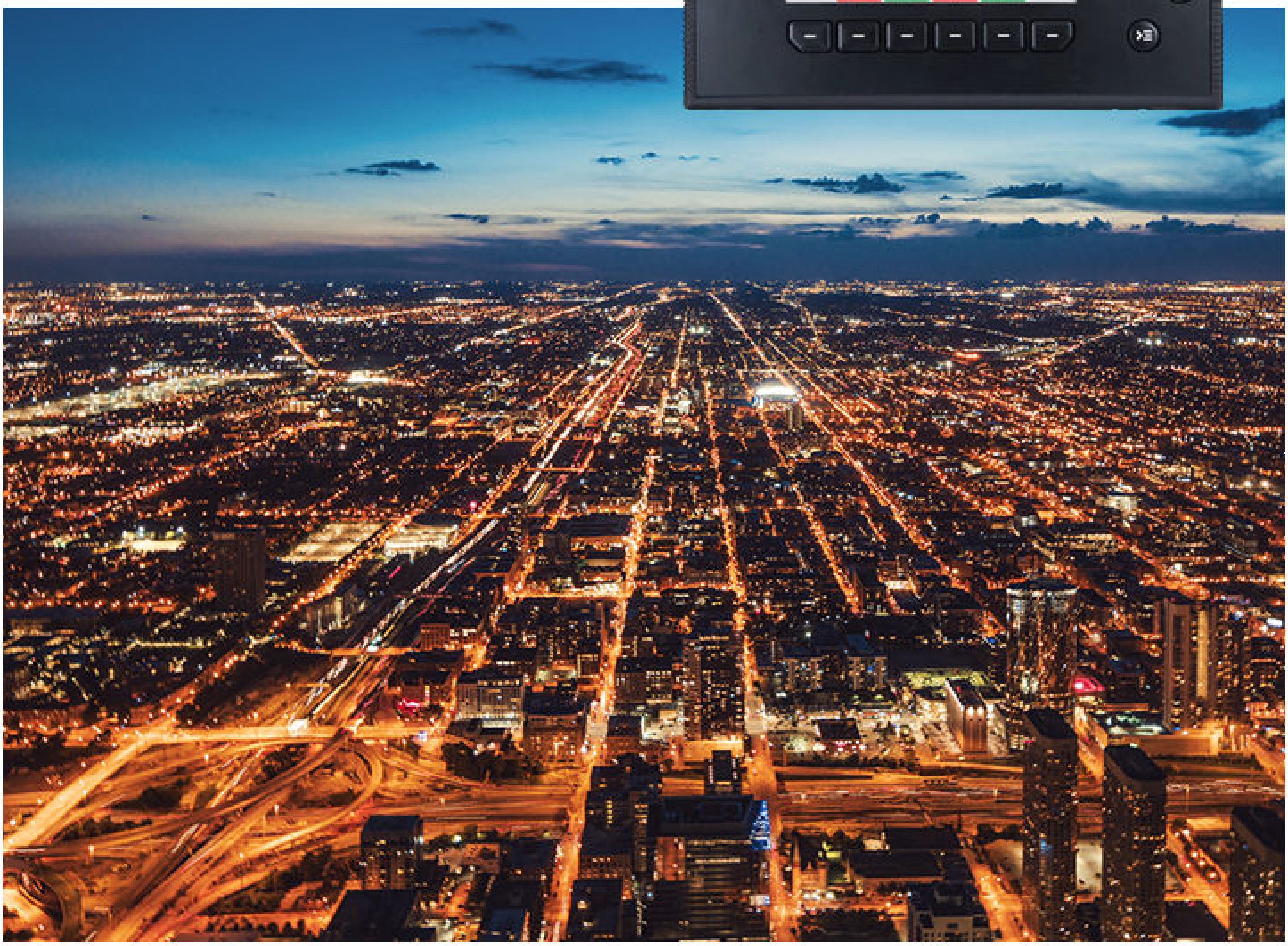
iE 250

4189341457A

Application notes

VDE AR-N 4110/4105 and G99 grid protection

DEIF Improve Tomorrow



1. Introduction to grid protections

2. External measurements, inputs and outputs

3. Grid protection functions

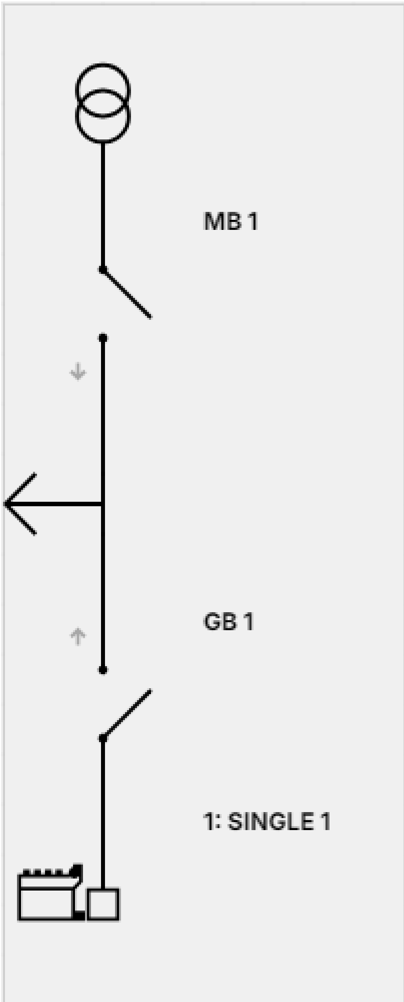
1. Introduction to grid protections

1.1 Grid protections

Grid protections is a group of functions for genset controllers. The functions allow the genset controller to meet VDE and G99 requirements, so that the genset connect to the grid.

Requirements

- The genset controller application must be a SINGLE GENSET controller with a mains connection.



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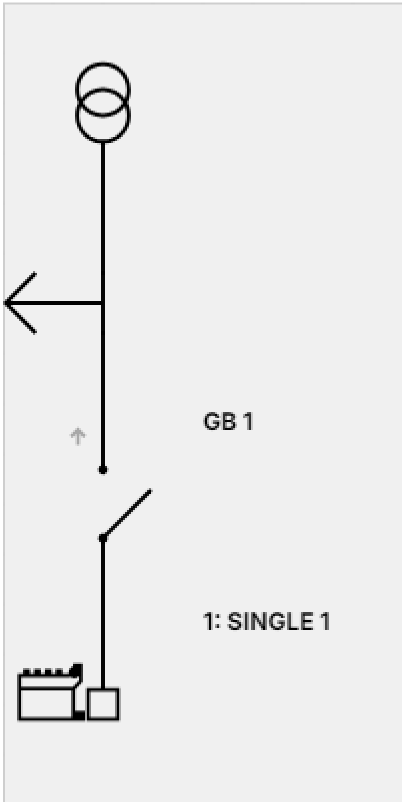


- The controller must have *LC* software.
- The controller must have the *Premium Land* licence.
  - You can use *WebConfig > License manager* to check the controller licence.
- The measurements at the grid connection must meet the requirements in this document.
- For each protection, the controller parameters must be configured to meet the local grid requirements.

1.2 Using the controller to meet VDE requirements

The functions required by VDE 4110 and 4105 are activated when the controller has the grid connection licence (which is included in the *Premium Land* licence). The user can then configure the controller according to the requirements of the local grid provider.

1.3 Using the controller to meet G99 requirements

The functions required by G99 are activated when the controller has the grid connection licence (which is included in the *Premium Land* licence). The user can then configure the controller according to the requirements of the local grid provider.

1.4 Software version

This document is based on the following software:

Controller	Application software	PICUS
iE 250 (LC)	2.0.15	1.0.25

The defaults are generally based on the requirements from DIN VDE AR-N 4105, DIN VDE AR-N 4150 and G99. However, you must check all relevant parameters and settings (especially for LVRT and HVRT) before the generator set is started for the first time.

1.5 Grid voltage and genset power

Nominal grid voltage

Several functions are based on the nominal grid voltage. The nominal grid voltage is defined in `Mains > Nominal settings > Nominal settings [1 to 4] > Voltage (V) > Nominal`.

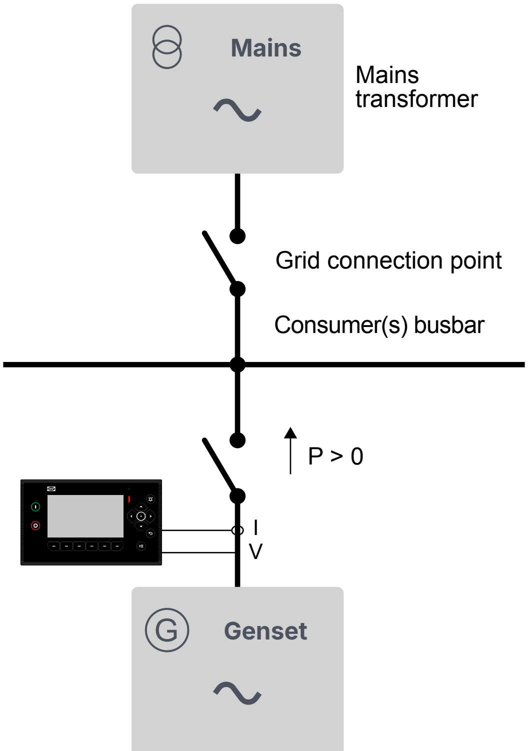
Nominal genset power

Several functions are based on the nominal genset power. The nominal genset power is defined in `Generator > Nominal settings > Nominal settings [1 to 4] > Power (P) > Nominal`.

1.6 Power direction

For all the protections, cos phi regulation, and the RRCR set points, the power from the genset is positive.

Positive power from the genset



NOTE For the reactive power direction, see Reactive power direction for variants A, B, C and E.

1.7 Phase-phase or phase-neutral voltage

By default, the controller uses phase-phase voltage measurements. For some protections, you can use `AC setup` to select the phase-phase or phase-neutral voltage measurement.

1.8 Abbreviations and glossary

Abbreviations

Abbreviation	Explanation
AVR	Voltage regulator
BDEW	*Bundesverband der Energie- und Wasserwirtschaft*, German Association of Energy and Water Industries The VDE grid protections are a successor to the BDEW requirements.
FRT	Fault Ride Through
GOV	Speed regulator
HVRT	High Voltage Ride Through
LVRT	Low Voltage Ride Through
PICUS	DEIF's PC Utility software
Pnom	Genset nominal power
Pref	The reference active power.
P %	Active power (P) as a percentage of the nominal power (Pnom).
Qnom	Genset nominal reactive power Calculations generally assume that Qnom = Pnom, although the generator capability curve is an exception.
Qref	The reference reactive power.
Q %	Reactive power (Q) as a percentage of the nominal power (Pnom).
RRCR	Radio Ripple Control Receiver Digital inputs can be used for external set point control. Digital outputs can be used to show the generator output.
U	Measured voltage
Uc	Nominal grid voltage
Unom	Nominal genset voltage
VDE	*Verband der Elektrotechnik*, one of Europe's largest technical-scientific associations

Glossary

Term	Explanation
genset	An electricity generating set with controllable speed (governor) and excitation (AVR).
genset controller	The iE 250 genset controller.
grid	The national electricity supply. Also called *mains*.
plant	The power producing facility where the genset is located.

1.9 Safety, warnings and legal information

1.9.1 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 or any relay terminals, as this could lead to injury or death.

1.9.2 Factory settings

The unit is delivered from the factory with default settings. These are not necessarily correct for the engine/generator set. Check all the settings before running the engine/generator set.

1.9.3 Legal information

DEIF takes no responsibility for installation or operation of the generator set. If there is any doubt about how to install or operate the engine/generator controlled by the controller, the company responsible for the installation or the operation of the set must be contacted.

NOTE The controller is not to be opened by unauthorised personnel. If opened anyway, the warranty will be lost.

1.9.4 Disclaimer

DEIF A/S reserves the right to change any of the contents of this document without prior notice.

The English version of this document always contains the most recent and up-to-date information about the product. DEIF does not take responsibility for the accuracy of translations, and translations might not be updated at the same time as the English document. If there is a discrepancy, the English version prevails.

1.9.5 Copyright

2. External measurements, inputs and outputs

2.1 AC measurements at the grid connection

For the grid protections, the AC measurements (voltage and power) **must** be at the grid connection point.

Voltage measurement

`Mains > AC setup > Connection point voltage measurement`

Name	Range	Description
Source	None External Analogue input	**None**: This is not allowed for grid protections. A connection point voltage measurement is required. **External**: The controller gets the connection point voltage using Modbus. **Analogue input**: A controller analogue input is connected to an external measurement of the voltage. The analogue input is assigned the function `Mains > Analogue > Connection point voltage measurement`, and configured for the external measurement.

Power measurement

`Mains > AC setup > Mains power measurement`

Name	Range	Description
Source	None I4 Analogue input	**None**: This is not allowed for grid protections. A power measurement is required. **I4**: The controller's 4th current transformer measures the current at the grid connection point. The controller uses this measurement with the voltage measurement to calculate the power. **Analogue input**: A controller analogue input is connected to an external measurement of the power. The analogue input is assigned the function `Mains > Analogue > P total [kW]`, and configured for the external measurement.

2.1.1 Using a transducer for voltage measurements

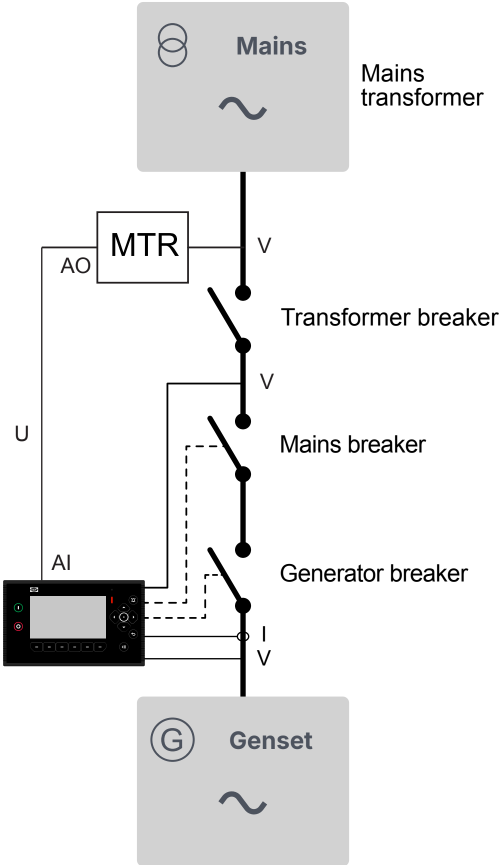
The *Q(U) U-shift* and *Q(U) Q-shift* functions can be based on a 4 to 20 mA grid voltage signal from a meter at the grid connection point. This is useful if there is a significant voltage drop in the measurement lines between the connection point and the controller.

NOTE When using an external analogue input, the wire break monitoring function must be activated. A fallback function must also be configured in case the input fails.

Voltage measurements from a DEIF MTR

The 4 to 20 mA signals from a DEIF MTR can be connected to a multi-input on the controller.

Example for voltage measurement as an analogue input from the grid connection point



To use an analogue input for the voltage at the grid connection:

- In the parameter `Mains > AC setup > Connection point voltage measurement > Source`, select *Analogue input*.
- For the analogue input function, select `Mains > Analogue > Connection point voltage measurement [V]`.

2.2 Priority of set point inputs

The regulation set points in the controller are either internal set points, or external set points. There are a number of different sources for external set points. The controller uses the following priority order for the regulation set points:

1. RRCR (highest priority)
2. If activated, and the frequency is outside the frequency deadband: Active power droop curve
3. Modbus
4. Controller analogue inputs
5. Internal set point

2.3 Set point outputs

The controller can output the P, Q and cos phi set points using analogue outputs and/or Modbus. See the **Modbus tables**.

You can use these analogue output functions:

- Regulators > GOV > GOV regulator reference [kW]
- Regulators > AVR > AVR regulator reference [kvar]
- Regulators > AVR > Cos phi reference [ ]

2.4 Display design

You can use the *Display designer* in PICUS to create grid connection dashboards. A wide range of data is available to display, including:

- Functions > Analogue output functions > Mains > Frequency (f) (from voltage) > Mains | L1
- Functions > Analogue output functions > Mains > Frequency (f) (from voltage) > Mains | Avg.
- Functions > Analogue output functions > Generator > Frequency (f) (from voltage) > Generator | L1
- Functions > Analogue output functions > Generator > Frequency (f) (from voltage) > Generator | Avg.
- Functions > Analogue output functions > Grid code > Reactive power regulation > Ramp switch timer

3. Grid protection functions

3.1 Power ramps

The controller has four sets of power ramps that are used during operation, and relevant for grid protections. You can configure a ramp up and ramp down curve for each set of power ramps.

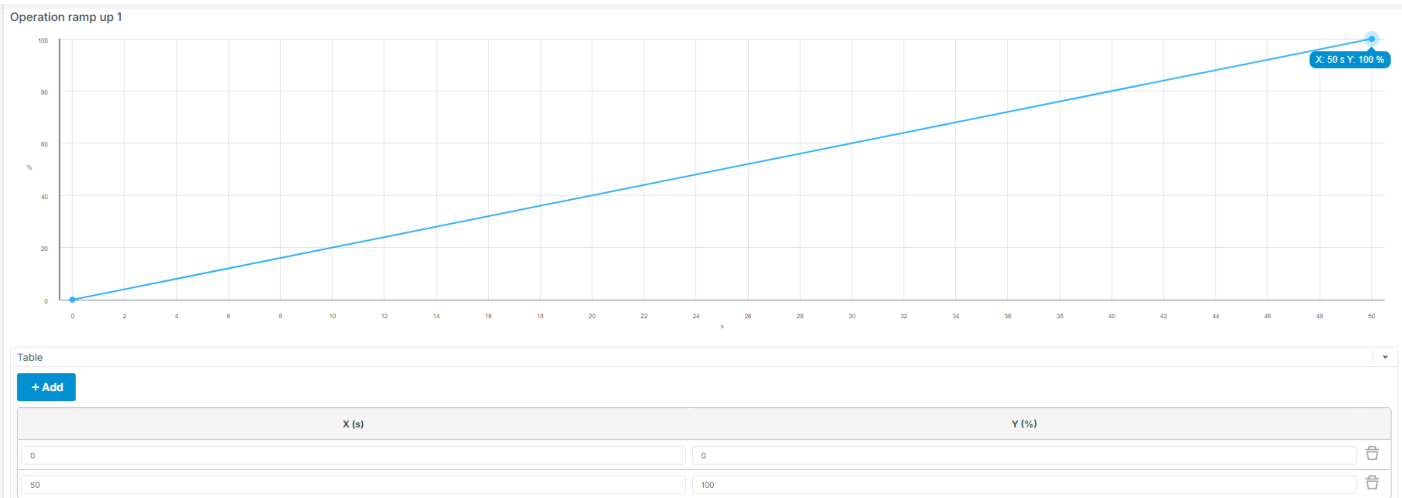
There are also ramps for entering operation, and deloading, but these ramps are not relevant for grid protections.

By default, ramp 1 is enabled. You can enable ramps 2 to 4 under `Regulators > GOV > Regulation set points > Active power ramp configuration`.

Ramp 1: Normal operation

`Regulators > GOV > Regulation set points > Active power ramp up > Operation ramp up 1`

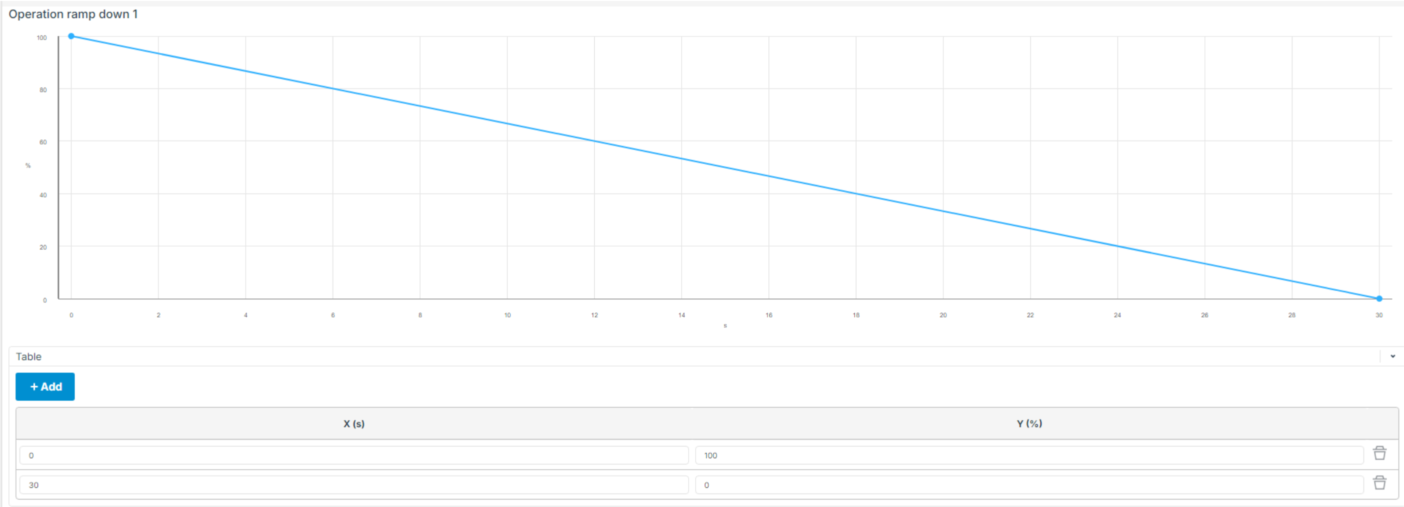
Name	Range	Description
Table > X (s)	0.0 to 3600.0 s	Time
Table > Y (%)	0 to 100 % of the generator nominal power	Power



`Regulators > GOV > Regulation set points > Active power ramp down > Operation ramp down 1`

Name	Range	Description
Table > X (s)	0.0 to 3600.0 s	Time
Table > Y (%)	0 to 100 % of the generator nominal power	Power

Example of *Operation ramp down 1* curve:



Ramp 2: Frequency outside the deadband

Ramp 2 is used when the frequency is outside the deadband. See Over- and under-frequency-dependent active power.

Use these parameters to configure ramp 2:

`Regulators > GOV > Regulation set points > Active power ramp up > Operation ramp up 2`

`Regulators > GOV > Regulation set points > Active power ramp down > Operation ramp down 2`

Ramp 3: Recovery after frequency and/or voltage outside the deadband

Ramp 3 is used when the frequency is back in the deadband, but the timer for the recovery is still running after a grid under- or over-frequency, or under- or over-voltage. See FRT curves (LVRT and HVRT).

Use these parameters to configure ramp 3:

`Regulators > GOV > Regulation set points > Active power ramp up > Operation ramp up 3`

`Regulators > GOV > Regulation set points > Active power ramp down > Operation ramp down 3`

Ramp 4: Recovery after a grid disconnection

Ramp 4 is used after a disconnection from the grid due to a grid protection, to ramp again after reconnection. See Mains sync inhibit (reconnection after a grid protection trip).

Use these parameters to configure ramp 4:

`Regulators > GOV > Regulation set points > Active power ramp up > Operation ramp up 4`

`Regulators > GOV > Regulation set points > Active power ramp down > Operation ramp down 4`

3.2 Reactive power ramp

Ramp functions are available for reactive power regulation. The ramp is used when the controller increases or decreases the reactive power.

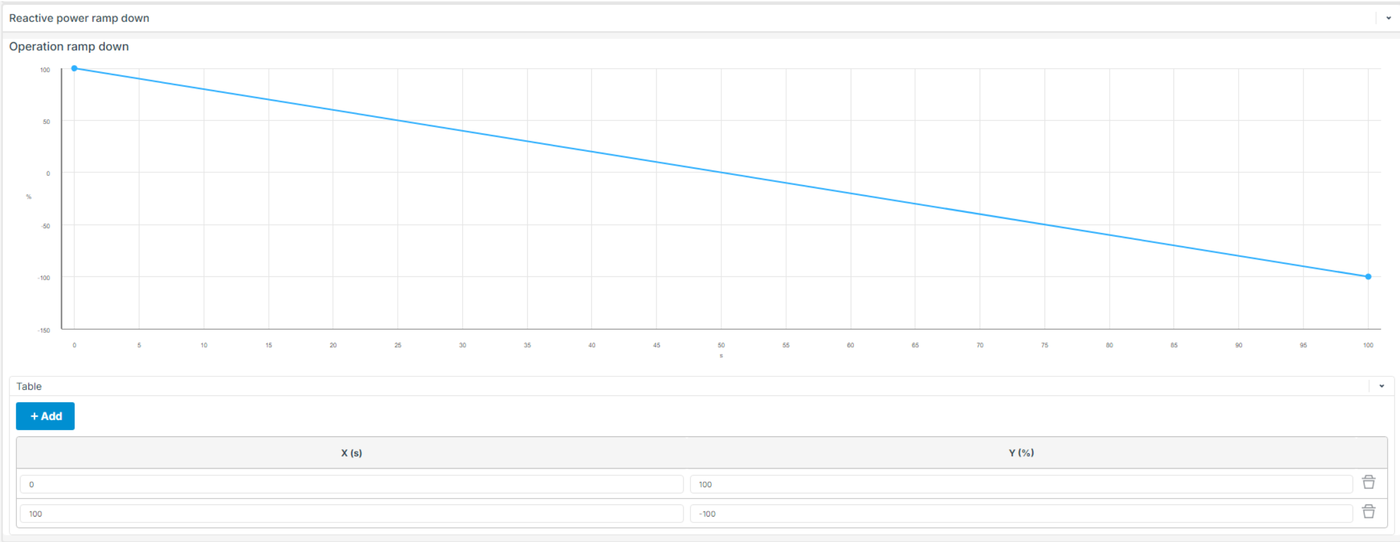
Parameters

`Regulators > AVR > Regulation set points > Reactive power operation ramp`

Name	Range	Description
Enable ramping	Linear Time constant	**Linear**: The curves defined in *Reactive power ramp up* and *Reactive power ramp down* are used.

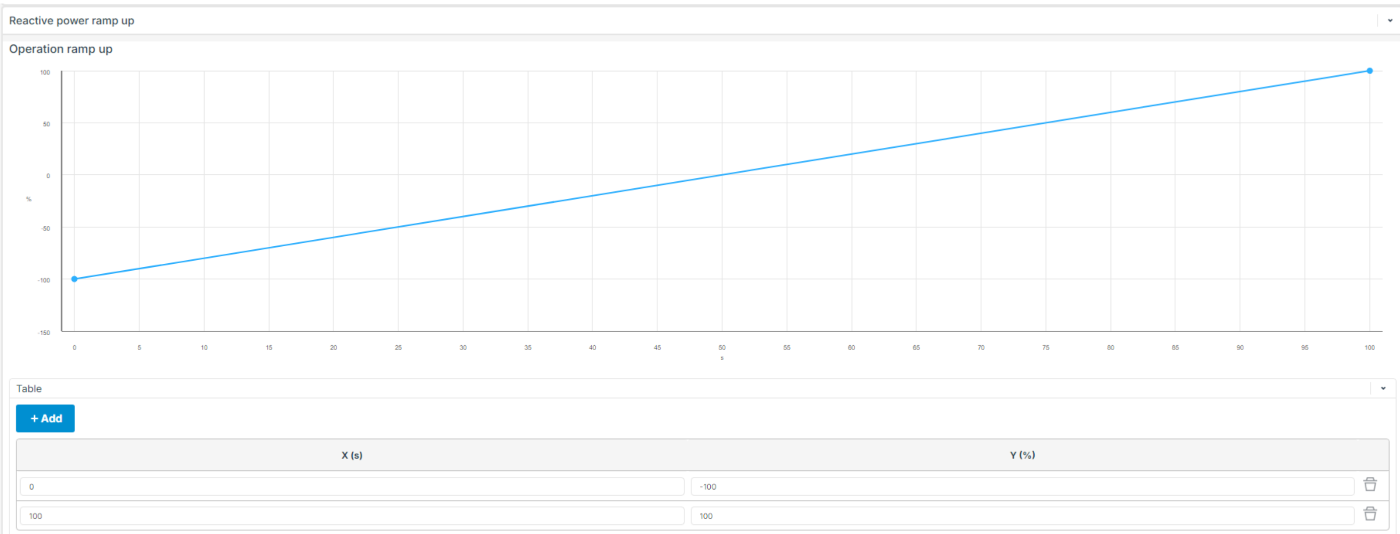
Name	Range	Description
		Time constant: *Time constant* is used.
Time constant	1.0 to 30.0 s	**Time constant** is selected: PT1-based time constant.

`Regulators > AVR > Regulation set points > Reactive power ramp up`



Use the table to configure the reactive power ramp up curve.

`Regulators > AVR > Regulation set points > Reactive power ramp down`



Use the table to configure the ramp down curve.

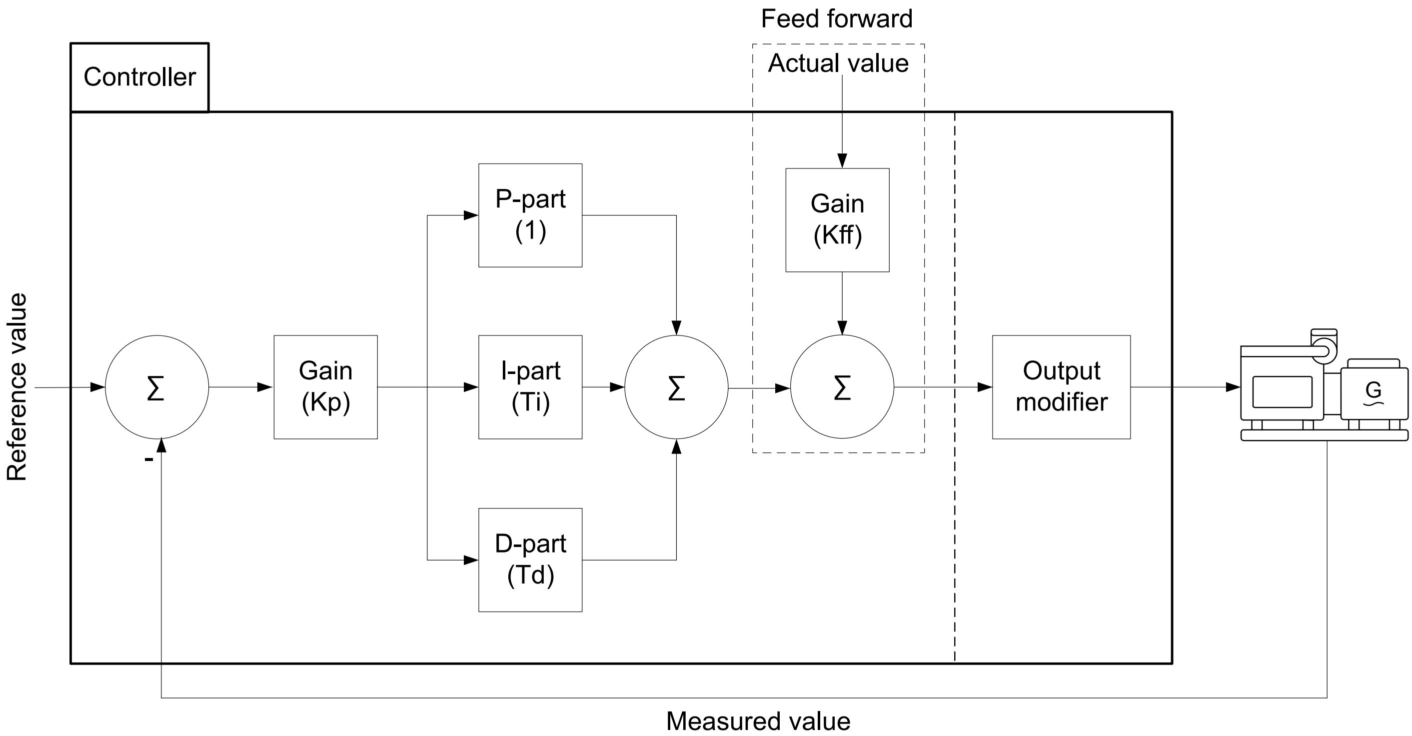
3.3 Feed forward

You can use the feed forward function to improve the regulation loop performance. You can activate the power regulator feed forward function. This suppresses the effect of frequency disturbances. You can also activate the reactive power regulator feed forward function to suppress voltage disturbances.

For example, without feed forward, if the frequency on the busbar increases, the controller could decrease the power from the genset. With feed forward, the effect of the busbar frequency change is minimised. Similarly, without feed forward, if the busbar voltage drops, the controller could reduce the reactive power from the genset. With feed forward, the effect of the busbar voltage change is minimised.

NOTE To support the grid and respond to frequency and voltage disturbances, the controller uses over- and under-frequency-dependent active power and reactive power regulation functions.

How the feed forward function works



For the power regulator feed forward function:

1. The controller calculates the PID regulation.
2. The controller calculates a contribution from the actual frequency and the configured gain.
3. The controller adds the feed forward contribution to the regulation output.

Parameters

`Grid code > Feed forward`

Parameter	Range	Description
Reactive power gain	0.00 to 50.00	**Q FF KFF**: The reactive power feed forward gain*.
Reactive power enable	Not enabled, Enabled	Enable the reactive power regulator feed forward.
Active power gain	0.00 to 50.00	**P FF KFF**: The power feed forward gain*.
Active power enable	Not enabled, Enabled	Enable the active power regulator feed forward.

Calculating the feed forward gain

To calculate the gain for a frequency disturbance (*P FF KFF*), you need the frequency range for the governor. For a symmetrical system, you can assume that the governor output in the middle of the range is 0.5. You can then calculate KFF using this formula:

$$KFF = \text{Governor output} / ((\text{Frequency}/\text{Nominal frequency}) - 1)$$

The gain for a voltage disturbance (Q FF KFF) is similar.

Power feed forward gain example

For example, for a nominal frequency of 60 Hz, the governor range is 56 to 64 Hz, that is ±4 Hz. When the frequency is 62 Hz, the governor output is 0.5.

KFF = 0.5 / ((62 Hz / 60 Hz) - 1) = 15

Reactive power feed forward gain example

For example, for a nominal voltage of 1 p.u., the AVR range is 0.88 to 1.12 p.u., that is ±0.12 p.u. When the voltage is 1.06 p.u., the AVR output is 0.5.

KFF = 0.5 / ((1.06 / 1) - 1) = 8.3

3.4 RRCR

The grid can use a Radio Ripple Control Receiver (RRCR) for load management. The controller uses digital inputs from the RRCR for its power and reactive power references.

The controller can also have digital outputs to the RRCR to communicate the generator operating values.

CustomLogic is used to connect the RRCR inputs to the controller references. Similarly, CustomLogic is used to translate operating values into RRCR outputs. This makes the RRCR configuration in the controller completely flexible.

RRCR inputs

To use the RRCR inputs, you must select `Grid code > RRCR > Inputs enable`.

Assign the RRCR signals to controller digital inputs by using the functions in `Grid code > RRCR > RRCR input [1 to 4]`.

RRCR outputs

To use the RRCR outputs, you must select `Grid code > RRCR > Outputs enable`.

Assign the RRCR signals to controller digital outputs by using the functions in `Grid code > RRCR > RRCR output [1 to 4]`.

CustomLogic project

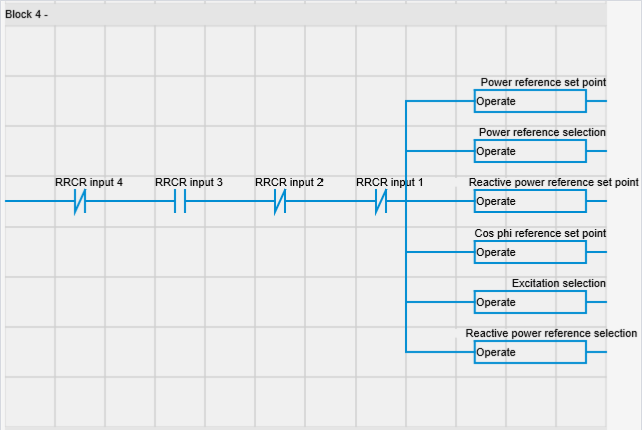
To use CustomLogic, you must select `Local > CustomLogic > Configuration > Enable`.

More information
To help you get started, DEIF has created a CustomLogic project to use as a template for RRCR. You can download this project from the controller documentation page (*RRCR project.xml* under *Application Notes*).

In PICUS, under CustomLogic, select *Open Project*. Select *RRCR project.xml*. PICUS loads 25 CustomLogic blocks. Blocks 0 to 15 connect the four RRCR input states to controller reference selections and set points. Blocks 16 to 24 connect the controller active power to the four RRCR digital outputs. Adjust the CustomLogic project to meet the grid RRCR requirements, then write it to the controller.

More information
See **CustomLogic** in the **PICUS manual**.

Configuring RRCR inputs

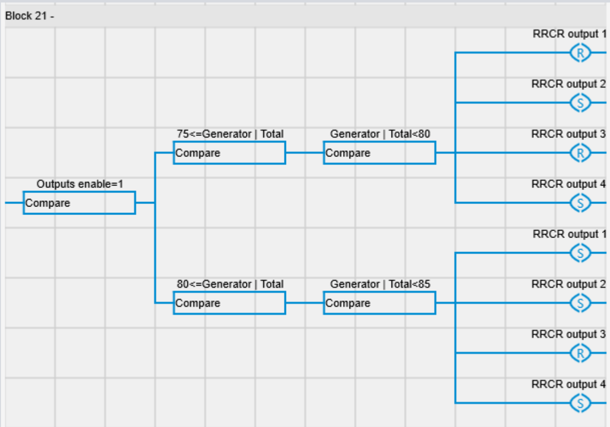


For block 4: The controller carries out the actions defined on the right only when ALL of these conditions are met:

- RRCR input 4 is OFF
- RRCR input 3 is ON
- RRCR input 2 is OFF
- RRCR input 1 is OFF

That is, if the conditions are met for block 4 in for the CustomLogic template for RRCR, then the power reference is activated, and the power reference set point is changed to 40 %.

Configuring RRCR outputs



For block 21:
Outputs enable=1: The *Outputs enable* parameter must be selected to continue on the logic ladder.
75<=Generator | Total: The total generator power must be more than 75 % of its nominal power to continue on the logic ladder.
Generator | Total<80: The total generator power must be less than 80 % of its nominal power to continue on the logic ladder.
Top branch: The generator power is between 75 and 80 %:

- CustomLogic deactivates RRCR output 1
- CustomLogic activates RRCR output 2
- CustomLogic deactivates RRCR output 3
- CustomLogic activates RRCR output 4

3.5 Frequency offset

To compensate for disturbances during testing, you can enable a frequency offset.

Parameters

`Grid code > Frequency offset`

Name	Range	Description
Frequency offset enable	Not enabled, Enabled	**Enabled**: The controller adds the frequency offset to the frequency reference.
Frequency offset source	External External → Off	**External**: The controller uses the frequency offset from an analogue input with the function `Grid code > Frequency offset > Frequency offset [Hz]`. **External → Off**: If the frequency is less than 10 % above or below the nominal frequency, the controller uses the value from the analogue input. If the frequency is 10 % above or below the nominal frequency, the frequency offset is not used.

3.6 Mains sync inhibit (reconnection after a grid protection trip)

If enabled, the *Mains sync inhibit* function inhibits mains breaker (MB) synchronisation after a grid protections trip.

As shown in the flowchart, the recovery timer (*Recovery delay select time*) is used to check whether the grid recovers quickly. If the grid recovers within this time, the short grid interruption timer (*Recovery delay 1 time*) starts. If the grid does not recover within this time, the controller waits until the grid recovers, then runs the long timer (*Recovery delay 2 time*).

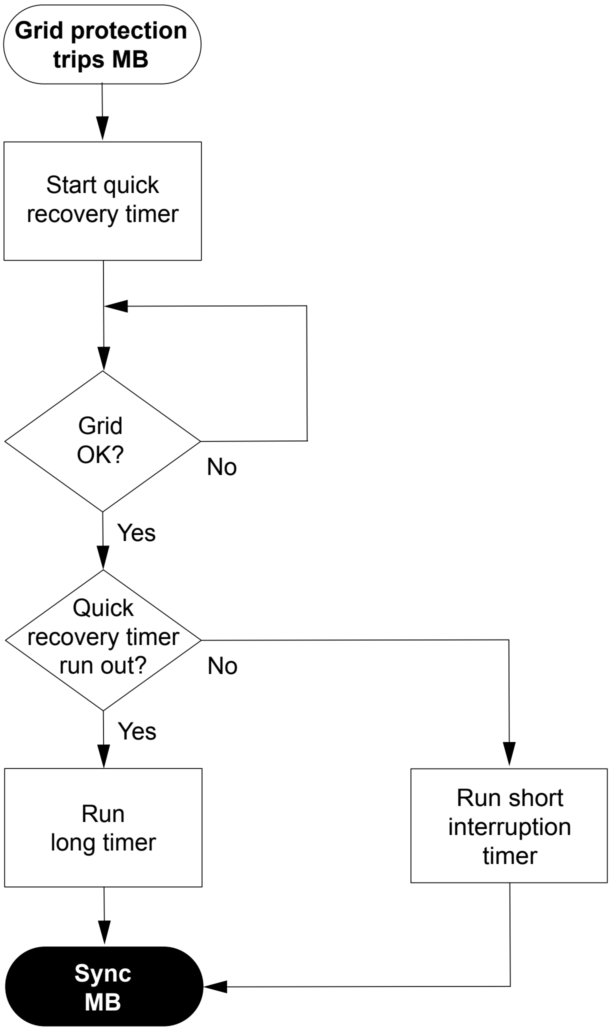
When the short or long timer runs out, the controller can synchronise the MB.

Parameters

`Grid code > Mains sync inhibit`

Name	Range	Details
Voltage low limit	80 to 100 % of the nominal voltage	Grid OK: The grid voltage must be higher than this limit.
Voltage high limit	100 to 120 % of the nominal voltage	Grid OK: The grid voltage must be lower than this limit.
Frequency low limit	90.0 to 100.0 % of the nominal frequency	Grid OK: The grid frequency must be higher than this limit.
Frequency high limit	100.0 to 110.0 % of the nominal frequency	Grid OK: The grid frequency must be lower than this limit.
Recovery delay select time	0.0 to 20.0 s	The grid quick recovery timer.
Recovery delay 1 time	0.0 to 60.0 s	The short grid interruption timer.
Recovery delay 2 time	0.0 to 2000.0 s	The long timer.
Action	Alarm actions	The alarm action when the grid is not OK, and/or the timers are running.

Flowchart



Examples

For these examples, the mains sync inhibit function is enabled.

- *Recovery delay select time* is 3.0 s.
- *Recovery delay 1 time* is 5.0 s.
- *Recovery delay 2 time* is 600.0 s.

Quick grid recovery

A grid connection function trips the mains breaker. The grid is OK again within 2.0 seconds.

The grid quick recovery timer runs for 2.0 seconds, then the grid is OK. The short grid interruption timer then runs for 5.0 s. The controller can therefore synchronise the mains breaker after 7.0 s.

Long recovery

A grid connection function trips the mains breaker. It takes 300 seconds before the grid is OK again.

The grid quick recovery timer runs for 3.0 seconds, but the grid is not OK. After 300 s, the grid is okay and the long timer starts. The long timer then runs for 600 s. The controller can therefore synchronise the mains breaker 900 s (15 minutes) after the initial trip.

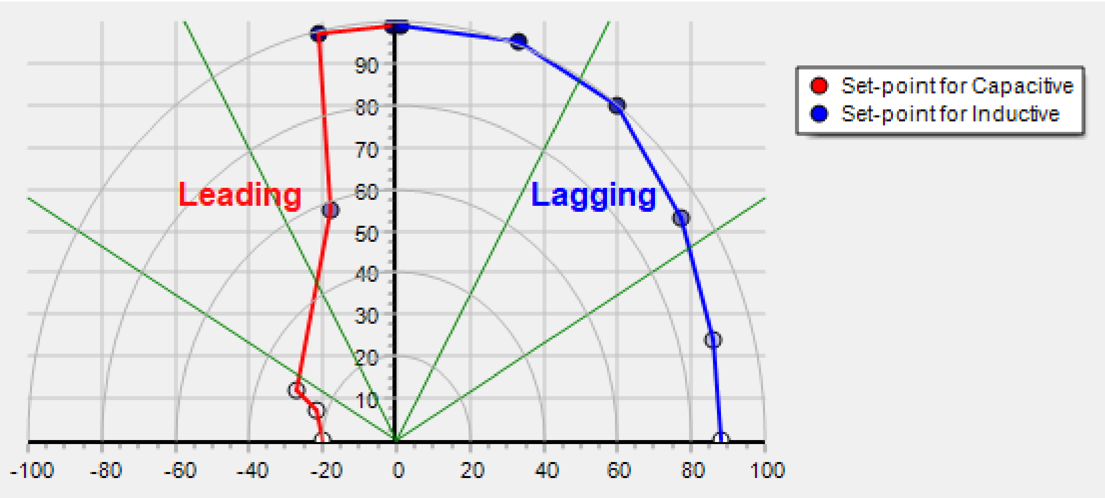
3.7 Capability curve

Active power-dependent reactive power limiting is a generator protection feature. It limits the reactive power production relative to actual power production.

Active power-dependent reactive power limiting can use the generator steady state reactive power capability curve. The actual curve depends on the generator. The curve should be included in the generator's data sheet. Contact the generator manufacturer to get this information.

To activate the reactive power limitation based on the capability curve, enable `Grid code > Capability curve > Protections > Import protection` and/or `Export protection`. Six active power and reactive power co-ordinates define the curve for import of reactive power. Similarly, six co-ordinates define the curve for export of reactive power.

Example of generator capability curve



The table below lists some of the terms that are used to describe the left and right side of this diagram.

Left side	Right side
Leading	Lagging
Capacitive	Inductive
Import*	Export*
Under-excited	Over-excited
Absorption	Injection

NOTE * The controller software uses *Import* and *Export*.

If the set point for reactive power is outside the limiting curve, the controller restricts the reference to the regulator. When the reactive power set point moves inside the limiting curve, the controller regulates reactive power (or cos phi).

Protections can also be activated to disconnect the generator from the grid.

The *AVR limiting set point* defines when regulation is stopped. If this parameter is *100 %*, the controller regulates all the way to the capability curve. For *95 %*, regulation stops at 5 % away from crossing the limit curve.

3.7.1 Parameters for capability curve

These parameters define the active power-dependent reactive power limiting.

`Generator > Nominal settings > Nominal settings [1 to 4] > Apparent power (S)`

Name	Range	Description
Nominal	12.5 to 25000.0 kVA	Nominal apparent power

`Regulators > AVR > Limiting type`

Name	Range	Description
AVR limiting type	Off	The controller does not limit the regulation of cos phi or reactive power.
	Droop curve	Depending on which regulator is active, the controller limits the regulation. For cos phi, the controller uses settings *Cos phi minimum* and *Cos phi maximum* (under `Grid code > Droop curve > Reactive power droop`). For reactive power, the controller uses settings *Reactive power minimum* and *Reactive power maximum* (under `Grid code > Droop curve > Reactive power droop`).
	Capability curve Q	The controller limits the regulation using the parameter settings for power-dependent reactive power limiting.

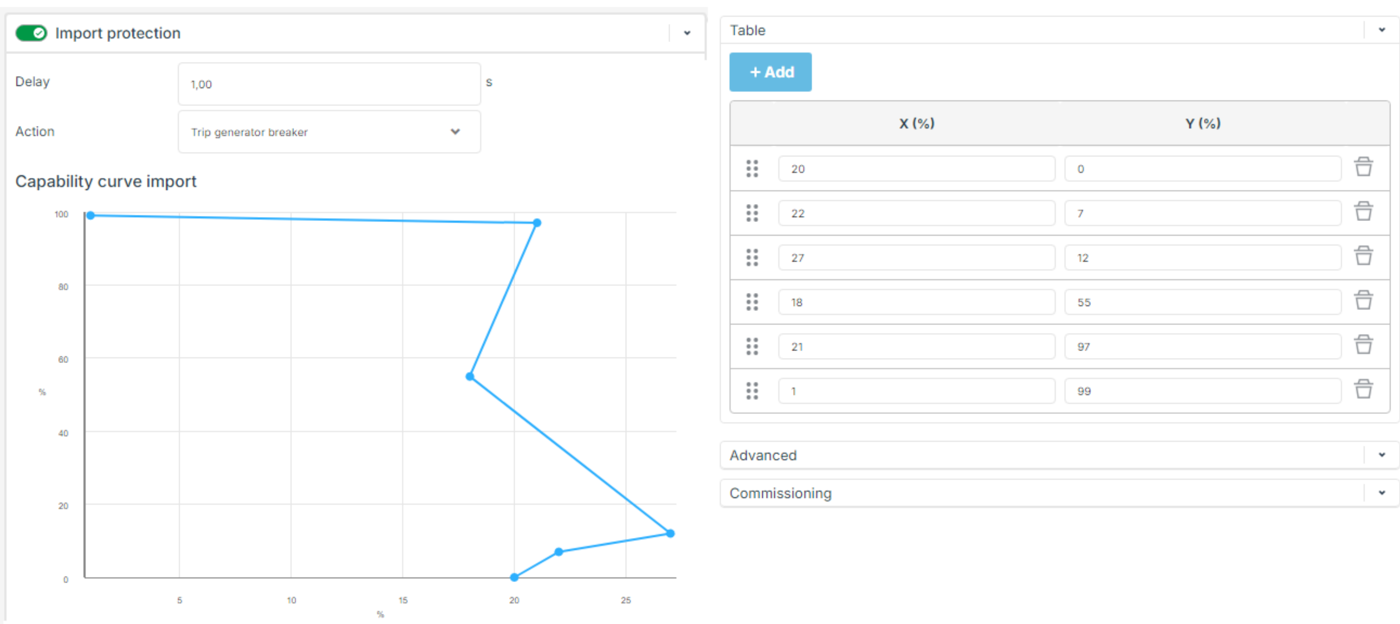
`Grid code > Capability curve > Configuration`

Name	Range	Description
AVR limiting set point	20 to 100 %	The cos phi/reactive power regulation stop with respect to the capability curve.
y-axis select	Apparent power (S) Power (P)	Select the y-axis for the capability curve.

`Grid code > Capability curve > Protections > Import protection`

Name	Range	Description
Delay	0.10 to 300.00 s	The delay for the import protection.
Table > X (%)	0.0 to 100.0 %	Reactive power
Table > Y (%)	0.0 to 100.0 %	Active power or Apparent power

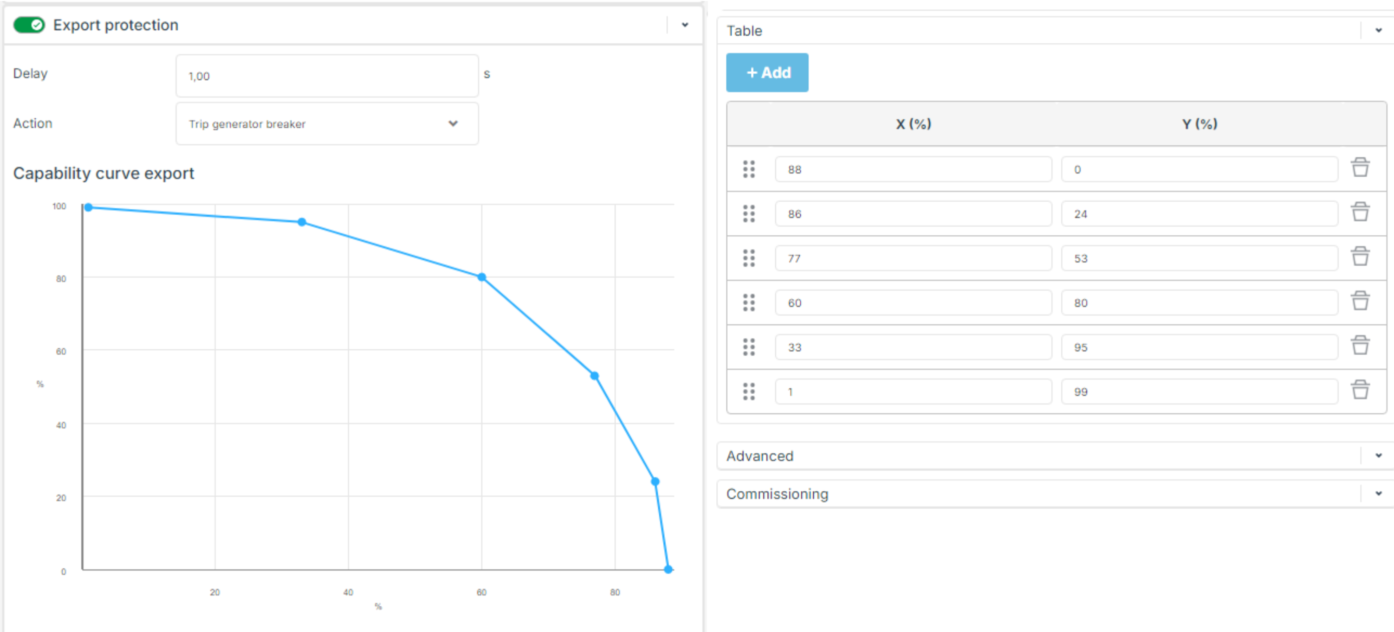
Example of import protection configuration



Grid code > Capability curve > Protections > Export protection

Name	Range	Description
Delay	0.10 to 300.00 s	The delay for the export protection.
Table > X (%)	0.0 to 100.0 %	Reactive power
Table > Y (%)	0.0 to 100.0 %	Active power or Apparent power

Example of export protection configuration



3.8 Reactive power regulation

For grid protections, there are several types of reactive power regulation.

The variant can be selected using the parameter, a digital input, or CustomLogic (*Output, Grid Support, Var Reg Type ...*).

Grid code > Reactive power regulation > Configuration

Name	Range	Description
Type selection	Default	The default control type is compatible with the BDEW rules. If reactive power droop is activated, reactive power regulation uses `Grid code > Droop curve > Reactive power droop`. Otherwise, reactive power regulation uses the set points in `Power management rules > Mains power > Common power factor control`.
	Variant A: Q(U) U-Shift	Reactive power regulation uses *Variant A: Q(U) U-Shift*.
	Variant B: Q(P) curve	Reactive power regulation uses *Variant B: Q(P) curve*.
	Variant C: Q(U) Q-shift	Reactive power regulation uses *Variant C: Q(U) Q-shift*.
	Variant D: Cos phi fixed	Reactive power regulation uses *Variant D: Cos phi fixed*.
	Variant E: Q fixed	Reactive power regulation uses *Variant E: Q fixed*.
Ramp switch timer	0 to 600 s	To prevent a sudden jump in reactive power set point, a ramp timer activates when the regulation type is changed. When the ramp is active, the new set point is reached at the selected ramp time. If the ramp timer is 0 s, the ramp is disabled.

3.8.1 Default reactive power regulation

When *Default* is selected, if reactive power droop is not activated, the reactive power regulation uses these set points. If reactive power droop is activated, the reactive power regulation uses `Grid code > Droop curve > Reactive power droop`.

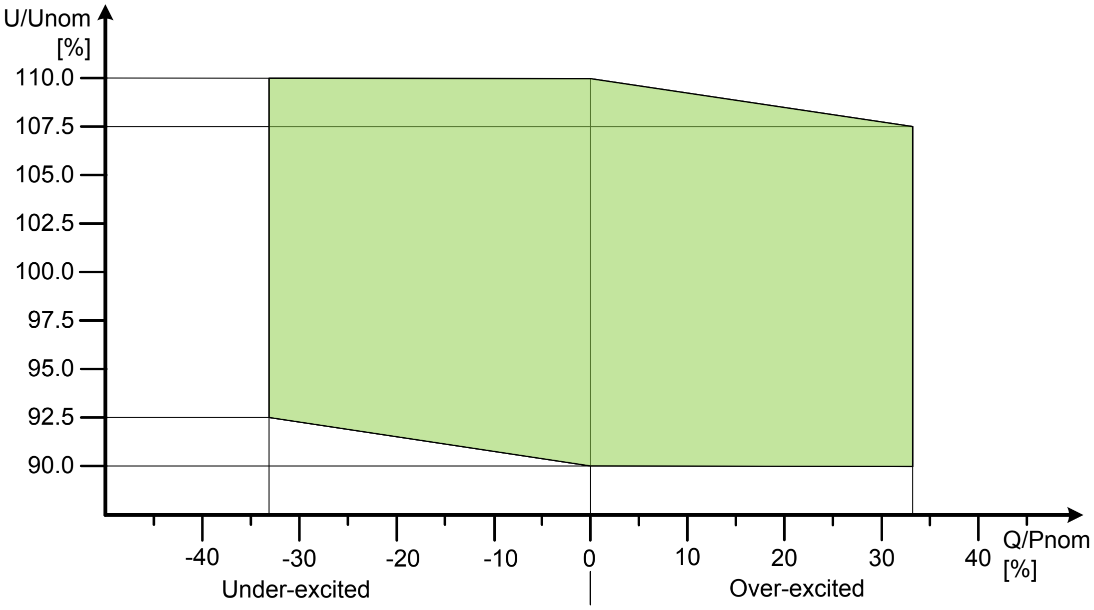
`Power management rules > Mains power > Common power factor control`

Name	Range	Description
Set point	0.700 to 1.000	Cos phi set point
Type	Inductive Capacitive	Cos phi inductive or capacitive
Controller settings Q	-100 to 100 %	Reactive power set point, as a percentage of Pnom
Controller settings cos phi or Q	Fixed cos phi Superior Fixed Q	**Fixed cos phi**: *Set point*. **Superior**: Not relevant for grid code protection. **Fixed Q**: *Controller settings Q*.

3.8.2 Grid voltage-dependent reactive power limiting

If the function is activated, the controller uses grid-voltage dependent reactive power limitation when one of the five types of reactive power regulation is activated. When the *Type selection* is *Default* (under `Grid code > Reactive power regulation > Configuration`), then the controller does not use grid voltage-dependent reactive power limiting.

Reactive power limiting



When the maximum or minimum limit is reached, reactive power limiting starts (that is, outside the green area). For example, when U/Unom is above 107.5 at 33 % Q/Pnom over-excited, or below 92.5 at 33 % Q/Pnom under-excited. The function can be activated for under- or over-voltage, or both.

The grid voltage-dependent reactive power limiting curve cannot be changed. At U/Unom = 90.0 and 110.0, the controller's reactive power set point is 0 kvar.

Grid voltage-dependent reactive power limiting does not automatically reduce the active power.

Example application

	Grid-voltage dependent reactive power limitation can allow the use of smaller generators. These generators have a lower current and mechanical load rating, and might not otherwise be able to supply enough reactive power.

3.8.3 Parameters for grid voltage-dependent Q limiting

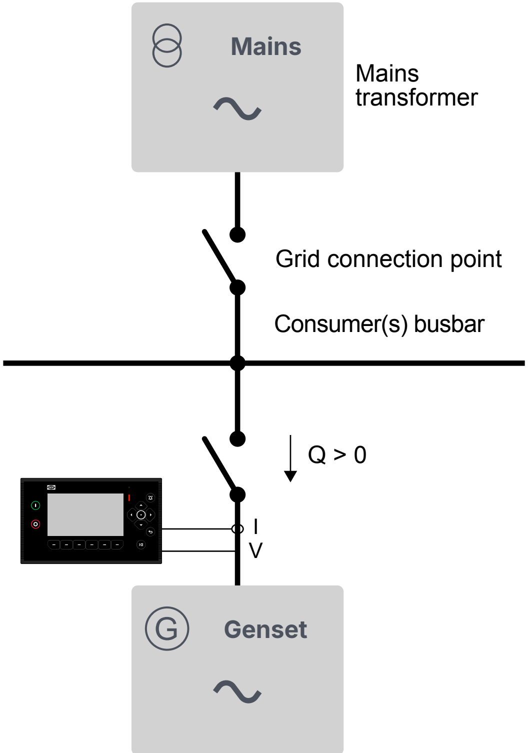
`Grid code > Reactive power regulation > Configuration`

Name	Range	Description
Limit Q under-excited	Not enabled, Enabled	**Enabled**: During low grid voltage, grid V-dependent Q limiting limits the reactive power.
Limit Q over-excited	Not enabled, Enabled	**Enabled**: During high grid voltage, grid V-dependent Q limiting limits the reactive power.

3.8.4 Reactive power direction for variants A, B, C, and E

For variants A, B, C, and E, the reactive power (Q) from the grid is positive. That is, positive reactive power is from the grid to the consumer.

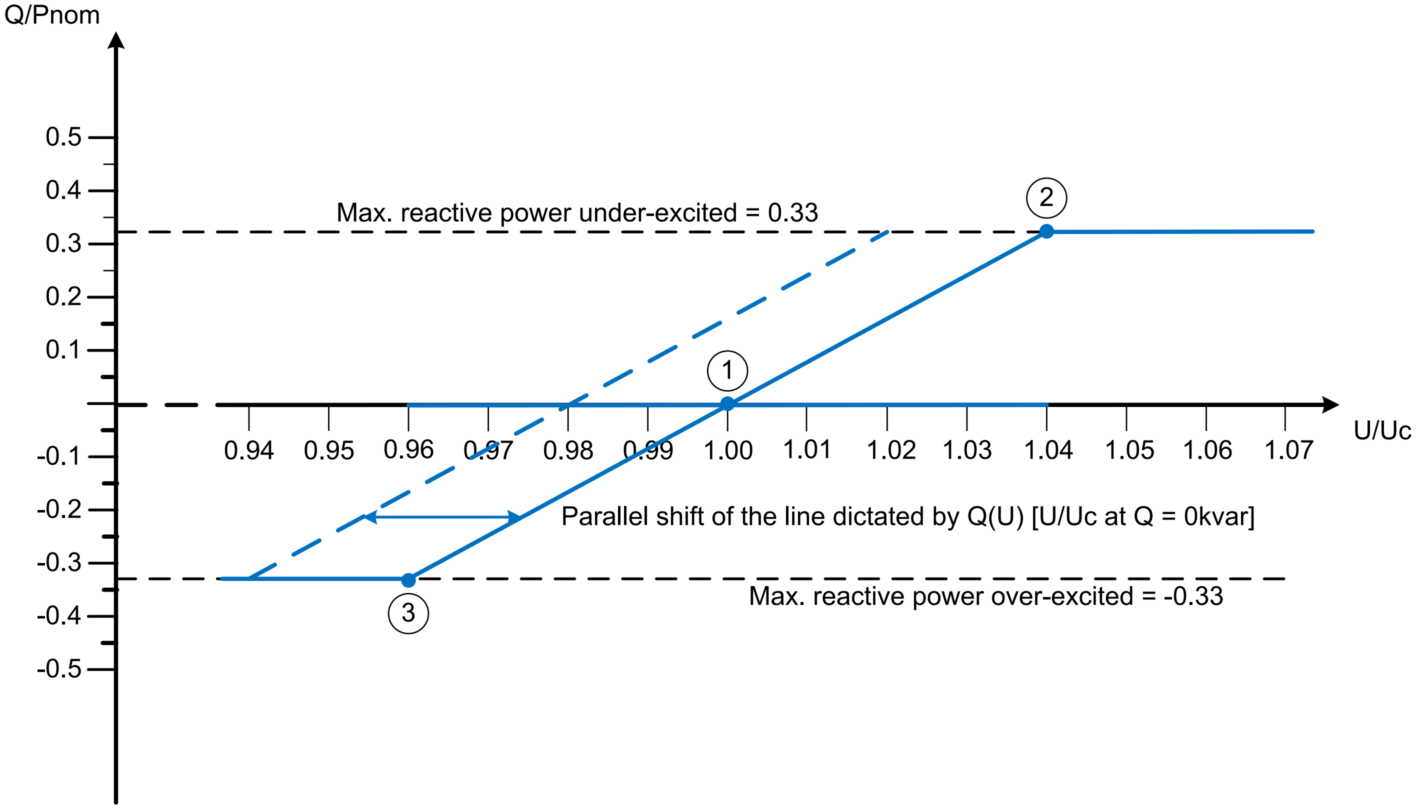
Positive reactive power to the genset



3.8.5 Variant A: Q(U) U-Shift

If *Q(U) U-shift* is selected, the reactive power is regulated with respect to the grid voltage. When the grid voltage is increasing, the reactive power is regulated in a capacitive direction. When the grid voltage is decreasing, the reactive power is regulated in an inductive direction.

Defaults for *Q(U) U-Shift*



The *Q(U) U-shift* curve is defined under `Grid code > Reactive power regulation > Variants > Variant A: Q(U) U-shift`.

Point 1 is defined by *Reference voltage at Q=0*.

Point 2 is defined by *Maximum voltage at Q max* and *Maximum Q during over-voltage* (over-excited).

Point 3 is defined by *Minimum Q during under-voltage* (under-excited). The voltage level for point 3 is defined automatically.

Point 1 can be moved horizontally using *Reference voltage offset value*, Modbus, or an analogue input. The movement of point 1 affects points 2 and 3.

Offset control

For offset control using Modbus, see the **Modbus tables**.

When using an analogue input for offset control, activate the wire break monitoring function. Configure CustomLogic to select another reactive power regulation function if the input fails.

3.8.6 Parameters for Variant A

`Grid code > Reactive power regulation > Variants > Variant A: Q(U) U-shift`

Name	Range	Description
Voltage deadband	0.00 to 5.00 %	
Reference voltage at Q=0	0.50 to 1.50	
Maximum voltage at Q max	0.50 to 1.50	
Maximum Q during over-voltage	0.00 to 0.40	
Minimum Q during under-voltage	-0.40 to 0.00	

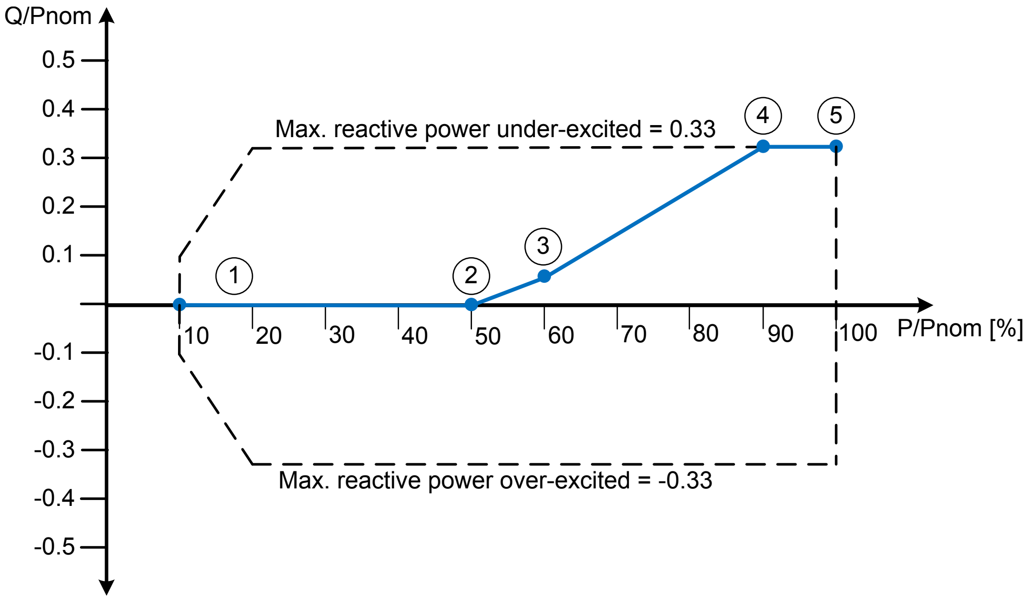
Name	Range	Description
Reference voltage offset value	-0.200 to 0.200	Offset value for reference voltage at Q=0.
External control	PICUS/Modbus Analogue	External control of the offset value for reference voltage at Q=0.

3.8.7 Variant B: Q(P) curve

This variant regulates the reactive power based on the measured active power.

The curve can have up to 10 co-ordinates. The default curve uses five co-ordinates.

Defaults for *Q(P) curve*



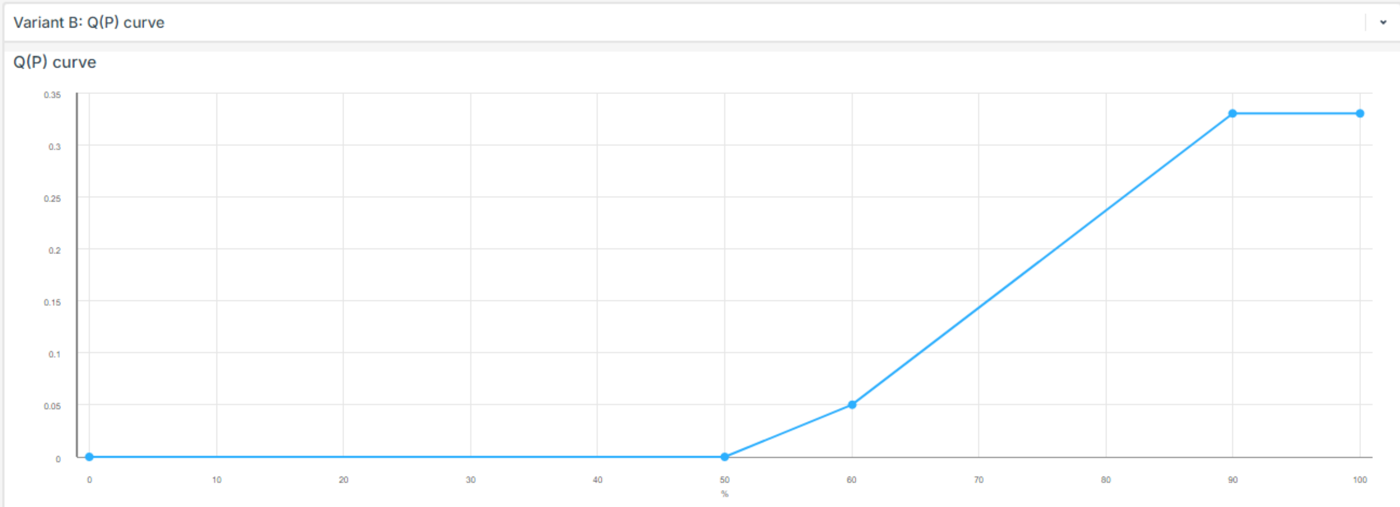
The active and reactive power % is related to the nominal active power.

3.8.8 Parameters for Variant B

`Grid code > Reactive power configuration > Variants > Variant B: Q(P) curve`

Name	Range	Description
Table > X (%)	0.0 to 100.0 %	P/Pnom
Table > Y ( )	-1.00 to 1.00	Q (in kvar) / Pnom (in kW) For example, if the Q/Pnom ratio is 0.05, for Pnom = 480 kW, then Q is 24 kvar. If Q/Pnom is -0.05, then Q is -24 kvar.

Example of Variant B: Q(P) curve



Table

+ Add

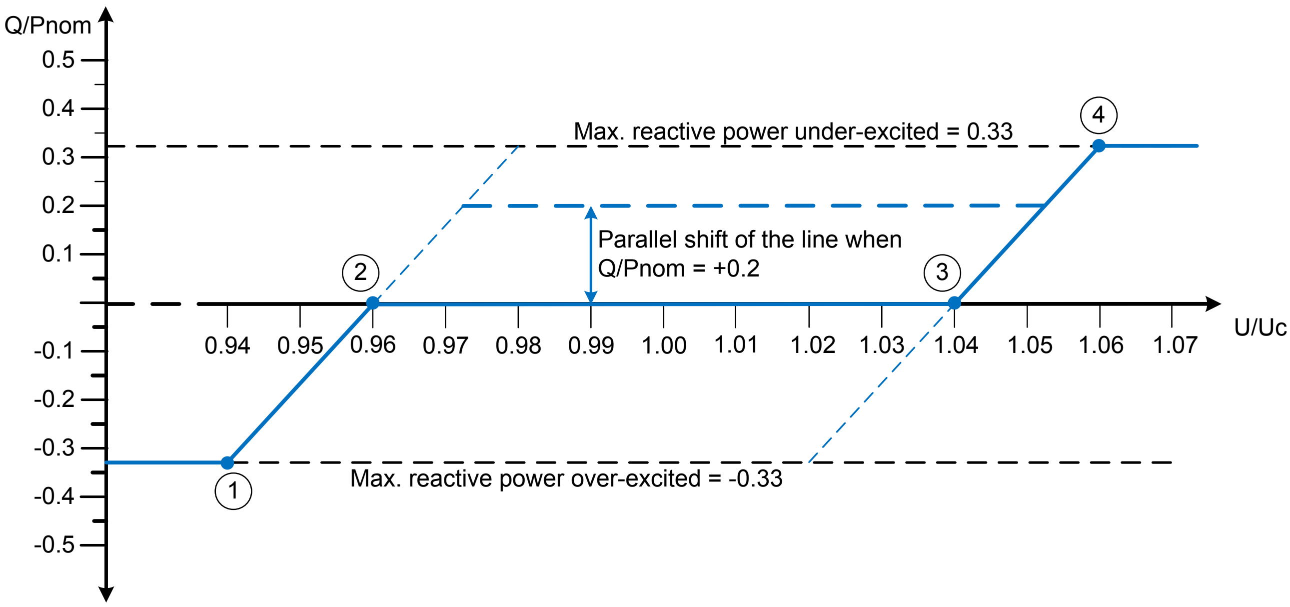
X (%)	Y ()
0	0
50	0
60	0.05
90	0.33
100	0.33

Use the table to configure the curve according to the requirements of the local grid provider.

3.8.9 Variant C: Q(U) Q-Shift

With *Q(U) Q-Shift*, the controller uses a fixed reactive power set point, to support the grid. If there is grid over- or under-voltage, the reactive power set point is adjusted based on the curve.

Defaults for *Q(U) Q-Shift*



The reactive power value between points 2 and 3 can be shifted by using an offset. The offset can be defined by a parameter, Modbus, or an analogue input. The offset is added to the actual reactive power.

The offset parameter is *Q/Pnom offset*.

Offset control

For offset control using Modbus, see the **Modbus tables**.

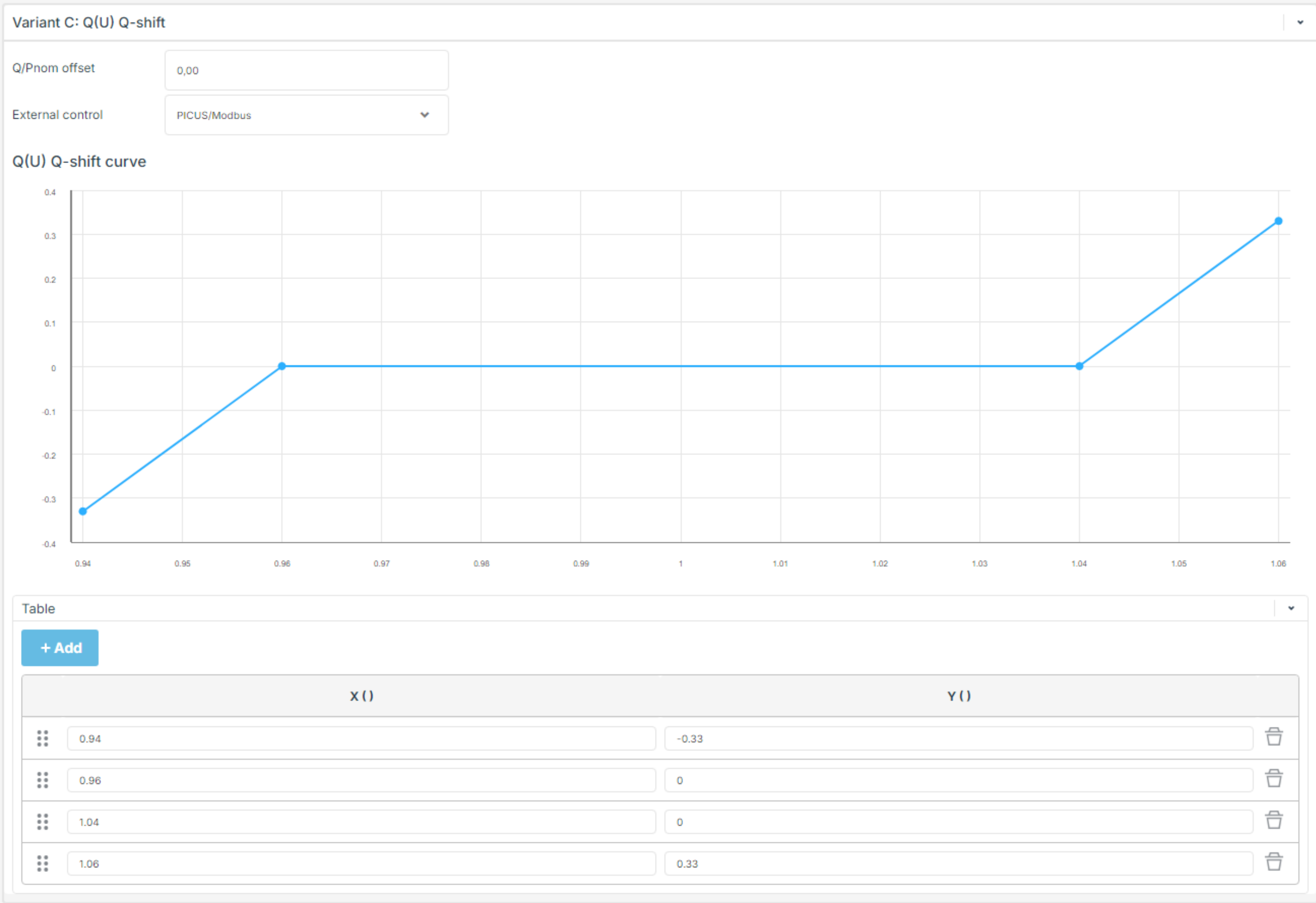
When using an analogue input for offset control, activate the wire break monitoring function. Configure CustomLogic to select another reactive power regulation function if the input fails.

3.8.10 Parameters for Variant C

`Grid code > Reactive power configuration > Variants > Variant C: Q(U) Q-shift curve`

Name	Range	Description
Q/Pnom offset	-0.40 to 0.40	Offset for Qref/Pnom
External control	PICUS/Modbus Analogue	External control of the offset value for Qref/Pnom
Table > X ( )	0.50 to 1.50	U/Uc
Table > Y ( )	-0.40 to 0.40	Q (in kvar) / P nominal (in kW) For example, for Pnom = 480 kW, if the Q/Pnom ratio is 0.05, then Q is 24 kvar. If Q/Pnom is -0.05, then Q is -24 kvar.

Use the table to configure the Variant C: Q(U) Q-shift curve.



3.8.11 Variant D: fixed cos phi

With this variant, the controller can have a fixed cos phi set point for regulation. The parameter has 3 decimals, as required in the VDE AR-N 4105/4110 rules. Inductive or capacitive cos phi can be selected. An offset value can be added to the cos phi value using the setting *Cosphi offset*, or Modbus.

For offset control using Modbus, see the **Modbus tables**.

3.8.12 Parameters for Variant D

`Grid code > Reactive power regulation > Variants > Variant D: Cos phi fixed`

Name	Range	Description
Cos phi set point	0.900 to 1.000	Cos phi set point
Cos phi direction	Inductive Capacitive	Cos phi inductive or capacitive (from the generator)
Cos phi offset	-0.100 to 0.100	Offset for the set point
External control	PICUS/Modbus Analogue	External control of the offset for cos phi **PICUS/Modbus**: If there is a value from Modbus, use it for the offset. Otherwise use the *Cos phi offset* parameter value. **Analogue**: Use the offset value from an analogue input.

3.8.13 Variant E: Q fixed

With this variant, the controller can have a fixed reactive power set point for regulation.

Parameter for Variant E

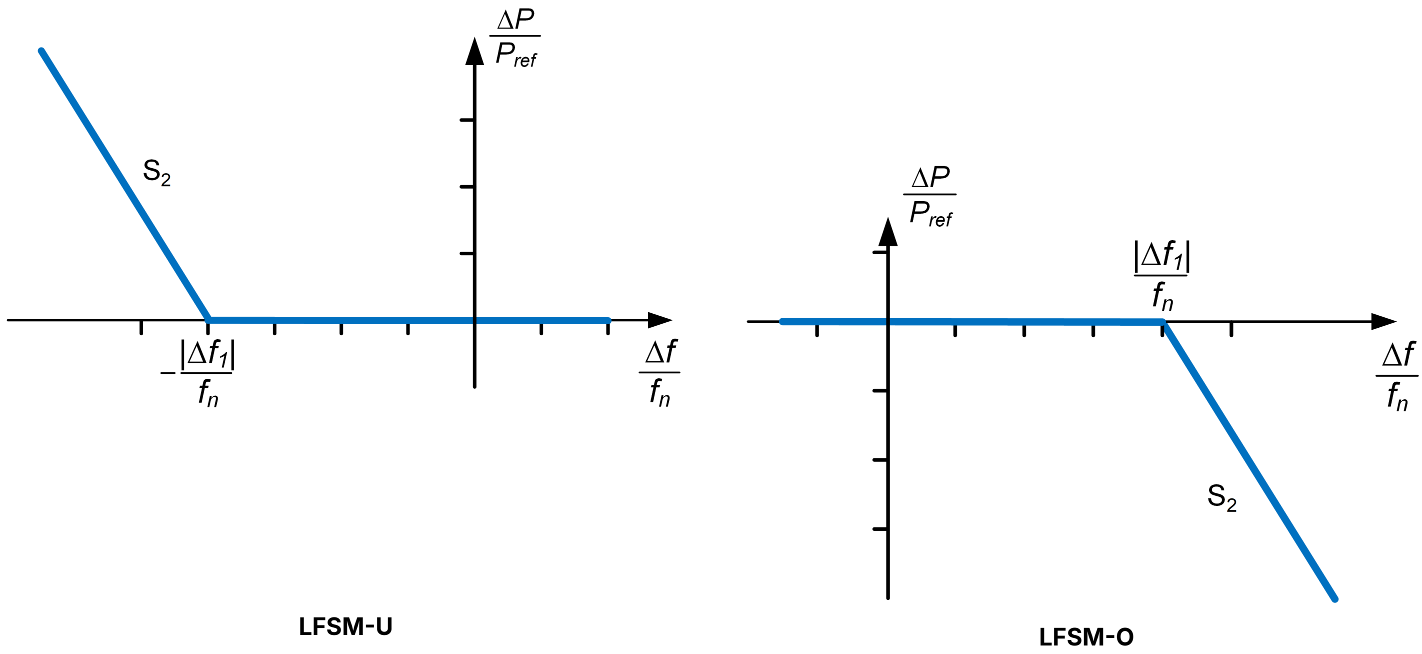
`Grid code > Reactive power regulation > Variants > Variant E: Q fixed`

Name	Range	Description
Q set point	-100.0 to 100.0 % of Q nominal	The reactive power set point for variant E.

3.9 Requirements for Generators frequency droop

Regulation (EU) 2016/631 (also known as RfG) (Requirements for Generators) states the requirements for the *Active power frequency response capability of power-generating modules*. The regulation includes a Limited Frequency sensitive mode - over-frequency (LFSM-O) and a Limited Frequency sensitive mode - under-frequency (LFSM-U). These use a Frequency threshold (f_1) and a Droop setting (S_2).

More information
See Over- and under-frequency-dependent active power for the grid connection functions used to meet the Requirements for Generators.



This formula defines the droop (S_2):

$$S_2\ [\%] = 100 \cdot \frac{|\Delta f| - |\Delta f_1|}{f_n} \cdot \frac{P_{ref}}{|\Delta P|}$$

S_2	[%]	Droop (2: LFSM)
Δf	[Hz]	The frequency deviation in the network.
Δf_1	[Hz]	The threshold frequency deviation from the nominal frequency (f_n). **LFSM-U**: The frequency threshold below which the generator must provide a positive active power output change. **LFSM-O**: The frequency threshold above which the generator must provide a negative active power output change.
f_n	[Hz]	The nominal frequency in the network. This corresponds to the controller nominal frequency (`Generator > Nominal settings > Nominal settings [1 to 4] > Frequency (f) > Nominal`).

P_{ref}	[W]	The reference active power. This corresponds to the controller nominal power (`Generator > Nominal settings > Nominal settings [1 to 4] > Power (P) > Nominal`). (the maximum capacity of the generator). ΔP is based on P_{ref}.
ΔP	[W]	The change in active power output from the generator.

3.9.1 Active power droop (for RfG)

General settings

Use the *Active power droop* parameters to meet the "active power frequency response capability of power-generating modules", seen in Requirements for Generators.

Settings

`Grid code > Droop curve > Active power droop`

Parameter	Range	#*	Comment
Enable	Not enabled, Enabled	1	
Dependency	Frequency, Voltage	2	
Calculation method	Active power installed Active power momentary	3	
Slope calculation method	Absolute Percentage	10	
Slope low absolute	-20 000 to 20 000 kW	11	This parameter is only visible if *Absolute* is selected for the *Slope calculation method*.
Slope high absolute	-20 000 to 20 000 kW	12	This parameter is only visible if *Absolute* is selected for the *Slope calculation method*.
Slope low percent	-100.0 to 100.0 %	13	This parameter is only visible if *Percentage* is selected for the *Slope calculation method*.
Slope high percent	-100.0 to 100.0 %	14	This parameter is only visible if *Percentage* is selected for the *Slope calculation method*.
Minimum active power	0 to 20 000 kW	8	
Maximum active power	0 to 20 000 kW	9	
Recovery delay	0 to 3600 s	-	You can configure a recovery delay.
Ramp 3 activation delay	0.0 to 10.0 s	-	You can delay the activation of ramp 3.
Deadband low	0.00 to 62.00 Hz	4	
Deadband high	0.00 to 62.00 Hz	5	
Hysteresis low	0.00 to 62.00 Hz	6	
Hysteresis high	0.00 to 62.00 Hz	7	

NOTE * More details below are given for each setting with a number in the # column.

Variables for calculations

f_{DBL}	[Hz]	The deadband low frequency (that is, for under-frequency).
f_{DBH}	[Hz]	The deadband high frequency (that is, for over-frequency).
f	[Hz]	The network frequency.
P(f)	[W]	The power at frequency f.
$P(f_{DBL})$	[W]	The power at the deadband low frequency.

$P(f_{DBH})$	[W]	The power at the deadband high frequency.
P_n	[W]	The controller nominal power (`Generator > Nominal settings > Nominal settings [1 to 4] > Power (P) > Nominal`).

Selecting RfG frequency droop

Use the following settings for RfG frequency droop:

Setting	#	Value	Notes
Curve enable	1	Enable	Enable the droop curve.
Curve select	2	Frequency	This ensures that the response is based on the actual system frequency.
Calculation method	3	Active power installed	This ensures that the droop response is based on the controller's nominal power (`Generator > Nominal settings > Nominal settings [1 to 4] > Power (P) > Nominal`). See P_{ref} above.

More information
You can request a spreadsheet for **RfG calculations** from DEIF.

Curve control settings

Setting	Unit	#	Notes
Deadband low	%	4	**DBL**: The frequency deadband (deviation from nominal, relative to the nominal). Below the deadband, droop curve 1 provides an active power output change calculated from *Slope low*. $DBL\ [\%] = \frac{\lvert \Delta f \rvert}{f_n} \cdot 100 = \frac{\lvert f_{DBL} - f_n \rvert}{f_n} \cdot 100$ **For RfG:** Configure deadband low to match the RfG LFSM-U threshold value (f_1 [Hz]): $DBL\ [\%] = \frac{\lvert f_1 - f_n \rvert}{f_n} \cdot 100$ Example: Threshold value (f_1) = 49.8 Hz Nominal frequency (f_n) = 50 Hz DBL = ∣49.8 - 50∣ / 50 · 100 = 0.4 %
Deadband high	%	5	**DBH**: The frequency deadband (deviation from nominal, relative to the nominal). Above the deadband, droop curve 1 provides an active power output change calculated from *Slope high*. $DBH\ [\%] = \frac{\lvert \Delta f \rvert}{f_n} \cdot 100 = \frac{\lvert f_{DBH} - f_n \rvert}{f_n} \cdot 100$ **For RfG:** Configure deadband high to match the RfG LFSM-O threshold value (f_1 [Hz]): $DBH\ [\%] = \frac{\lvert f_1 - f_n \rvert}{f_n} \cdot 100$ Example: Threshold value (f_1) = 50.2 Hz Nominal frequency (f_n) = 50 Hz DBH = ∣50.2 - 50∣ / 50 · 100 = 0.4 %
Hysteresis low	%	6	**HYSL**: The hysteresis is a deviation from nominal frequency relative to the nominal. Above this hysteresis the controller regards the system as recovered from the low frequency excursion. **For RfG:** Hysteresis is not relevant. Disable it by setting HYSL above DBL.
Hysteresis high	%	7	**HYSH**: The hysteresis is a deviation from nominal frequency relative to the nominal. Below this hysteresis the controller regards the system as recovered from the high frequency excursion.

Setting	Unit	#	Notes
			For RfG: Hysteresis is not relevant. Disable it by setting HYSH above DBH.
Minimum active power	kW	8	**P_{min} (MIN)**: The minimum active power. This limits the change in the active power output. **For RfG:** Configure P_{min} according to the system capabilities.
Maximum active power	kW	9	**P_{max} (MAX)**: The maximum active power. This limits the change in the active power output. **For RfG:** Configure P_{max} according to the system capabilities.

Droop curve slope

The droop curve 1 function includes two ways to configure the slope for the active power output change.

Setting	#	Value	Notes
Droop slope calculation method	10	Absolute	The slope is configured using absolute power values (see 11 and 12).
	10	Percentage	The slope is configured using percentage power values (see 13 and 14).

Absolute method for droop slope calculation

Setting	#	Unit	Notes
Slope low absolute	11	kW	**SLPL (LFSM-U)**: The slope of the active power output change when the network frequency is decreasing. **Using absolute frequency values:** $SLPL\left[\frac{W}{\%}\right] = \frac{P(f) - P(f_{DBL})}{\frac{\lvert f - f_{DBL} \rvert}{f_n} \cdot 100}$ For f < f_{DBL}; do not exceed P_{max}. **For RfG:** Configure the slope low value to match the RfG LFSM-U droop value (S_2 [%]): $SLPL\left[\frac{W}{\%}\right] = \frac{P_{ref}}{S_2}$ Example: LFSM-U droop (S_2) = 5 % Nominal power (P_n) = 480 kW SLPL [W/%] = 480 kW / 5 % = 96 kW/%
Slope high absolute	12	kW	**SLPH (LFSM-O)**: The slope of the active power output change when the network frequency is increasing. **Using absolute frequency values:** $SLPH\left[\frac{W}{\%}\right] = \frac{P(f) - P(f_{DBH})}{\frac{f - f_{DBH}}{f_n} \cdot 100}$ For f > f_{DBH}; do not exceed P_{min}. **For RfG:** Configure the slope high value to match the RfG LFSM-O droop value (S_2 [%]): $SLPH\left[\frac{W}{\%}\right] = \frac{-P_{ref}}{S_2}$ Example: LFSM-O droop (S_2) = 5 %

Setting	#	Unit	Notes
			Nominal power (P_n) = 480 kW SLPH [W/%] = -480 kW / 5 % = -96 kW/%

Percentage method for droop slope calculation

Setting	#	Unit	Notes
Slope low percentage	13	%	**SLPL (LFSM-U)**: The slope of the active power output change when the network frequency is decreasing. **Using absolute frequency values:** $SLPL\,[-] = \frac{\frac{P(f) - P(f_{DBL})}{P_n}}{\frac{\lvert f - f_{DBL} \rvert}{f_n}}$ For $f < f_{DBL}$; do not exceed P_{max}. **For RfG:** Configure the slope low value to match the RfG LFSM-U droop value (S_2 [%]): $SLPL\,[-] = \frac{100}{S_2}$ Example: LFSM-U droop (S_2) = 5 % SLPL [-] = 100 / 5 = 20 [-]
Slope high percentage	14	%	**SLPH (LFSM-O)**: The slope of the active power output change when the network frequency is increasing. **Using absolute frequency values:** $SLPH\,[-] = \frac{\frac{P(f) - P(f_{DBH})}{P_n}}{\frac{f - f_{DBH}}{f_n}}$ For $f > f_{DBH}$; do not exceed P_{min}. **For RfG:** Configure the slope high value to match the RfG LFSM-O droop value (S_2 [%]): $SLPH\,[-] = \frac{-100}{S_2}$ Example: LFSM-O droop (S_2) = 5 % SLPH [-] = -100 / 5 = -20 [-]

3.9.2 Verify the expected active power change

Calculation of the expected change in active power output at a certain deviating frequency

The following formulas aid test situations to verify the expected active power change caused by a certain frequency excursion.

Testing using the absolute method for droop slope calculation

Frequency range	Calculation and notes
Frequency below the deadband low frequency: $f < f_{DBL}$	The active power output change when the network frequency is decreasing. **Using absolute frequency values:**

Frequency range	Calculation and notes
Slope low (SLPL) - LFSM-U	$\Delta P\,[W] = -SLPL \cdot \frac{f - f_{DBL}}{f_n} \cdot 100$ SLPL [W/%]: Slope low (LFSM-U) ΔP [W]: The change in power output relative to the pre-disturbance power (do not exceed P_{max}). Example: Slope low (SLPL) = 96 kW/% Deadband low (f_{DBL}) = 49.8 Hz Nominal frequency (f_n) = 50 Hz Frequency of interest = 49 Hz ΔP[W] = -96 k · (49 - 49.8) / 50 · 100 = 153.6 kW **Using relative frequency values:** $\Delta P\,[W] = -SLPL \cdot (\Delta f - \Delta f_{DBL})$ Δf [%]: The network frequency relative to f_n (do not exceed P_{max}) Δf_{DBL} [%]: The deadband low frequency relative to f_n (at under-frequency) Example: Slope low (SLPL) = 96 kW/% Deadband low (Δf_{DBL} = -DBL) = (49.8 - 50) / 50 · 100 = -0.4 % Nominal frequency (f_n) = 50 Hz Frequency of interest = (49 - 50) / 50 · 100 = -2 % ΔP[W] = -96 kW · (-2 - -0.4) = 153.6 kW
Frequency above the deadband high frequency: $f > f_{DBL}$ Slope high (SLPH) - LFSM-O	The active power output change when the network frequency is increasing. **Using absolute frequency values:** $\Delta P\,[W] = SLPH \cdot \frac{f - f_{DBH}}{f_n} \cdot 100$ SLPH [W/%]: Slope high (LFSM-O) For $f > f_{DBH}$; do not exceed P_{min}. ΔP [W]: The change in power output relative to the pre-disturbance power (do not exceed P_{min}). Example: Slope high (SLPH) = -96 kW/% Deadband high (f_{DBH}) = 50.2 Hz Nominal frequency (f_n) = 50 Hz Frequency of interest = 51 Hz ΔP[W] = -96 k · (51 - 50.2) / 50 · 100 = -153.6 kW **Using relative frequency values:** $\Delta P\,[W] = SLPH \cdot (\Delta f - \Delta f_{DBH})$ Δf [%]: The network frequency relative to f_n (do not exceed P_{min}) Δf_{DBH} [%]: The deadband high frequency relative to f_n (at over-frequency) Example: Slope high (SLPH) = -96 kW/% Deadband high (Δf_{DBH} = DBH) = (50.2 - 50) / 50 · 100 = 0.4 % Nominal frequency (f_n) = 50 Hz Frequency of interest = (51 - 50) / 50 · 100 = 2 % ΔP[W] = -96 kW · (2 - 0.4) = -153.6 kW

Testing using the percentage method for droop slope calculation

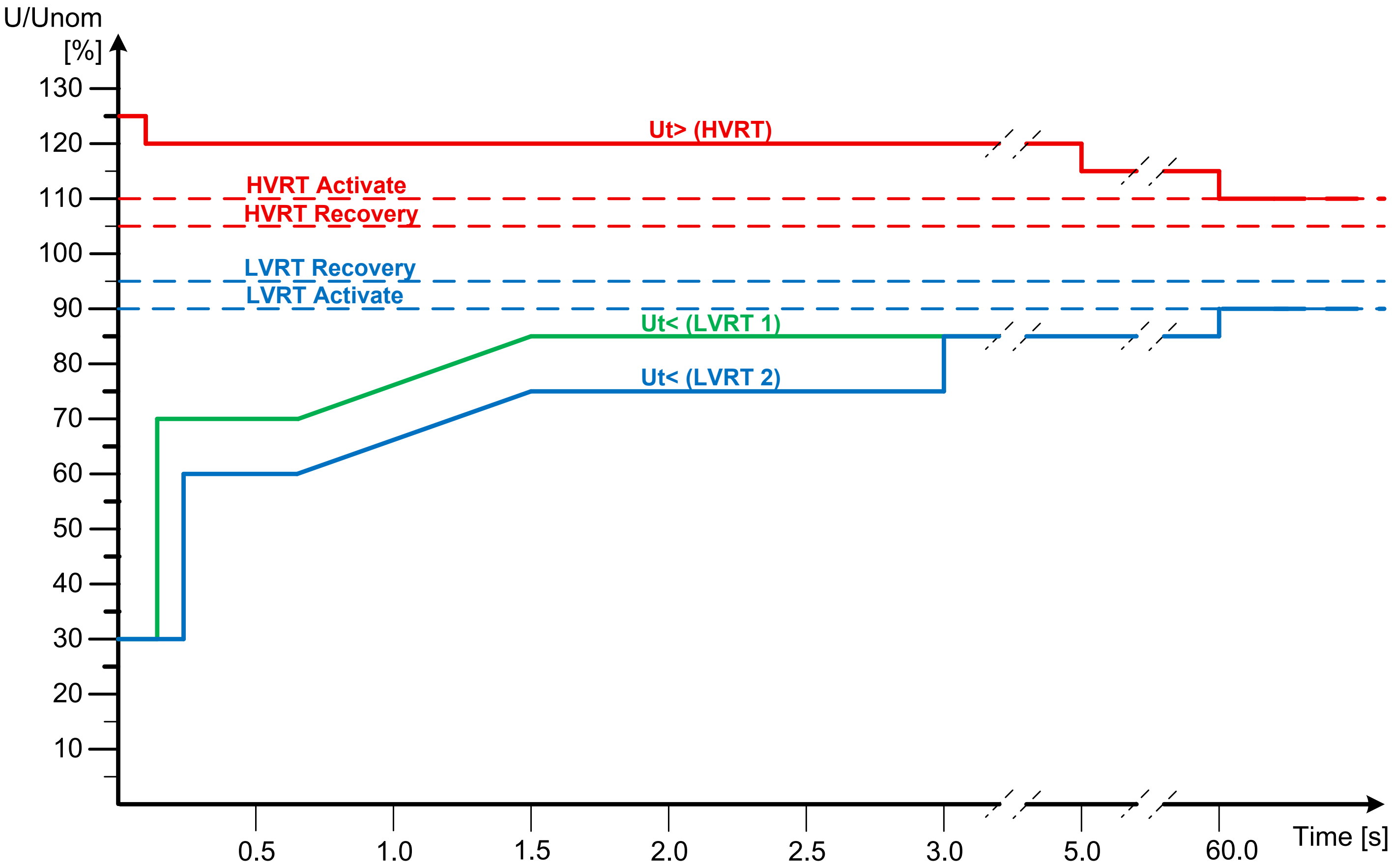
Frequency range	Calculation and notes
Frequency below the deadband low frequency: $f < f_{DBL}$ Slope low (SLPL) - LFSM-U	The active power output change when the network frequency is decreasing. **Using absolute frequency values:** $\frac{\Delta P}{P_n}$ [%] = $-SLPL \cdot \frac{f - f_{DBL}}{f_n} \cdot 100$ SLPL [-]: Slope low (LFSM-U) $\Delta P/P_n$ [%]: The change in power output relative to the pre-disturbance power (do not exceed P_{max}). Example: Slope low (SLPL) = 20 [-] Deadband low (f_{DBL}) = 49.8 Hz Nominal frequency (f_n) = 50 Hz Frequency of interest = 49 Hz $\Delta P/P_n$ [%] = -20 · (49 - 49.8) / 50 · 100 = 32 % **Using relative frequency values:** $\Delta P/P_n$ [%] = $-SLPL \cdot (\Delta f - \Delta f_{DBL})$ Δf [%]: The network frequency relative to f_n (do not exceed P_{max}) Δf_{DBL} [%]: The deadband low frequency relative to f_n (at under-frequency) Example: Slope low (SLPL) = 20 [-] Deadband low (Δf_{DBL} = -DBL) = (49.8 - 50) / 50 · 100 = -0.4 % Nominal frequency (f_n) = 50 Hz Frequency of interest = (49 - 50) / 50 · 100 = -2 % $\Delta P/P_n$ [%] = -20 · (-2 - -0.4) = 32 %
Frequency above the deadband high frequency: $f > f_{DBH}$ Slope high (SLPH) - LFSM-O	The active power output change when the network frequency is increasing. **Using absolute frequency values:** $\frac{\Delta P}{P_n}$ [%] = $SLPH \cdot \frac{f - f_{DBH}}{f_n} \cdot 100$ SLPH [-]: Slope high (LFSM-O) For $f > f_{DBH}$; do not exceed P_{min}. $\Delta P/P_n$ [%]: The change in power output relative to the pre-disturbance power (do not exceed P_{min}). Example: Slope high (SLPH) = -20 [-] Deadband high (f_{DBH}) = 50.2 Hz Nominal frequency (f_n) = 50 Hz Frequency of interest = 51 Hz $\Delta P/P_n$ [%] = -20 · (51 - 50.2) / 50 · 100 = -32 % **Using relative frequency values:** $\Delta P/P_n$ [%] = $SLPH \cdot (\Delta f - \Delta f_{DBH})$ Δf [%]: The network frequency relative to f_n (do not exceed P_{min}) Δf_{DBL} [%]: The deadband high frequency relative to f_n (at over-frequency) Example: Slope high (SLPH) = -20[-] Deadband high (Δf_{DBH} = DBH) = (50.2 - 50) / 50 · 100 = 0.4 % Nominal frequency (f_n) = 50 Hz Frequency of interest = (51 - 50) / 50 · 100 = 2 % $\Delta P/P_n$ [%] = -20 · (2 - 0.4) = -32 %

3.10 FRT curves (LVRT and HVRT)

Fault ride through (FRT) keeps the generator connected even though the grid voltage is above or below the expected value. The FRT curves define how long the generator remains connected to the grid.

For dynamic grid support, the controller has two Low Voltage Ride Through (LVRT) curves and one High Voltage Ride Through (HVRT) curve.

Example of FRT curves



For each curve, configure a protection to disconnect the generator from the grid. Each activate and recovery level can also be set. The LVRT protection activates if the specified phases drop below the set voltage values (below the curve). Between any two neighbouring points, the curve is a straight line.

There are configurable settings to stop GOV and/or AVR regulation during FRT.

The controller counts FRT activations. In PICUS, select `Configure > Counters > Grid code`. For each curve, the number of activations and alarm actions are shown.

3.10.1 Parameters for FRT curves

`Grid code > Fault ride through > Suspend regulation`

Name	Range	Description
FRT suspend GOV regulation enable	Not enabled, Enabled	**Not enabled**: GOV regulation is not affected when an FRT curve is activated. **Enabled**: GOV regulation is stopped when any FRT curve is activated.
FRT suspend GOV regulation timeout	0.00 to 120.00 s	Timer for stopping GOV regulation, when an FRT curve is activated.

Name	Range	Description
FRT suspend AVR regulation enable	Not enabled, Enabled	**Not enabled**: AVR regulation is not affected when an FRT curve is activated. **Enabled**: AVR regulation is stopped when any FRT curve is activated.
FRT suspend AVR regulation timeout	0.00 to 120.00 s	Timer for stopping AVR regulation, when an FRT curve is activated.

`Grid code > Fault ride through > Low voltage ride through [1 to 2]`

Name	Range	Description
Activation phase type	One phase-phase Two phase-phase Three phase-phase Any phase-phase One phase-neutral Two phase-neutral Three phase-neutral Any phase-neutral Symmetrical phase-phase Asymmetrical phase-phase Symmetrical asymmetrical any phase-phase Symmetrical phase-neutral Asymmetrical phase-neutral Symmetrical asymmetrical any phase-neutral	The fault type for which the measurements have to exceed the set point to activate the fault ride through curve.
Recovery threshold	0.0 to 100.0 % of nominal voltage	Threshold for deactivation of the LVRT curve.
Recovery delay	0.00 to 120.00 s	Recovery delay for deactivation of the LVRT curve.
Link configuration	Not enabled, Enabled	**Not enabled**: Each FRT curve is activated and handled independently of the other FRT curves. **Enabled**: The FRT curves are activated based on the same incident, and the recovery is co-ordinated.
Minimum activation time	0.00 to 120.00 s	
Action	Alarm actions	
Table > X (s)	0.000 to 7200.000 s	Use the table to configure the LVRT curve.
Table > Y (%)	0.000 to 100.000 % of nominal voltage	

`Grid code > Fault ride through > High voltage ride through`

Name	Range	Description
Activation phase type	See LVRT above for the list.	The fault type for which the measurements have to exceed the set point to activate the fault ride through curve.
Recovery threshold	100.0 to 130.0 % of nominal voltage	Threshold for deactivation of the HVRT curve.

Name	Range	Description
Recovery delay	0.00 to 120.00 s	Recovery delay for deactivation of the HVRT curve.
Link configuration	Not enabled, Enabled	**Not enabled**: Each FRT curve is activated and handled independently of the other FRT curves. **Enabled**: The FRT curves are activated based on the same incident, and the recovery is co-ordinated.
Minimum activation time	0.00 to 120.00 s	
Action	Alarm actions	
Table > X (s)	0.000 to 7200.000 s	Use the table to configure the HVRT curve.
Table > Y (%)	100.000 to 130.000 % of nominal voltage	

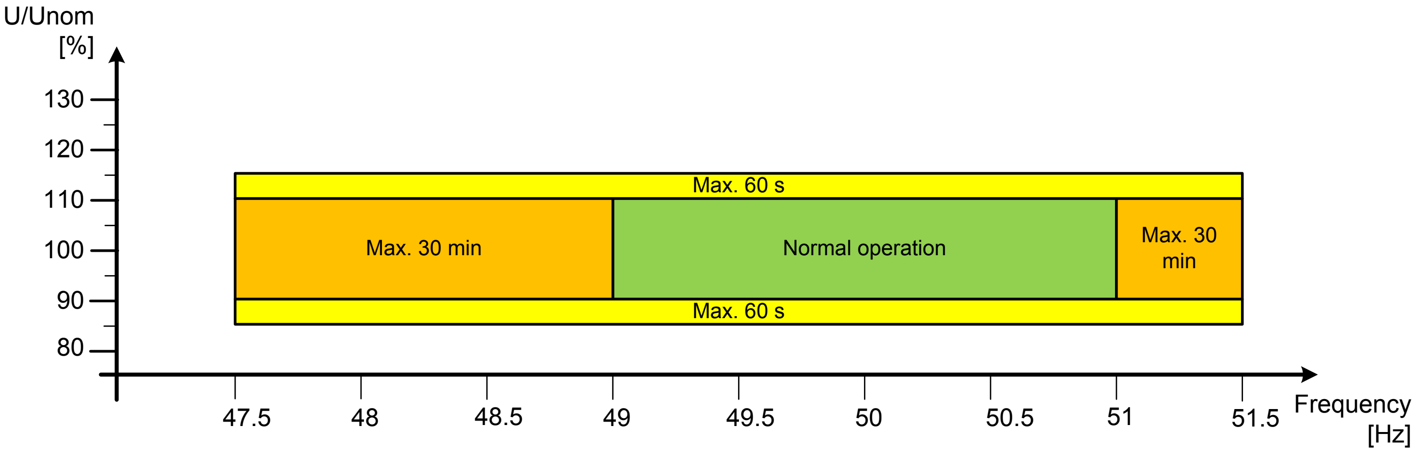
3.11 ROCOF (df/dt)

The **Designer's handbook** has a detailed description of the ROCOF (df/dt) function. This function is configured in `Mains > Additional protections > ROCOF (df/dt)`.

3.12 Quasi-stationary operation

During quasi-stationary operation, the genset runs parallel to grid even though the voltage and frequency are outside the normal operation area. If the time limit is reached, the alarm fail class is activated. The normal operation area is 90 to 110 % of nominal voltage, and 49 to 51 Hz (nominal frequency ± 1 Hz).

Example for VDE quasi-stationary operation



3.12.1 Parameters for quasi-stationary operation

The controller's standard AC protections include several mains voltage and frequency protections. You can configure their set points and timers to define the area and long durations for quasi-stationary operation.

Voltage protections

`Mains > Voltage protections > Over-voltage [1 to 3]`

Name	Range	Description
Set point	90.0 to 120.0 % of nominal voltage	See the **Designer's handbook**.
Delay	0.00 s to 2 hours	

`Mains > Voltage protections > Under-voltage [1 to 4]`

Name	Range	Description
Set point	10.0 to 100.0 % of nominal voltage	See the **Designer's handbook**.
Delay	0.00 s to 2 hours	

Frequency protection

`Mains > Frequency protections > Over-frequency [1 to 3]`

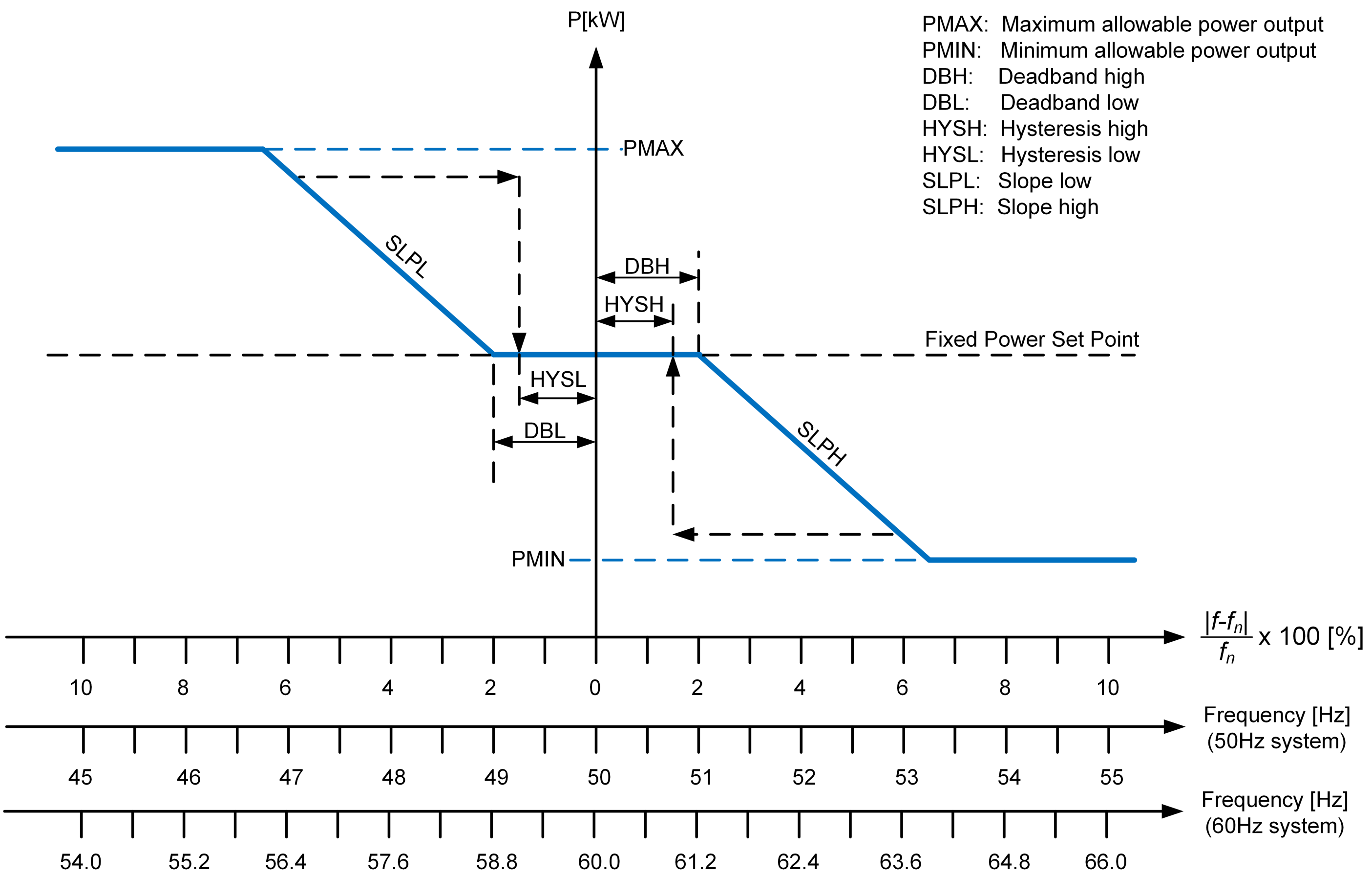
Name	Range	Description
Set point	100.0 to 130.0 % of nominal frequency	See the **Designer's handbook**.
Delay	0.00 s to 2 hours	

`Mains > Frequency protections > Under-frequency [1 to 4]`

Name	Range	Description
Set point	80.0 to 100.0 % of nominal frequency	See the **Designer's handbook**.
Delay	0.00 s to 2 hours	

3.13 Over- and under-frequency-dependent active power

During a critical grid condition all power production plants must support the grid frequency.



You can use *Droop curve* to create a curve to control the produced power, based on grid under- and over-frequency. If the frequency is outside of the deadband, the produced power is regulated with a gradient reaction (Power Ramp 2).

When the grid frequency returns inside the deadband, the *Recover delay* timer activates, and there is a gradient change for power regulation (Power Ramp 3).

When the *Recover delay* timer runs out, if the grid frequency remains in the deadband zone, the gradient changes to normal operation (Power Ramp 1).

The calculation of decrease or increase of active power can be switched between *Active power installed* (nominal power) or *Active power momentary* (actual power).

The slope can be based on absolute value or %.

Example of `Calculation method`

The generator has a nominal power of 1000 kW. The grid frequency is 50 Hz. A slope of 40 % is required for each 1 Hz increase or decrease of grid frequency.

40 % of 1000 kW = 400 kW. 1 Hz/50 Hz = 2 %. *Slope low (7133)* must therefore be 400 kW/2 % = 200 kW/%.

If `Grid code > Droop curve > Active power droop > Active power momentary` is selected, the calculation uses the load to adjust the slope. If the generator is running at 500 kW, the slope is 200 kW/% x (500 kW / 1000 kW) = 100 kW/%.

For `Grid code > Droop curve > Active power droop > Active power installed`, the calculation uses the value in `Slope low`.

More information
See Requirements for Generators frequency droop for information on how the grid protections complies with Regulation (EU) 2016/631 (also known as RfG).

3.13.1 Parameters

Power ramp parameters

See Power ramps.

- **Ramp 1: Normal operation**
  - Ramp 1 is for normal operation in the deadband (between DBL and DBH).
- **Ramp 2: Frequency outside the deadband**
  - Ramp 2 is for operation outside the deadband (below DBL or above DBH).
- **Ramp 3: Recovery after frequency and/or voltage outside the deadband**
  - Ramp 3 is used if the operation is in the deadband again (between DBL and DBH) after Ramp 2 was activated.
  - Ramp 3 is used for recovery until the set point is reached.
  - After the set point is reached, the controller changes to normal operation and uses Ramp 1.

Droop

Configure the active power droop. This is described in Active power droop (for RfG).

3.14 Low voltage low reactive power

Two protections are available for *Low voltage low reactive power*. You can configure the parameters in `[Generator or Mains] > Additional protections > V< and Q< [1 to 2]`.

More information
See **Low voltage low reactive power** in the **Designer's handbook**.

3.15 Mains frequency alarms

Mains over-frequency and mains under-frequency alarms are required for G99. The controller's standard AC protections include several mains over-frequency and under-frequency protections that can be used for this. These alarms can be configured with delays up to 2 hours. They are described in the **Designer's handbook**.