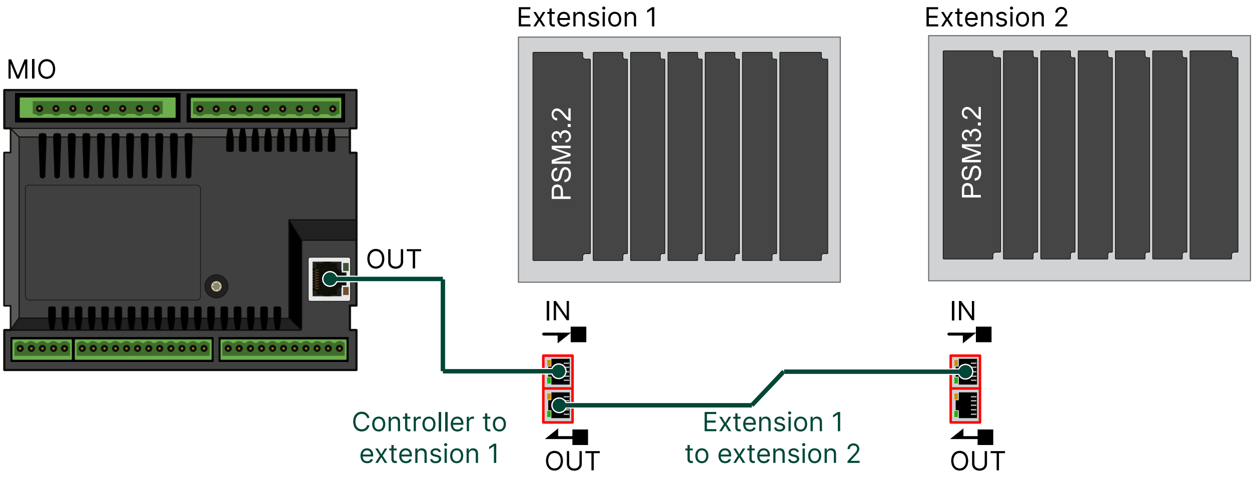
13.3.2 Current measurements

The MIO2.1 measures the current, then uses these measurements for protective functions. The current measurements are shared with the controller for supervision and logging. For power functions, the A-side voltage measurements are used combination with the relevant current measurements (terminals 72 to 77, or 70 to 71).

You do not have to connect 4th current (terminals 70 and 71). You can use the 4th current input to measure the neutral current, the earth current, or a custom current (for example, the mains current).

13.3.3 Extension rack communication

Extension racks are connected to a controller using the EtherCAT port on the MIO2.1. Do not use this port for any other communication.



NOTE EtherCAT ring connections for redundancy are not possible.

Internal communication requirements

The OUT port must always be connected to the IN port on the next extension rack.

Power off the extension rack(s) before you exchange or re-connect them to another controller.

- Up to 5 extension racks can be connected to the same controller.
- The controller and extension rack must be connected directly (without a switch between them).

EtherCAT cable requirements

- The cables must not be longer than 100 metres from point-to-point.
- The cables must meet or exceed the SF/UTP CAT5e specification.
- The cable bend radius must not be tighter than the minimum bend radius specified by the cable manufacturers.
  - We recommend that you always follow the cable manufacturer's bend radius requirements.
  - It is recommended to use velcro-strips (and not cable-ties) for the Ethernet cables.

13.3.4 CPU load as an analogue output

You can configure an analogue output with a function for the CPU load. The controller uses the configured curve to convert this value to an analogue output. You can configure functions for the CPU load overall, or for any of the CPU cores.

Analogue output

`Hardware > CPU > Load`

Function	I/O	Units	Details
`Currently [%]`	Analogue output	0 to 100 %	The controller measures the overall CPU load as a percentage.
`Average over 10 seconds [%]`	Analogue output	0 to 100 %	The controller measures the average CPU load over 10 seconds as a percentage.
`Average over 1 minute [%]`	Analogue output	0 to 100 %	The controller measures the average CPU load over 1 minute as a percentage.
`Average over 10 minutes [%]`	Analogue output	0 to 100 %	The controller measures the average CPU load over 10 minutes as a percentage.

Hardware > CPU > Core # *

Function	I/O	Units	Details
`Currently [%]`	Analogue output	0 to 100 %	The controller measures the CPU core # load as a percentage. *
`Average over 10 seconds [%]`	Analogue output	0 to 100 %	The controller measures the average CPU core # over 10 seconds as a percentage. *
`Average over 1 minute [%]`	Analogue output	0 to 100 %	The controller measures the average CPU core # over 1 minute as a percentage. *
`Average over 10 minutes [%]`	Analogue output	0 to 100 %	The controller measures the average CPU core # over 10 minutes as a percentage. *

NOTE Where # is for Core 1, 2, 3, or 4

14. Glossary

14.1 Terms and abbreviations

Term	Abbreviation	Explanation
Action		The pre-defined set of actions that an alarm initiates. Also known as fail class.
AGC 150		AGC 150 Generator, Mains and BTB controllers can be used in a power management system with iE 250.
AGC-4		AGC-4 Generator, Mains and BTB controllers can be used in a power management system with iE 250.
AGC-4 Mk II		AGC-4 Mk II Generator, Mains and BTB controllers can be used in a power management system with iE 250.
Alarm levels		The number of alarms that can be assigned to an operating value. For example, the Over-current protection by default has two alarm levels.
Alarm monitoring system	AMS	Third party equipment used to monitor the controller system's alarms, for example, by using Modbus TCP/IP communication.
Alternating current	AC	
Alternating current module 3.1	ACM3.1	A replaceable PCB with voltage and current measurement inputs. Used in the ML 300 controller or extension racks.
American National Standards Institute	ANSI	
American wire gauge	AWG	A standardised wire gauge system, also known as the Brown & Sharpe wire gauge.
Analogue input	AI	Terminals on a controller hardware module that the controller uses to measure an analogue input. The analogue input type and range are typically selected during commissioning from a list of pre-configured voltage, current, and resistance measurement input ranges. A pre-configured analogue input function or alarm can also be assigned to the input.
Analogue output	AO	Terminals on a controller hardware module that the controller uses to send an analogue output. The analogue output type and range are typically selected during commissioning from a list of pre-configured voltage and current output ranges. A pre-configured analogue output function can also be assigned to the output.
Apparent power	S	The 3-phase apparent power, measured in kVA.
[A-side]		The A-side side of the breaker. For a **GENSET** controller, this is the generator side. For a **BUS TIE breaker** controller, this is Busbar A.
Asset		The equipment that the controller controls.
Automatic mains failure		A plant mode where the gensets automatically take over the load from the mains connection if the mains fails.
Automatic voltage regulator	AVR	Regulates the genset voltage. The AVR is external equipment. The AVR can have a fixed voltage set point. Alternatively, the DEIF controller can control the AVR.
Available power		In power management, available power is the capacity of the system to supply more power.
Base load		The generator supplies a constant load. For **GENSET** controllers, configure the asymmetric load sharing parameters to have a base load from a specific genset.
Bi-directional input		The wiring to a controller's digital input and common terminals may be swapped around without affecting the input's operation.
Blackout		The busbar voltage is less than 10 % of the nominal voltage, and all generator breakers are open.

Term	Abbreviation	Explanation
Blind module		A hardware module that consists of only a module faceplate. These are installed over empty slots, to protect the controller electronics.
Breaker		A mechanical switching device that closes to connect power sources to the busbar, or to connect busbar sections. The breaker opens to disconnect the power sources or to split the busbar.
[B-side]		The B-side side of the breaker. For a **GENSET** controller, this is the busbar. For a **BUS TIE breaker** controller, this is Busbar B.
Busbar		The copper conductors which connect the power sources to the power consumers. Represented on the single-line application drawing as the line that connects all the power sources and power consumers. If the bus tie breaker is open, there are two separate and independent busbar sections. Similarly, if the bus tie breaker is closed, there is only one busbar.
Bus tie breaker	BTB	Physically disconnects two main busbars from each other, so that they operate as two separate (split) busbars. Also reconnects split busbars so that they operate as one busbar. A **BUS TIE breaker** controller can control a bus tie breaker.
BUS TIE breaker controller		Controls and protects a bus tie breaker. The controller ensures that the two busbars are synchronised before closing the bus tie breaker.
Canadian Electrical Code	CEC	A standard published for the installation and maintenance of electrical equipment in Canada.
Commissioning		The careful and systematic process that takes place after installation and before the system is handed over to the operator. Commissioning must include checking and adjusting the controller.
Common terminal	COM	This is generally connected to either a power source, or the supply return. See the wiring examples for more information.
Configuration		Assigning input and output functions to terminals, and setting parameters, so that the controller is suitable for the application where it is installed. Configuration also refers to the arrangement of hardware and wiring.
Conformité Européenne	CE	The product meets the legal requirements described in the applicable directive(s). All products with CE marking have free access to markets in the European Economic Area (EEA).
Connected		A power source is connected to the system if it is running, synchronised with the busbar, and its breaker is closed.
Controller		DEIF equipment that measures system conditions and then uses outputs to make the system respond appropriately.
Current transformer	CT	A transformer for a current measurement, so that the current at the controller is within the controller's specifications.
CustomLogic		The ladder logic system included in the controller software, which can be configured for customised responses to measured or calculated values.
Diesel generator	DG	A **GENSET** controller can control a diesel generator.
Differential current module	ACM3.2	A replaceable PCB with current measurement inputs on consumer and neutral sides. Used in the ML 300 controller or extension racks.
Digital input	DI	Terminals on a controller hardware module that the controller uses to measure a digital input. A pre-configured digital input function or alarm can be assigned to the input.
Digital output	DO	Terminals on a controller hardware module that the controller uses to send a digital output. A pre-configured digital output function can be assigned to the output.
Direct current	DC	

Term	Abbreviation	Explanation
Electromagnetic compatibility	EMC	An equipment characteristic relating to the equipment's performance in the presence of electromagnetic interference, as well as its emission of electromagnetic interference.
Electromagnetic interference	EMI	The radiation emitted by the equipment as well as radiation that can affect the performance of equipment.
Electrostatic discharge	ESD	
Emulation		A controller test environment, accessible from PICUS, that does not require live AC power. A virtual operation mode, to simulate the effect of various real world actions.
Endian		Endian refers to how the order of bytes in a multi-byte value is perceived or acted upon. It is the system of ordering the individual elements in a digital word in a computer's memory as well as describing the order of transmission of byte data over a digital link.
Engine interface module 3.1	EIM3.1	A replaceable PCB, with its own power supply. This module includes 4 relay outputs, 4 digital inputs, an MPU and W input, and 3 analogue inputs. Used in the ML 300 controller or extension racks.
European Norm	EN	Standards issued by the European Committee for Standardisation (also known as Comité Européen de Normalisation).
Firmware		Software that is installed in the controller. This software enables the controller to: process inputs and outputs, display operating data, keep track of the equipment status, and so on.
Fixed power		A plant mode where the plant produces a fixed amount of power.
Generator		The machine that converts mechanical energy into electricity.
Generator breaker	GB	The breaker between a generator (for example, a genset) and the busbar.
Generator tacho (measurement/ output)	W	A generator tacho measurement. This can be used as a backup measurement for generator speed.
Genset		A prime mover (for example, a diesel engine) combined with a generator.
GENSET controller		Controls and protects a genset. This includes control of the generator breaker. The Power Management System can automatically start and stop gensets to ensure that the required power is available.
Governor	GOV	Regulates the engine speed.
Governor and AVR module 3.1	GAM3.1	A replaceable PCB, which includes load sharing capability. This module also includes 4 relay outputs, 2 analogue current or voltage outputs, a pulse width modulation output, and 2 analogue current or voltage inputs. Used in the ML 300 controller or extension racks.
Governor and AVR module 3.2	GAM3.2	A replaceable PCB with its own power supply, two analogue outputs, a pulse width modulation output, five digital inputs, a status relay output, and four relay outputs. Used in the ML 300 controller or extension racks.
Ground		A connection between the equipment and earth. For marine applications, a ground is a connection to the ship's frame.
	GOST	Regional standards maintained by the Euro-Asian Council for Standardization, Metrology and Certification.
High speed digital input	HSDI	MPU/W/NPN/PNP sensor digital input.
Horn output		The controller's digital output(s) that can be connected to a horn, a siren, lights, or other equipment. This alerts the operator that one or more alarms are activated.
Hysteresis		An offset added to prevent rapid switching when a value is near the control point.

Term	Abbreviation	Explanation
Ingress Protection Rating, or International Protection Rating	IP	The degree of protection against solids and water provided by mechanical casings and electrical enclosures.
Inhibit		A pre-defined condition that inhibits the alarm action. For example, for the inhibit ACM wire break, if the controller detects a wire break on the voltage measurements, the voltage unbalance alarm is prevented from occurring. Inhibited alarms are not shown in the alarm display.
Input output module 3.1	IOM3.1	A replaceable PCB, with 4 relay outputs, and 10 digital inputs. Used in the ML 300 controller or extension racks.
Input output module 3.2	IOM3.2	A replaceable PCB, with 4 relay outputs, 4 analogue multifunctional outputs, 4 digital inputs, and 4 analogue multifunctional inputs. Used in the ML 300 controller or extension racks.
Input output module 3.3	IOM3.3	A replaceable PCB, with 10 analogue multifunctional inputs. Used in the ML 300 controller or extension racks.
Input output module 3.4	IOM3.4	A replaceable PCB, with 12 transistor outputs, and 16 digital inputs. Used in the ML 300 controller or extension racks.
Institute of Electrical and Electronics Engineers	IEEE	
International Association of Classification Societies	IACS	
International Electrotechnical Commission	IEC	
International Organization for Standardization	ISO	
Internet Protocol version 4	IPv4	A protocol for communication across networks. IPv4 currently routes the most traffic on the Internet, but will gradually be replaced by IPv6.
Internet Protocol version 6	IPv6	A protocol for communication across networks. Among other things, IPv6 has a much larger address space than IPv4.
Island mode		A plant mode where the plant runs without connection to the mains (grid).
	JEM-TR177	Japan Electrical Manufacturers Association's noise standard.
Latch		An extra layer of protection that keeps the alarm action activated. When the alarm is not active and acknowledged, it can be unlatched.
Light emitting diode	LED	Used to show the controller and equipment status and alarms.
Liquid crystal display	LCD	The screen of the display unit. The information displayed varies, depending on the controller mode, the equipment operation and the operator input.
Load sharing		The controllers adjust the gensets so that each genset supplies the right amount of the total power. For equal load sharing, each genset supplies the same proportion of its nominal power.
Load take-over	LTO	A plant mode where the gensets take over the load from the mains connection.
Local control	LOCAL	A controller operating mode. Operator commands using the display unit push-buttons (for example, close breaker) start pre-programmed sequences in the controller. Remote commands are ignored.

Term	Abbreviation	Explanation
Magnetic pickup	MPU	Measures the genset speed (that is, RPM). This sensor is normally located at the genset flywheel.
Mains breaker	MB	The breaker between a mains and the busbar.
MAINS controller	MAINS	Controls a mains breaker (MB) to a mains, and optionally a tie breaker (TB).
Mains power export	MPE	A plant mode where the power exported to (or imported from) a mains connection is kept constant.
Manual mode	Manual	A controller operating mode. Operator commands (for example, close breaker) start pre-programmed sequences in the controller. Apart from trips, the controller does not automatically open or close breakers or start or stop the asset.
Mean Time Between Failures	MTBF	
Mean Time To Failure	MTTF	
Multi-line 300	ML 300	A DEIF product platform.
Multi-master system		All controllers perform all the power management calculations, based on shared information.
Name	[ ]	Square brackets show that the name inside the square bracket must be adapted according to the controller type. For example, for a **GENSET** controller, [A-side] is "Generator".
National Electrical Code	NEC	A standard for the safe installation of electrical wiring and equipment in the United States.
Network time protocol	NTP	Used to synchronise the time of a computer client or server to another server or reference time source.
Neutral	N	The neutral line in a three-phase electrical system.
Network ring		An Ethernet connection topology where the controllers are connected in a line, and the last controller is connected back to the first.
Network chain		An Ethernet connection topology where the controllers are connected in a line.
Nominal setting	nom or NOM	The expected voltage and frequency for the system, and each power source's maximum load and current. Many of the controller's alarms are based on percentages of the nominal settings.
	NPN	A type of transistor.
Number	#	Hash represents a number. The description is the same for each item in the range. For example, "Controller ID #" represents any of the possible controller IDs.
Oil pressure	OP	
Operate time		The time that the controller takes to measure, calculate, and change the controller output. For each alarm, the reaction time is based on the minimum setting for the time delay.
Out of service		A state that an alarm can be assigned to by an operator. Out of service alarms are inactive alarms. Out of service alarms do not automatically return to service and require operator action.
Parameter		A value, or set point, used to determine the controller's operation. Parameters include nominal values, the configuration options for the configurable inputs and outputs, and alarm settings.
Peak shaving	PS	A plant mode where the plant produces power so that the mains power import does not exceed the set point.
Personal computer	PC	Used to run the PICUS software. For example, a laptop computer.

Term	Abbreviation	Explanation
Phase L1	L1	The power line for one phase of a three-phase electrical system. Corresponds to R in Germany, Red in the UK and Pacific, Red in New Zealand, Black in the USA, and U on electrical machine terminals. The above colour codes are for guidance only. If uncertain perform a phase measurement.
Phase L2	L2	The power line for one phase of a three-phase electrical system. Corresponds to S in Germany, Yellow in the UK and Pacific, White in New Zealand, Red in the USA, and V on electrical machine terminals. The above colour codes are for guidance only. If uncertain perform a phase measurement.
Phase L3	L3	The power line for one phase of a three-phase electrical system. Corresponds to T in Germany, Blue in the UK and Pacific, Blue in New Zealand, Blue in the USA, and W on electrical machine terminals. The above colour codes are for guidance only. If uncertain perform a phase measurement.
Phasor		A complex plane representation (that is, a magnitude and direction) of a sinusoidal wave.
Power	P	The 3-phase active power, measured in kW.
Power factor	PF	The 3-phase power factor.
Power in Control Utility Software	PICUS	The DEIF utility software, used to design, configure, troubleshoot and monitor a system.
Power management system	PMS	The power management controllers work together as a power management system.
Printed circuit board	PCB	Supports and electrically connects components.
Programmable logic controller	PLC	A digital computer used for the automation of electromechanical processes.
Proportional integral derivative	PID	A feedback controller.
Pt100, Pt1000		Platinum temperature sensors
Pulse width modulation	PWM	Terminals with an output that uses variable pulse widths, and behaves as an analogue output.
	PNP	A type of transistor.
Rack		An aluminium box with a rack system that houses the hardware modules. Each controller consists of a rack and a number of hardware modules.
Rapid spanning tree protocol	RSTP	A protocol used to compute the topology of a local area network.
Reactive power	Q	The 3-phase reactive power, measured in kvar.
Reference		The signal sent to a control system that represents the desired value of the output.
Remote control	REMOTE	A controller operating mode. Remote commands (for example, close breaker) start pre-programmed sequences in the controller. The remote commands can come from a PLC, PICUS or a digital input. Commands from the display unit push-buttons are ignored.
Resistance measurement input	RMI	Variable resistance device, used for some of the input terminals on genset controllers.
Root mean squared	RMS	Refers to the mean magnitude of a sinusoidal wave. For example, RMS V refers to the mean AC voltage.
Running		A genset is regarded as running if the engine is started and there is running detection. A running engine does not necessarily have to be synchronised with the busbar.

Term	Abbreviation	Explanation
Section		Part of the busbar that is isolated from the rest of the busbar because bus tie breaker(s) are open. Busbar sections can run independently of each other, and do not have to be synchronised.
Shelve		A temporary state that an alarm can be assigned to by an operator. Shelved alarms are inactive alarms, but only for a selected period by the operator. When the period of time expires, the alarm is automatically unshelved by the system restoring the alarm to the previous alarm state. Alarm conditions are checked again.
Shielded foiled twisted pair	SFTP	SFTP cables are used to minimise electromagnetic interference.
Shutdown		An emergency or fast stop of the genset engine. No cooldown time is allowed.
SINGLE genset controller	SINGLE	Controls and protects prime mover and generator, the generator breaker and optionally a mains breaker.
Single-phase		A system where the load is connected between one phase and the neutral. Note: Single-phase does NOT mean a 3-wire single-phase distribution system, where the waveforms are offset by a half-cycle (180 degrees) from the neutral wire.
Supervision		A PICUS function to monitor the operation of the entire system, and to send commands to any of the controllers.
Supervisory control and data acquisition system	SCADA	
Switchboard		The cabinet where the power sources are connected to the power consumers.
System		The gensets, the other power sources, all breakers, the busbars, and all their controllers. Within the system, the DEIF controllers work together to supply the power required safely and efficiently.
Third-party equipment		Equipment other than the DEIF controller. For example: The genset, the genset engine control system, the wiring, the busbars, and the switchboard.
Tie breaker	TB	The breaker between a mains breaker and the busbar.
Time	t	
Time delay		An alarm must exceed its set point continuously for the period in its Time delay parameter before the alarm is activated.
Transmission control protocol/internet protocol	TCP/IP	The Internet protocol suite. It provides end-to-end connectivity by specifying data handling.
Trip		An emergency or fast opening of a breaker. No attempt is made to de-load the breaker before it opens.
United Kingdom	UK	
United States of America	US, USA	The USA sometimes requires different technical standards. They also use their own system of units.
Universal serial bus	USB	Communication protocol.
	UL 94	A plastics flammability standard released by Underwriters Laboratories of the USA.
Voltage	V	Electrical potential difference. U is used as an abbreviation for voltage in most of Europe, Russia and China.

Term	Abbreviation	Explanation
Voltage and frequency	V & Hz	For certain controller actions, both the voltage and frequency must be within the specified range. For example, for busbar OK, or to start synchronising a genset to the busbar.
Voltage transformer	VT	A transformer for a voltage measurement, so that the voltage at the controller is within the controller's specifications.

14.2 Units

The table below lists the units used in the documentation, as well as the US units where these are different. In the documentation, the US units are given in brackets, for example, 80 °C (176 °F).

Unit	Name	Measures	US unit	US name	Conversion	Alternative units
A	ampere	Current				
bar	bar	Pressure	psi	pounds per square inch	1 bar = 14.5 psi	1 bar = 0.980665 atmosphere (atm) 1 bar = 100,000 Pascal (Pa)
°C	degrees Celsius	Temperature	°F	Fahrenheit	T[°C] = (T[°F] - 32 °) × 5 / 9	T[°C] = T[Kelvin (K)] - 273.15
dB	decibel	Noise or interference (a logarithmic scale)				
g	gram	Weight	oz	ounce	1 g = 0.03527 oz	
g	gravitational force	Gravity, g = 9.8 m/s^2	ft/s^2		g = 32.2 ft/s^2	
h	hour	Time				
Hz	hertz	Frequency (cycles per second)				
kg	kilogram	Weight	lb	pound	1 kg = 2.205 lb	
kPa	kilopascal	Pressure	psi	pounds per square inch	1 kPa = 0.145 psi	
m	metre	Length	ft	foot (or feet)	1 m = 3.28 ft	
mA	milliampere	Current				
min	minute	Time				
mm	millimetre	Length	in	inch	1 mm = 0.0394 in	
ms	millisecond	Time				
N·m	newton metre	Torque	lb-in	pound-force inch	1 N·m = 8.85 lb-in	
RPM	revolutions per minute	Frequency of rotation (rotational speed)				
s	second	Time				
V	volt	Voltage				
V AC	volt (alternating current)	Voltage (alternating current)				
V DC	volt (direct current)	Voltage (direct current)				

Unit	Name	Measures	US unit	US name	Conversion	Alternative units
W	watt	Power				
Ω	ohm	Resistance				

14.3 Symbols

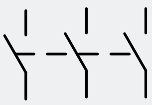
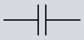
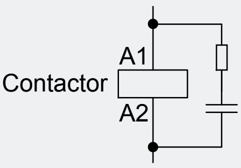
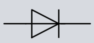
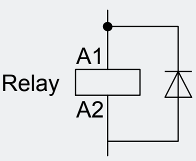
14.3.1 Mathematical symbols

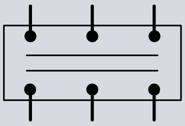
Abbreviation	Symbolises	Example
+	Addition	2 + 3 = 5
-	Subtraction	5 - 2 = 3
x	Multiplication (numbers)	2 × 3 = 6
/	Division	15 / 3 = 5
·	Multiplication (units)	5 N·m = 5 Newton metres
Σ	Summation	Σ Nominal power for connected gensets = 1000 kW + 1500 kW + 500 kW = 3000 kW

14.3.2 Drawing symbols

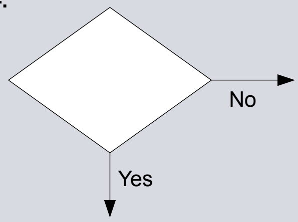
The drawings use EU symbols.

Electrical symbols

Symbol	Symbol name
	3-phase breaker
	Capacitor
	Contactor with RC snubber
•	Connector dot
	Current transformer (S1 and · show "current in"; S2 shows "current out")
	Diode
	Fuse
Ω	Ohmmeter
	Relay with freewheeling diode

Symbol	Symbol name
	Resistor (IEC-60617)
	Single-line diagram closed breaker
	Single-line diagram open breaker
o	Temporary connection dot (for example, connection to a meter)
	Voltage transformer. This is a generic voltage transformer, without any information about the transformer connections. These could for example be: open delta, star-star, closed delta, and so on.

14.3.3 Flowchart symbols

Symbol	Notes
#. 	Decision # shows step number.
	Process
	Alarm
	Information message
	Start or end