AGC-4 Mk II

4189341345B

Option A10

VDE AR-N 4110/4105 and G99 grid protection

Improve Tomorrow

1. Option description

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1. Option description

1.1 Option A10

Option A10 is a software option for genset and mains controllers, so that they can meet VDE and G99 requirements.

1.2 VDE requirements

This is a summary of the VDE requirements. These are also included under each function description.

Both genset and mains controllers

General: Option A10 activates the functions required by VDE 4110 and 4105.

Quasi-stationary operation: To meet the VDE and G99 requirements, extra long timers (2000 s) are available for option A10.

Reactive power regulation, Type 4: Variant D) fixed cos phi: To meet VDE requirements, the cos phi set point parameter for regulation has 3 decimals.

Only genset controllers

Alternator capability curve: The VDE rules refer to a P/Q diagram. To meet VDE requirements, use the nominal active power (in kW) in the S nominal (in kVA) settings.

Only mains controllers

Plant control: The mains controller can control the point of connection.

1.3 G99 requirements

This is a summary of the G99 requirements. These are also included under each function description.

NOTE G99 compliance is only for systems with a nominal frequency of 50 Hz.

Quasi-stationary operation: To meet the VDE and G99 requirements, extra long timers (2000 s) are available for option A10.

Busbar over-frequency 4 (menu 1920) and busbar under-frequency 5 (menu 1930) alarms: These protections are required for G99, and can be configured with delays up to 6000 s. This document has no additional description for these protections.

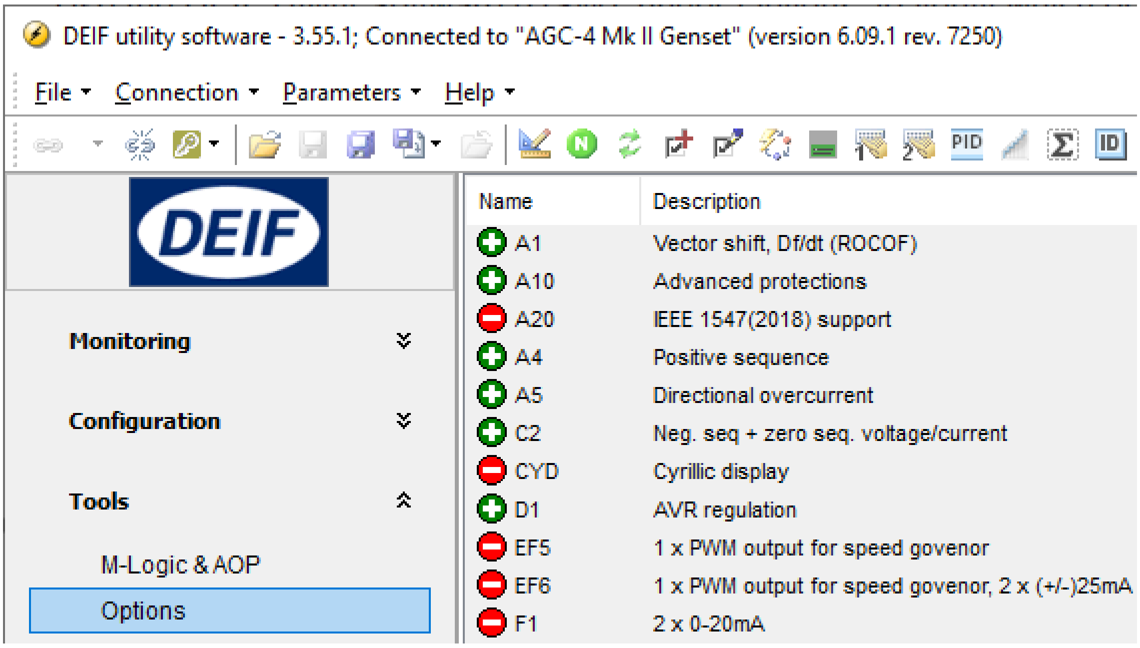
df/dt: To meet the G99 requirements, configure df/dt in parameters 1420 and 1422.

1.4 Options required for option A10

The standard controller contains all the options required by option A10, and also the recommended accuracy (class 0.5).

Use the DEIF Utility Software (USW), under *Options*, to verify which options are activated.

Example of activated options for Option A10



1.5 Deactivating option A20

It is possible to have a controller with both option A10 and option A20. However, option A10 and option A20 cannot be active at the same time. To deactivate option A20 (and activate option A10):

1. Make sure that you have a backup of the controller's configuration.
2. Push the JUMP button on the DU-2 display unit.
3. Use the arrow buttons to select **9101**, then push the **SEL** button.
4. **9101 National regula** is shown. Push the **SEL** button.
5. Push the up/down button to select **OFF**. Push the right button to select **SAVE**, then push the **SEL** button.
   - The controller is reset to factory defaults and restarts.
6. Configure the controller as required.

1.6 Software version

This document is based on the following software:

Controller	Application software	PC utility software
AGC-4 Mk II	6.09	3.55

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.

1.7 Nominal grid voltage and scaling

Several functions are based on the nominal grid voltage.

The nominal grid voltage is defined in *BB Nominal U 1*, parameter 6053, or *BB Nominal U 2*, parameter 6063. *Bus nom. set*, parameter 6052, determines which value is used.

Scaling, parameter 9030, also affects some of the functions. Some functions refer to this as *Meas area*. Different settings can be used for *10V-2500V*, *100V-25000V* (default), *10kV-250kV* and *0.4kV-75kV*.

1.8 Selecting the reactive power measurement

By default, the reactive power is based on the phase-phase voltage measurement and the current measurement. You can use *Q calc method* (parameter 9132) to use the phase-neutral voltage measurement for the Q calculation.

1.9 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
Pnom	Genset nominal power
Pref	For a mains controller, the nominal plant power that the option A10 protections are based on. See Using the mains controller as the plant controller.
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.
Q %	Reactive power (Q) as a percentage of the nominal power (Pnom).
RRCR	Radio Ripple Control Receiver Binary inputs are used for external set point control.
U	Measured voltage
Uc	Nominal grid voltage - see here for more information.
USW	DEIF's PC Utility software
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	DEIF AGC-4 Mk II genset controller.
grid	The national electricity supply. Also called *mains*.
mains controller	DEIF AGC-4 Mk II mains controller.
plant	The power producing facility where the genset is located.

1.10 Safety, warnings and legal information

1.10.1 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 and the relay terminals, as this could lead to injury or death.

1.10.2 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.

1.10.3 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.

1.10.4 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.

1.10.5 Copyright

2. External measurements, inputs and outputs

2.1 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: Droop curve 1
3. Modbus/Profibus
4. CIO inputs
5. Option M12 analogue inputs
6. Internal set point

2.2 RRCR external set point control

The grid can use a Radio Ripple Control Receiver (RRCR) for load management. Option A10 allows the controller to use the RRCR signals for power and reactive power regulation.

More information
See **Additional Functions, RRCR external set point control** in the **Designer's Handbook** for more information.

2.3 External set points from a CIO 308 module

If a CIO 308 is connected using CAN bus, the controller can receive analogue set points as 4 to 20 mA signals. These can be monitored for wire break.

The following can only be chosen if the *Variant type* is *Default* (under *Advanced Protection*, *var(Q) grid support*).

- For a genset controller, the reactive power set point can only be chosen if *Fixed Q* is chosen in *ContrSet cosphi or Q*, parameter 7055.
- For a mains controller, the cos phi set point can only be chosen if *Fixed for imp/exp* is chosen in *Contr. sett. cosphi* , parameter 7054.

CIO Input	Function	Description
CIO 308 1.8	*External P set point* or *External f set point*	External active power or frequency set point (depends on the controller running mode)
CIO 308 1.11	*External U set point*, *External cos phi set point*, or *External Q set point*	External voltage, cos phi, or reactive power set point (depends on the controller running mode)

NOTE The external set points will only work if the CIO 308 has ID 1.

2.4 Display selections

For Option A10, you can use the USW to show additional operating information on the display.

To change the information shown on the display:

1. Select the *Configuration of the user views* icon.
   - The *Device display* window opens.
2. Select one of the views, then click one of the three display lines.
   - The *View line configuration* window opens.

3. Select the required display information under *Electrical data > Grid support* and select **OK**.
    - The USW shows the display line with the selection.
4. Select *Write views to the device* .

Display information	Description
Active power ramp #	The active power ramp
Droop1 recovtimer #s	The timer when the grid frequency is inside the deadband for the Droop Curve 1 function
f-Bus L1 Avg #.###Hz	Averaged grid frequency measurement for L1
f-Bus L2 Avg #.###Hz	Averaged grid frequency measurement for L2
f-Bus L3 Avg #.###Hz	Averaged grid frequency measurement for L3
f-Gen L1 Avg #.###Hz	Averaged generator frequency measurement for L1
f-Gen L2 Avg #.###Hz	Averaged generator frequency measurement for L2
f-Gen L3 Avg #.###Hz	Averaged generator frequency measurement for L3
Ramp switch #s	The ramp switch timer, when switching between reactive power regulation variants
Regulation variant	The reactive power regulator that the controller is using

2.5 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**.

To set up the analogue outputs, configure the following parameters in the parameter list.

Text	Parameter	Default	Range	Description
P ref Output type	5693	Disabled	Disabled 0-20mA 4-20mA 0-10V -10V-0-10V	Output for the *Power* set point. Select the AGC analogue output under *Transducer A* and/or *B*.
P ref Output max	5694	500 kW	0 to 20000 kW	The maximum of the range for the power set point.
P ref Output min	5695	0 kW	-9999 to 20000 kW	The minimum of the range for the power set point.
Q ref Output Type	5703	Disabled	Disabled 0-20mA 4-20mA 0-10V -10V-0-10V	Output for the *Reactive Power* set point. Select the AGC analogue output under *Transducer A* and/or *B*.
Q ref Output max	5704	400 kvar	0 to 16000 kvar	The maximum of the range for the reactive power set point.
Q ref Output min	5705	0 kvar	-8000 to 16000 kvar	The minimum of the range for the reactive power set point.
Cosphi ref Outp type	5713	Disabled	Disabled 0-20mA 4-20mA 0-10V -10V-0-10V	Output for the cos phi set point. Select the AGC analogue output under *Transducer A* and/or *B*.
Cosphi ref Outp max	5714	0.8	0.5 to 0.99	The maximum of the range for the cos phi set point.
Cosphi ref Outp min	5715	-0.8	-0.99 to -0.5	The minimum of the range for the cos phi set point.

3. Genset controller functions

This chapter describes the option A10 requirements and functions that are specific to the genset controller. For the functions that both the genset and mains controller support, see General functions.

3.1 Nominal power

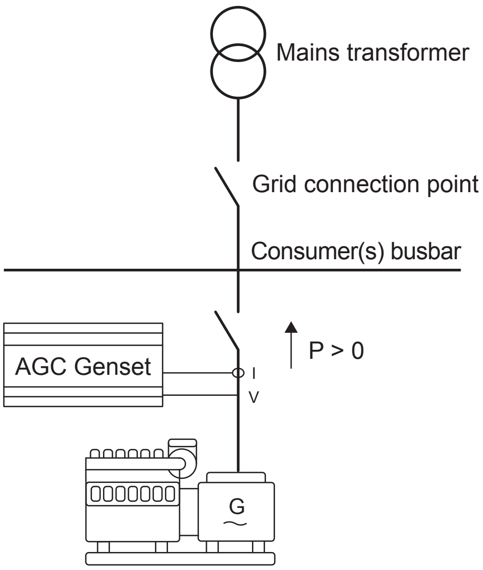
Several functions are based on the nominal power.

The nominal power is defined in *Nom. P 1*, parameter 6002; *Nom. P 2*, parameter 6012; *Nom. P 3*, parameter 6022; or *Nom. P 4*, parameter 6032. *Enable nom. set*, parameter 6006, determines which value is used.

3.1.1 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.

3.2 Power management

For a genset controller in a power management application, you can select which power ramp to use. You can also configure the regulation to use if the mains controller fails.

Power ramp selection

Configure the settings under *Advanced Protection, PM: Mains-Unit, Power ramp*.

Setting	Default	Range	Description
Ramp selection	Use ramp from DG	Use ramp from DG Use ramp from MAINS	**Use ramp from DG**: The controller uses the values in its own parameters for the ramp. **Use ramp from MAINS**: The controller uses the ramp configured in the mains controller.

Mains controller failure

Configure the settings for the controller to use if the mains controller fails under *Advanced Protection, PM: Mains-Unit, Mains-Unit failure*.

Setting	Default	Range	Description
Operation mode	Loadsharing	Loadsharing Keep mode	**Loadsharing**: If the mains controller fails, the genset shares the load equally with the other gensets in the application. **Keep mode**: The controller shares the load sharing using the same mode as before the mains controller failure.
P mode	Use default P	Use default P Keep set-point	**Use default P**: If the mains controller fails, the genset controller uses the *Default P* set point. **Keep set-point**: If the mains controller fails, the genset controller continues with its last set point from the mains controller.
Default P [% of Pnom]	0	0 to 100	The set point used for *Use default P*.
Q mode	Use default Cosphi	Use default Cosphi Use default Q Keep set-point Cosphi Keep set-point Q	**Use default Cosphi**: If the mains controller fails, the genset controller uses the *Default Cosphi set-point*. **Use default Q**: If the mains controller fails, the genset controller uses the *Default Q* set-point. **Keep set-point Cosphi**: If the mains controller fails, the genset controller continues with its last set point from the mains controller. **Keep set-point Q**: If the mains controller fails, the genset controller continues with its last set point from the mains controller.
Default Cosphi set-point	1.000	0.000 to 1.000	The set point used for *Use default Cosphi*.
Default Cosphi direction	Inductive (GEN)	Inductive (GEN) Capacitive (GEN)	The cos phi direction for the set point.
Default Q [% of Pnom]	0	0 to 100	The set point used for *Use default Q*.

3.3 AC measurements at the grid connection

For Option A10, the AC measurements must be at the grid connection point.

If a mains controller is used as the plant controller, the mains controller measures the voltage and current at the connection point. Transducers are therefore not required.

However, for a *Single DG* application, you must use a transducer for the AC measurements.

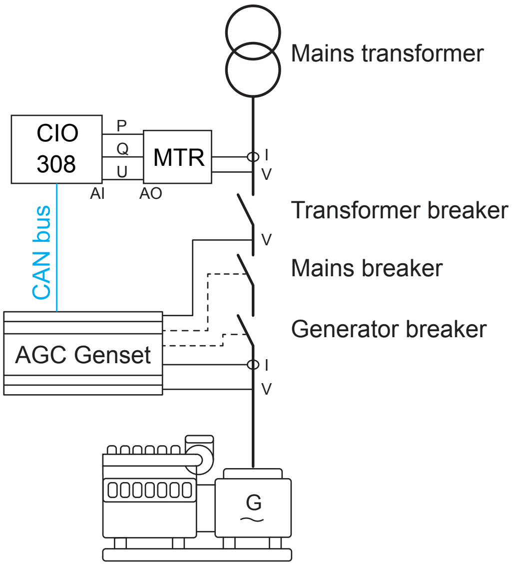
3.3.1 Grid connection point too distant

If the grid connection point is some distance away from the controller, it is not practical to run long wires for grid AC voltages and currents, and/or low voltage signals (for example, 4 to 20 mA).

To solve this problem, a DEIF MTR and CIO 308 can be placed at the grid connection point, and connected to the controller. The controller then uses the transducer AC measurements (instead of its own AC measurements) for regulation. However, the controller still uses its own AC measurements for its AC protections.

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.

Example for AC measurements from a distant grid connection point



To activate the U, P and Q functions, use M-Logic and parameters.

3.3.2 Using a transducer for voltage measurements

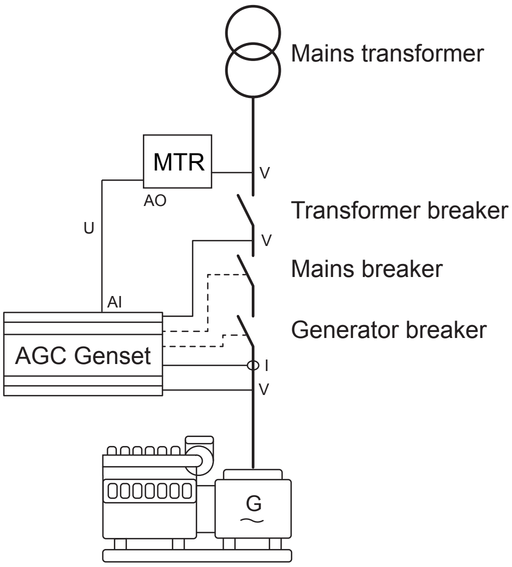
The *Q(U) U-shift* and *Q(U) Q-shift* functions can be based on a 4 to 20 mA grid voltage signal from a DEIF MTR at the grid connection point. This is useful if there is a significant voltage drop between the connection point and the controller.

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 the 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

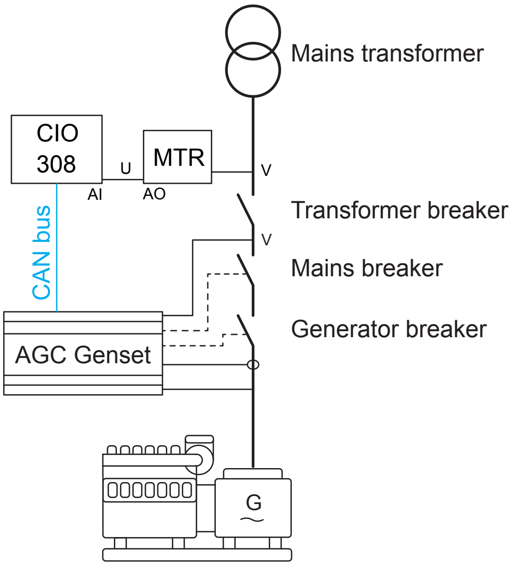


To activate the U function, use M-Logic and parameters.

Voltage measurements from a DEIF MTR and CIO

Alternatively, the 4 to 20 mA signal (U L1L2) from the DEIF MTR can be connected to the CIO 308 terminal 20 input (that is, CIO 308 1.20 or 2.20 or 3.20).

Example for voltage measurement over CAN from the grid connection point



To activate the U function, use M-Logic and parameters.

3.3.3 Using M-Logic for external AC measurements

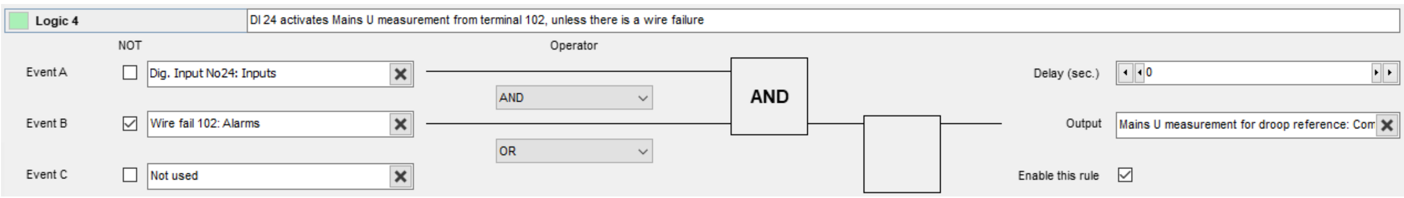
The controller uses the M-Logic configuration to link the analogue input to the requirement measurement. For safety, include the analogue input wire break monitoring in the M-Logic configuration.

U measurement from a transducer

To activate the U measurement directly from a transducer (no CIO):

- In *Mains U measure*, parameter 7283, select *Multi input 102 (transducer)*.
  - Set the transducer range in parameters 7261 and 7262.
- For wire break monitoring, mount a resistor parallel to the controller's analogue input (see the *Installation instructions* for details).
- In *W. fail 102*, parameter, 4240, enable the alarm.
- Configure the function in M-Logic. Use *Output, Command, Mains U measurement for droop reference*.

Example of M-Logic for U measurement from a transducer

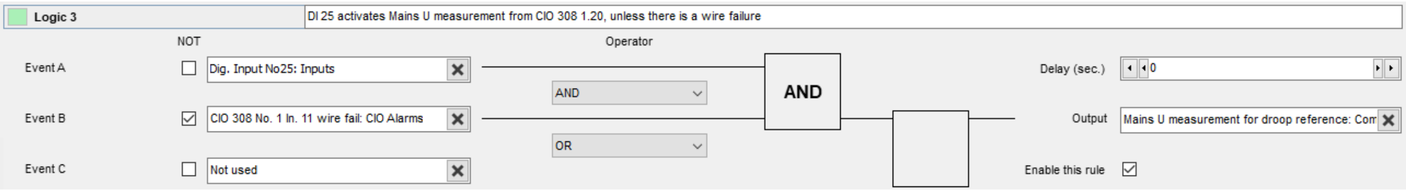


U measurement from a CIO

To activate the U measurement from a CIO:

- In *Mains U measure*, parameter 7283, select *CIO 308 [1/2/3].20 (transducer)*.
  - Set the transducer range in parameters 7261 and 7262.
- Configure the function in M-Logic:
  - For the wire break alarm, use *Event, CIO alarms, CIO 308 No. [1/2/3] In. 20 wire fail*.
  - To activate the function, use *Output, Command, Mains U measurement for droop reference*.

Example of M-Logic for U measurement from a CIO



P measurement from a CIO

To activate the P measurement from a CIO, follow the procedure for activating a U measurement from a CIO. However, configure the parameters, input and output for P.

Q measurement from a CIO

To activate the Q measurement from a CIO, follow the procedure for activating a U measurement from a CIO. However, configure the parameters, input and output for Q.

3.3.4 Parameters for transducer U, P and Q measurement

To use a U, P or Q measurement from a transducer, configure the following parameters in the parameter list.

U measurement from a transducer

Text	Parameter	Default	Range	Description
Transducer Range	7281	0 V	0 to 25000 V	Maximum voltage
Transducer Range	7282	0 V	0 to 25000 V	Minimum voltage
Mains U measure	7283	Multi input 102	Multi input 102 (transducer) CIO308 1.20 (transducer) CIO308 2.20 (transducer) CIO308 3.20 (transducer)	Selection of the analogue input
Mains U Ext Nom	7284	400 V	100 to 25000 V	Nominal grid voltage for the transducer

P measurement from a transducer

Text	Parameter	Default	Range	Description
Transducer Range	7261	0 kW	0 to 20000 kW	Maximum active power
Transducer Range	7262	0 kW	-20000 to 0 kW	Minimum active power
Mains P measure	7263	Multi input 102	Multi input 102 (transducer) Mains controller only: 3 ph CT power meas CIO308 1.14 (transducer) CIO308 2.14 (transducer) CIO308 3.14 (transducer)	Selection of the analogue input

Q measurement from a transducer

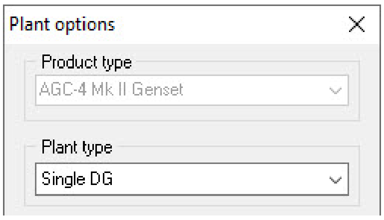
Text	Parameter	Default	Range	Description
Transducer Range	7271	0 kvar	-20000 to 20000 kvar	Maximum reactive power
Transducer Range	7272	0 kvar	-20000 to 20000 kvar	Minimum reactive power
Mains Q measure	7273	Multi input 102	Multi input 102 (transducer) CIO308 1.17 (transducer) CIO308 2.17 (transducer) CIO308 3.17 (transducer)	Selection of the analogue input

3.4 Feed forward

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

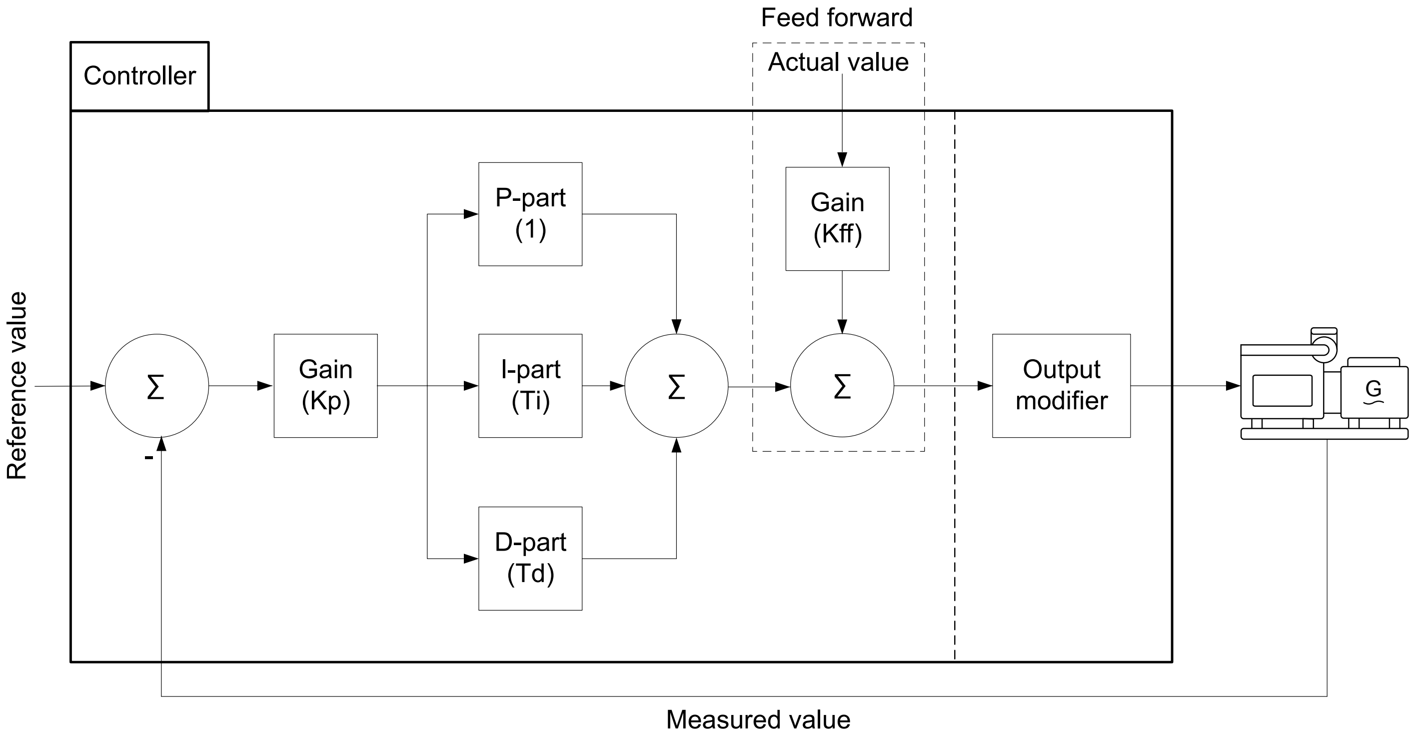
For example, without feed forward, if the frequency on the busbar increases, the controller could decrease the power from the genset. With feed forward, the effect of the busbar frequency change is minimised. Similarly, without feed forward, if the busbar voltage drops, the controller could reduce the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

The feed forward function in power and reactive power regulators is only available if you select *Single DG* (single stand-alone generator parallel to grid) as the plant type in the application configuration.



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 (genset and mains) 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

Text	Parameter	Default	Range	Description
P FF Ena	2831	OFF	OFF; ON	Enable the power regulator feed forward.
P FF KFF	2832	12.5	0 to 50	The power feed forward gain*.
Q FF Ena	2833	OFF	OFF; ON	Enable the reactive power regulator feed forward.
Q FF KFF	2834	10	0 to 50	The reactive power feed forward gain*.

NOTE * The feed forward gain is calculated (as described below) and then set. The gain is not used for tuning the system. You can use a feed forward gain that is lower than the calculated gain. However, do not use a higher gain, since it will cause positive feedback.

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 = Governor output / ((Frequency/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

3.5 Alternator capability curve with limiting

Active power-dependent reactive power limiting is a generator protection feature which is part of option C2. It limits the reactive power production relative to actual power production.

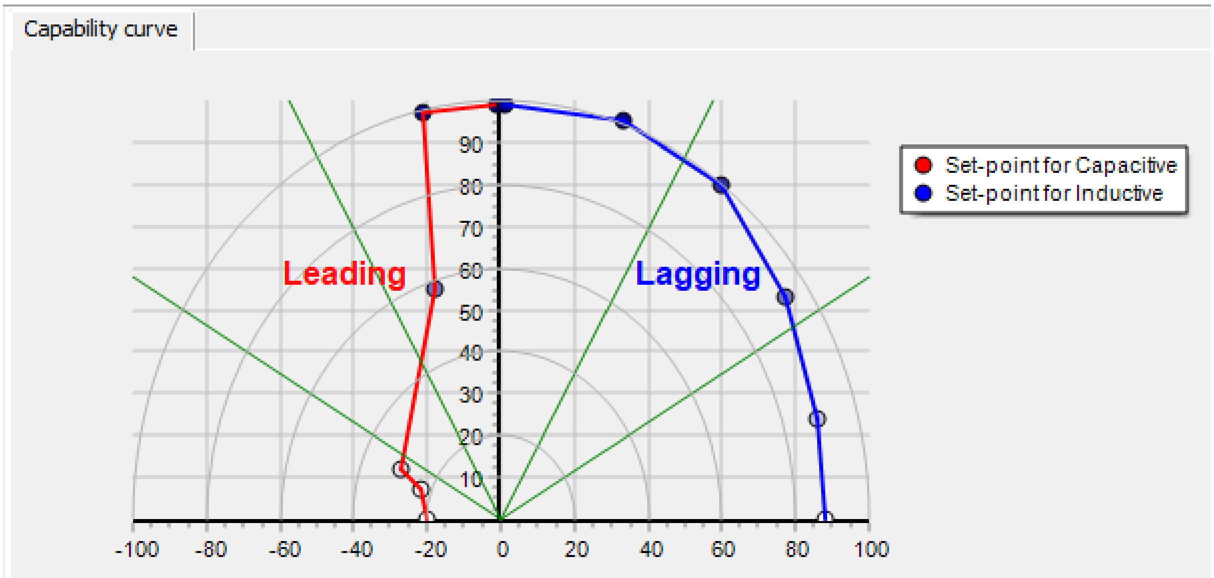
Active power-dependent reactive power limiting can use the generator steady state reactive power capability curve. The actual curve depends on the generator. The curve should be included in the generator's data sheet. Contact the generator manufacturer to get this information.

To activate the reactive power limitation based on the capability curve, set *AVR limiting type*, parameter 2811, to *Capability curve Q*.

NOTE Configure the alarms in the parameter list. Use *G P dep. Q<*, parameter 1761, for import, and *G P dep. Q>*, parameter 1791, for export.

The curves are configured under *Advanced Protection*, *Capability curve*. 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 from the USW



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. Use menu 1760 to configure an alarm for exceeding the capability curve under the excitation limit. Use menu 1790 to configure an alarm for exceeding the capability curve over the excitation limit.

The *AVR lim. setpoint*, parameter 2812, 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.

S nominal(import) (1766) and *S nominal(export) (1796)* under *Advanced Protection*, *Capability curve*, define the limit of the y-axis. It can relate to active power (P/Q diagram) or apparent power (S/Q diagram).

Example of apparent and active power for the capability curve

The generator has a 1000 kW nominal power and a 1250 kVA nominal apparent power.

For an S/Q diagram as the capability curve, use 1250 kVA for the *S nominal* settings (under *Advanced Protection*, *Capability curve*). On the capability curve, 100 % of nominal apparent power is then 1250 kVA.

Alternatively, for a P/Q diagram as the capability curve, use 1000 kVA for the *S nominal* settings. On the capability curve, 100 % of nominal power is then 1000 kW.

The VDE rules refer to a P/Q diagram. Most generator manufacturers provide an S/Q diagram. To meet the VDE rules, use the nominal active power (in kW) in the *S nominal* settings.

3.5.1 Parameters for capability curve

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

The settings are configured under *Advanced Protection*, *Capability curve*.

Set-point for Capacitive (Under-excited; Absorption) **(red curve)**

Reactive power	Default	Active power	Default
G P dep Q<Q1	20 %	G P dep P<P1	0 %
G P dep Q<Q2	22 %	G P dep P<P2	7 %
G P dep Q<Q3	27 %	G P dep P<P3	12 %
G P dep Q<Q4	18 %	G P dep P<P4	55 %
G P dep Q<Q5	21 %	G P dep P<P5	97 %
G P dep Q<Q6	1 %	G P dep P<P6	99 %

Set-point for Inductive (Over-excited; Injection) **(blue curve)**

Reactive power	Default	Active power	Default
G P dep Q>Q1	88 %	G P dep P>P1	0 %
G P dep Q>Q2	86 %	G P dep P>P2	24 %
G P dep Q>Q3	77 %	G P dep P>P3	53 %
G P dep Q>Q4	60 %	G P dep P>P4	80 %
G P dep Q>Q5	33 %	G P dep P>P5	95 %
G P dep Q>Q6	1 %	G P dep P>P6	99 %

AVR limiting type**, parameter 2811**

Set point	Default	Description
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 *Cosphi min set* and *Cosphi max set* (under *Advanced Protection*, *Droop curve 2*, *Cosphi curve*). For reactive power, the controller uses settings *Q min* and *Q max* (under *Advanced Protection*, *Droop curve 2*, *Q curve*).
Capability curve Q		The controller limits the regulation using the parameter settings for power-dependent reactive power limiting.

AVR lim. setpoint**, parameter 2812**

Default	Range	Description
95 %	20 to 100 %	The cos phi/reactive power regulation stop with respect to the capability curve

Scaling, parameter 9030, determines which *S nominal* the controller uses. The setting for the default scaling is shown below.

S nominal **for** ***100-25000V***

Setting	Default for 100-25000V	Range for 100-25000V	Description
S nominal	600 kVA	10 to 32000 kVA	Nominal apparent power

3.6 Reactive power regulation

For option A10, there are seven types of reactive power regulation in the genset controller. Select the regulation type under *Advanced Protection*, *var(Q) grid support*:

Reactive power regulation variants

Setting	Default	Range	Description
Variant type	Default	Default	Reactive power regulation uses *Droop Curve 2* if this is activated. Otherwise, reactive power regulation uses parameter 7054 (Q) or 7052 (cosphi) as the set point.
		Variant A: Q(U) U-Shift	Reactive power regulation uses *Type 1: Q(U) U-shift*.
		Variant B: Q(P) 10pts reg-curve	Reactive power regulation uses *Type 2: Q(P) Regulation*.
		Variant C: Q(U) Q-Shift	Reactive power regulation uses *Type 3: Q(U) Q shift*.
		Variant D: Cosphi (fixed)	Reactive power regulation uses *Type 4: Cosphi (fixed)*.
		Variant E: Q (fixed)	Reactive power regulation uses *Type 5: Q (fixed)*.
		Variant F: Superior	If there is a mains controller, the genset controller uses the set point from the mains controller.

The default control type is compatible with the BDEW rules. The variant can be selected using the setting, a digital input or M-Logic (*Output, Grid Support, Var Reg Type* ...).

Example of M-Logic to activate a regulation type

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, the ramp is disabled.

Ramp timer setting

Setting	Default	Range	Description
Switching ramp timer	240 s	0 to 600 s	Time to the new set point when the regulation type is changed.

3.6.1 Default reactive power regulation

If *Default* is selected, select the reactive power regulation set points in the parameter list.

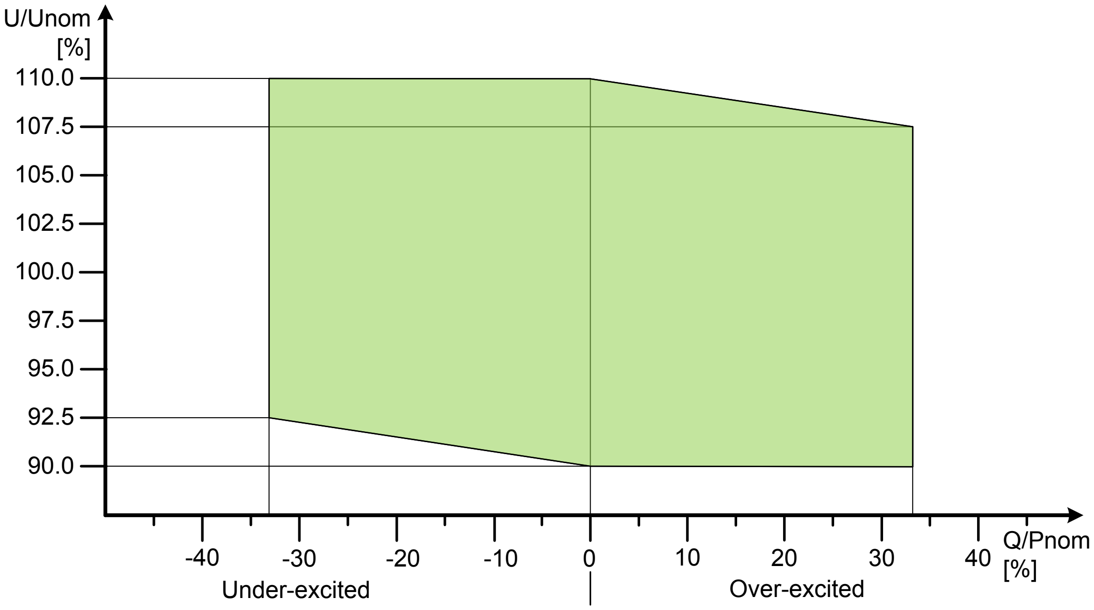
The controller uses the curves under *Advanced Protection, Droop curve 2*.

Text	Parameter	Default	Range	Description
Contr. sett. cosphi	7052	0.9	0.10 to 1.00	Cos phi set point with 2 decimals
Contr. sett. cosphi	7053	Inductive	Inductive Capacitive	Cos phi inductive or capacitive
Contr. sett. Q	7054	0 %	-100 to 100 %	Reactive power set point, as a percentage of Pnom
ContrSet cosphi or Q	7055	Off	Off Superior Fixed Q	Off = Cos phi internal set point (that is, parameter 7052). Superior = Set point from Mains controller in G5 applications (that is, the Mains parameter 7052 or 7054) Fixed Q = Reactive power internal set point (that is, parameter 7054).

3.6.2 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 (that is, Type 1, 2, 3, 4 or 5). When the *Variant type* is *Default* (under *Advanced Protection*, *var(Q) grid support*), 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.

3.6.3 Settings for grid voltage-dependent reactive power limiting

Configure the settings under *Advanced Protection*, *var(Q) grid support*.

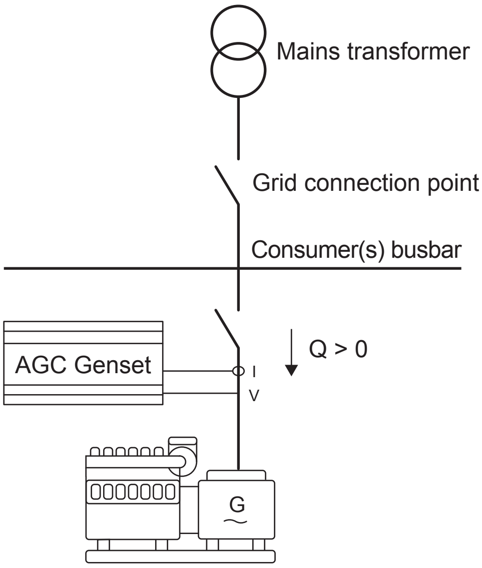
Setting	Default	Range	Description
Q-Limitation at U/Uc < 0.925 (under-excited)	OFF	OFF	The function* does not limit the reactive power during low grid voltage.
		ON	The function* limits the reactive power during low grid voltage.
Q-Limitation at U/Uc > 1.075 (over-excited)	OFF	OFF	The function* does not limit the reactive power during high grid voltage.
		ON	The function* limits the reactive power during high grid voltage.

NOTE * The function = Grid voltage-dependent reactive power limiting.

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

For variants A, B, C and E (reactive power regulation types 1, 2, 3 and 5), the reactive power (Q) from the grid is positive. That is, positive reactive power is from the grid to the consumer.

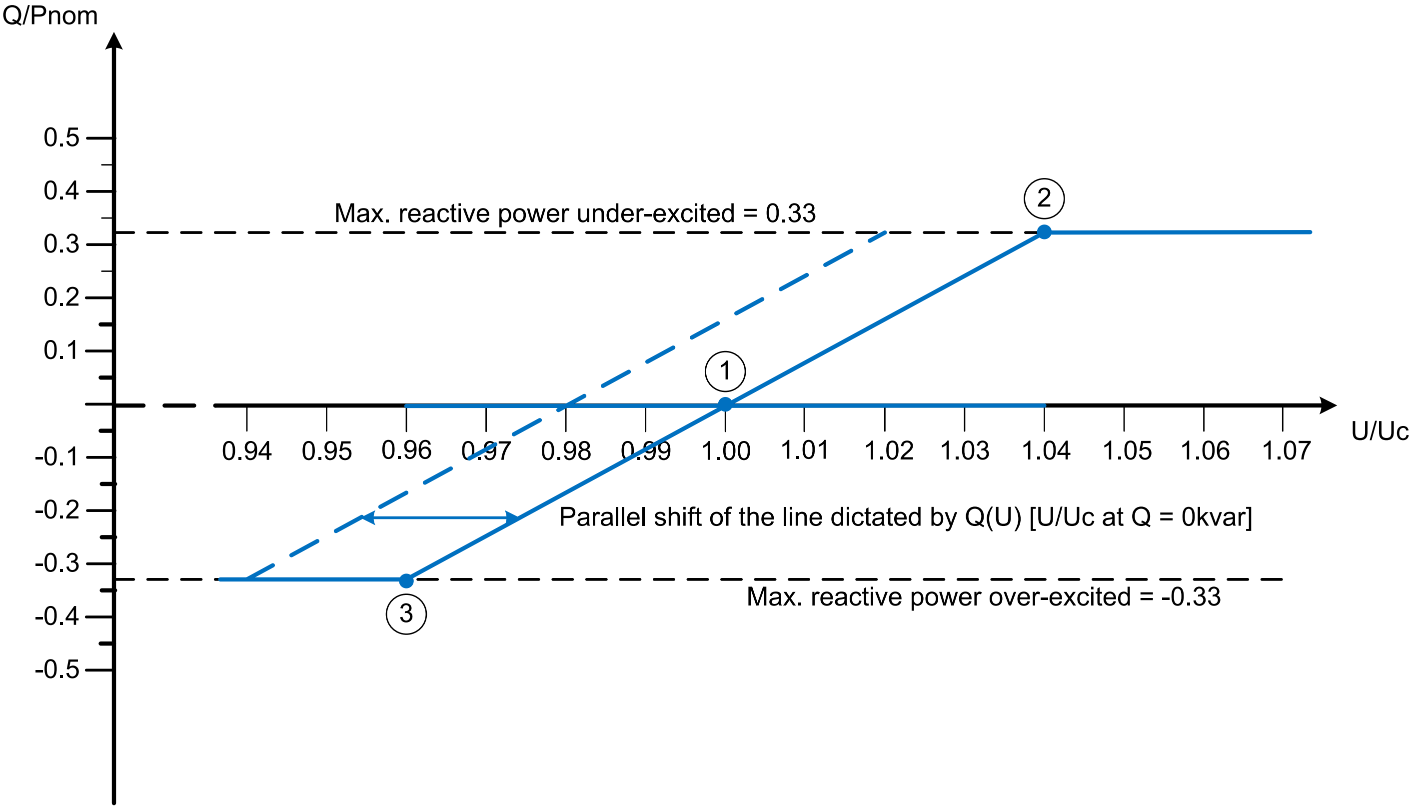
Positive reactive power to the genset



3.6.5 Type 1: Variant A) Q(U) U-Shift

If the *Q(U) U-shift* curve 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.

Default settings for *Q(U) U-Shift*



The *Q(U) U-shift* curve is defined under *Advanced Protection*, *var(Q) grid support*.

Point 1 is defined by *Q(U) [U/Uc at Q=0kvar]*.

Point 2 is defined by *Q(U) [U/Uc at Q max]* and *Q(U) [Q/Pnom max]* (over-excited).

Point 3 is defined by *Q(U) [U/Uc at Q max]*, and *Q(U) [Q/Pnom min]* (under-excited). The voltage level for point 3 is defined automatically.

Point 1 can be moved horizontally using *Q(U) shift X-axis [U/Uc]*, Modbus or an analogue input (4 to 20 mA). The movement of point 1 affects points 2 and 3.

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

The analogue signal for offset control must come from CIO 308 input 1.23.

Wire break monitoring and fallback function

When using an analogue input, the CIO 308 input 1.23 wire break monitoring function must be activated. This can be done in the USW. Select the CIO icon, then select the CIO 308. Select I23. Under *Wire break detection*, select *Enabled*.

One of the three other reactive power regulation functions must also be selected (using M-Logic) as the fallback function if the input fails.

M-Logic example: Use fixed cos phi regulation if the input fails

3.6.6 Settings for Type 1: Variant A

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 1: Q(U) U-shift*.

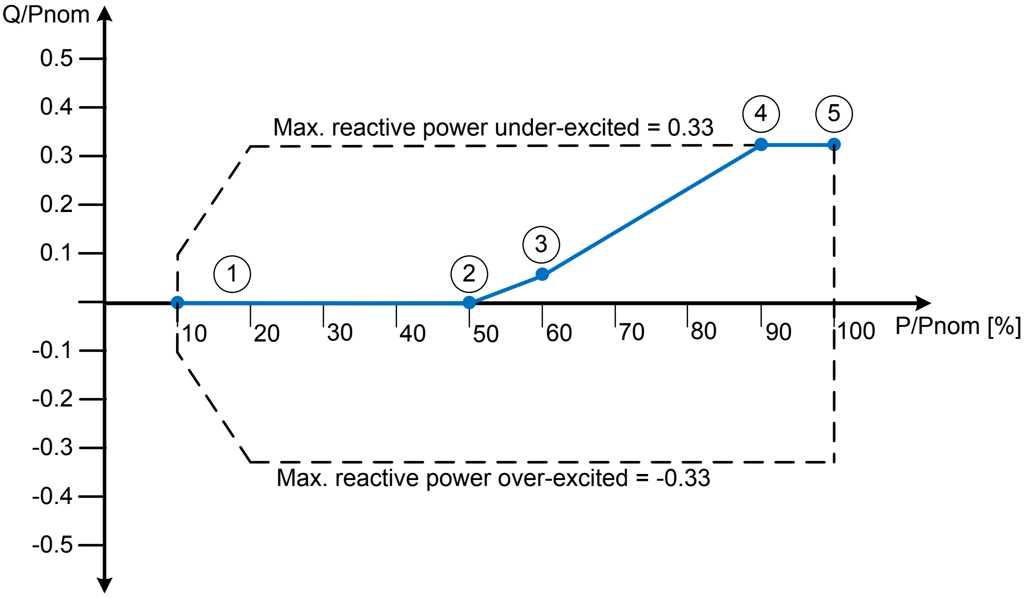
Setting	Default	Range	Description
Q(U) deadband	0 %	0 to 50 %	Voltage deadband
Q(U) [U/Uc at Q = 0kvar]	1	0.5 to 1.5	Reference voltage at Q= 0 kvar
Q(U) [U/Uc at Q max]	1.04	0.5 to 1.5	Maximum voltage at maximum Q
Q(U) [Q/Pnom max]	0.33	0 to 0.4	Maximum Q during over-voltage
Q(U) [Q/Pnom min]	-0.33	-0.4 to 0	Minimum Q during under-voltage
Q(U) shift X-axis [U/Uc]	0	-0.2 to 0.2	Offset value for reference voltage at Q=0 kvar
Q(U) Ext control	OFF	OFF Modbus Analogue	External control of the offset value for reference voltage at Q=0.

3.6.7 Type 2: 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.

Example for *Type 2: Variant B) Q(P) curve*



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

3.6.8 Settings for Type 2: Variant B

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 2: Q(P) Regulation*.

Curve settings

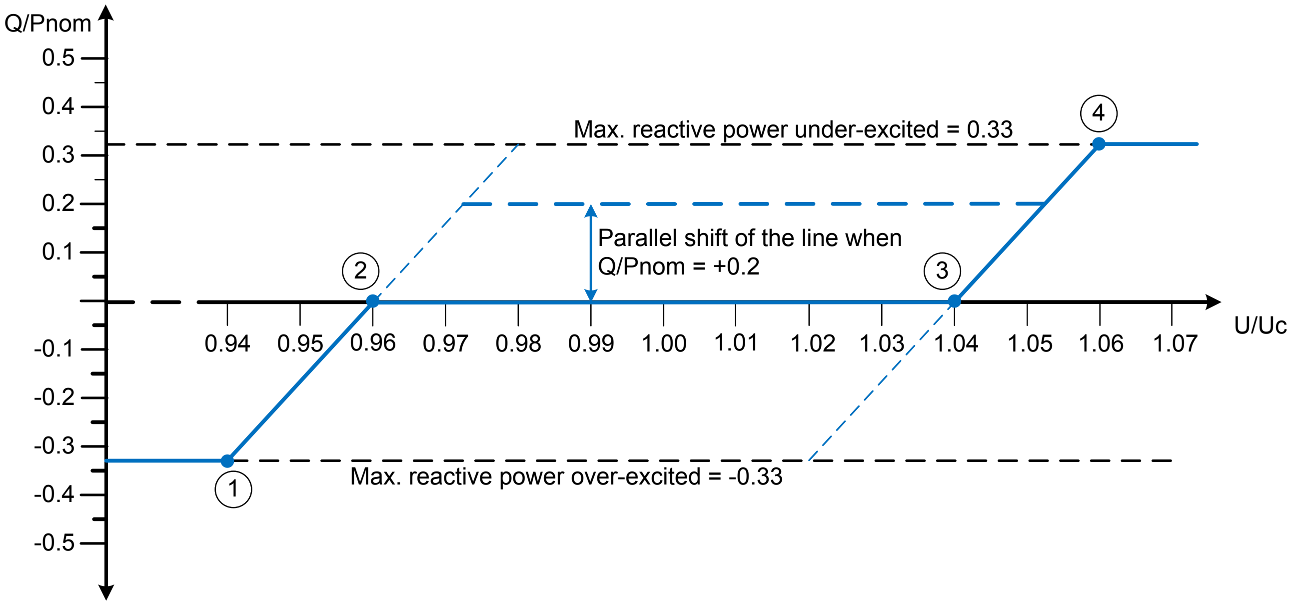
Active power	Default	Reactive power	Default
[P/Pnom] set-point 1	10	[Q/Pnom] set-point 1	0
[P/Pnom] set-point 2	50	[Q/Pnom] set-point 2	0
[P/Pnom] set-point 3	60	[Q/Pnom] set-point 3	0.05
[P/Pnom] set-point 4	90	[Q/Pnom] set-point 4	0.33
[P/Pnom] set-point 5	100	[Q/Pnom] set-point 5	0.33
[P/Pnom] set-point 6	100	[Q/Pnom] set-point 6	0.33
[P/Pnom] set-point 7	100	[Q/Pnom] set-point 7	0.33
[P/Pnom] set-point 8	100	[Q/Pnom] set-point 8	0.33
[P/Pnom] set-point 9	100	[Q/Pnom] set-point 9	0.33
[P/Pnom] set-point 10	100	[Q/Pnom] set-point 10	0.33

The ratio of Q to Pnom assumes that Q is in kvar and P is 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.

3.6.9 Type 3: 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.

Example for *Type 3: Variant C) 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 setting, Modbus or analogue input. The offset is added to the actual reactive power.

The offset setting is *Q(U) shift Y-axis [Q/Pnom]*.

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

The analogue signal for offset control must come from CIO 308 input 1.23.

Wire break monitoring and fallback function

When using an analogue input, the CIO 308 input 1.23 wire break monitoring function must be activated. This can be done in the USW. Select the CIO icon, then select the CIO 308. Select I23. Under *Wire break detection*, select *Enabled*.

One of the three other reactive power regulation functions must also be selected (using M-Logic) as the fallback function if the input fails.

M-Logic example: Use fixed cos phi regulation if the input fails

3.6.10 Settings for Type 3: Variant C

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 3: Q(U) Q-shift*.

Curve settings

Voltage	Default	Reactive power	Default
[U/Uc] set-point1	0.94	[Q/Pnom] set-point 1	-0.33
[U/Uc] set-point2	0.96	[Q/Pnom] set-point 2	0
[U/Uc] set-point3	1.04	[Q/Pnom] set-point 3	0
[U/Uc] set-point4	1.06	[Q/Pnom] set-point 4	0.33

Other settings

Setting	Default	Range	Description
Q(U) shift Y-axis [Q/Pnom]	0	-0.4 to 0.4	Offset value for Qref/Pnom
Q(U) Ext Control	OFF	OFF Modbus Analogue	External control of the offset value for Qref/Pnom

The ratio of Q to Pnom assumes that Q is in kvar and P is 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.

3.6.11 Type 4: 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**.

3.6.12 Settings for Type 4: Variant D

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 4: Cosphi (fixed)*.

Setting	Default	Range	Description
Cosphi set-point	1	0.900 to 1.000	Cos phi set point with 3 decimals
Cosphi direction	Inductive (GEN)	Inductive (GEN) Capacitive (GEN)	Cos phi inductive or capacitive
Cosphi offset	0	-0.1 to 0.1	Offset for the set point
Cosphi Ext control	OFF	OFF ON	External control of the offset for cos phi

3.6.13 Type 5: Variant E) fixed Q

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

Settings for Type 5: Variant E

Configure the settings under *Advanced Protection, var(Q) grid support, Type 5: Q (fixed)*.

Setting	Default	Range	Description
Q set point [% of Pnom]	0	-100 to 100	

3.6.14 Type 6: Variant F) Superior

With this variant, the genset controller uses the kvar/cos phi set point from the mains controller. If no mains controller is present, the genset controller can use a configurable default set point.

3.7 Q ramp

Two ramp functions for reactive power regulation can be activated. The ramp is used when the controller increases or decreases the reactive power.

Configure these parameters in the USW.

Text	Parameter	Default	Range	Description
Q ramp to setp.	2821	2 %/s	0.1 to 20 %/s	Ramp up for reactive power
Q ramp to zero	2822	2 %/s	0.1 to 20 %/s	Ramp down for reactive power
Q ramp enable	2823	OFF	OFF Linear Time constant	**OFF**: Deactivate the ramp. **Linear**: Parameters 2821 and 2822 are used. **Time constant**: Parameter 2824 is used.
Q time constant	2824	2 s	1 to 30 s	PT1-based time constant, used if **Time constant** is selected in parameter 2823.

3.8 df/dt (ROCOF)

The **Option A1 Mains protection package** has a detailed description of the df/dt function. This function is configured in parameter 1420 and 1422.

4. Mains controller functions

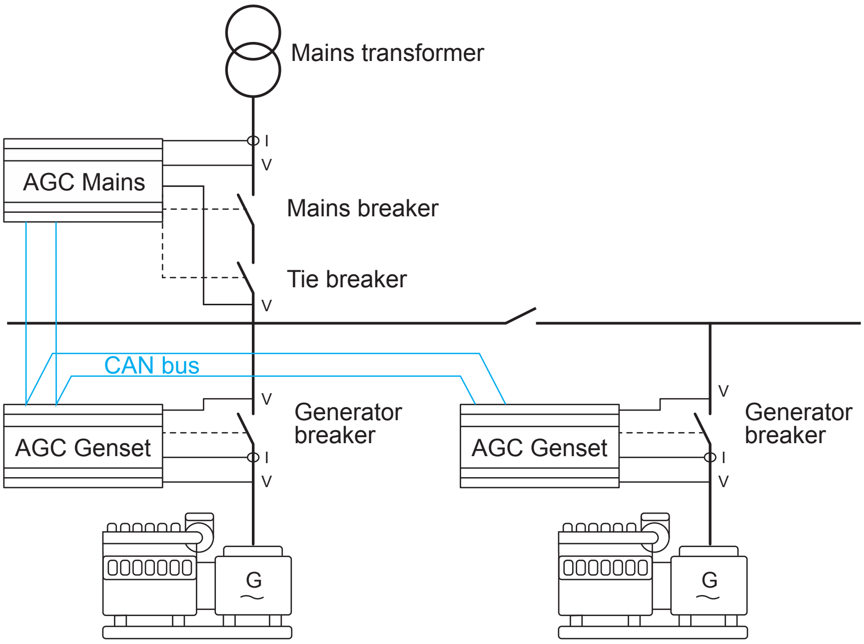
This chapter describes the option A10 requirements and functions that are specific to the mains controller.

For the functions that both the genset and mains controller support, see General functions.

4.1 Using the mains controller as the plant controller

If a mains controller is used as the plant controller, the mains controller measures the voltage and current at the connection point. Transducers are therefore not required.

Application example



To improve reliability, redundant CAN bus communication is recommended.

Plant requirements

All the controllers (that is, all mains and genset controllers) must have option A10 (advanced grid protection) and option G5 (power management).

For the genset controllers to use the Q/cos phi set points from the mains controller, select *Advance Protection > var(Q) grid support > Variant type > Variant F: Superior* in each genset controller. If this is not selected, the genset controller acts as if it is controlling a stand-alone genset.

Select the mains controller power reference

You can select the power reference for the mains controller under *Advance Protection > var(Q) grid support > Basic > Pnom reference (Pref)*.

Pb inst. (dynamic): The mains controller power reference is based on all connected gensets.

P installed (fixed): The mains controller power reference is based on the installed power of the gensets configured in *P installed*.

4.2 Nominal power

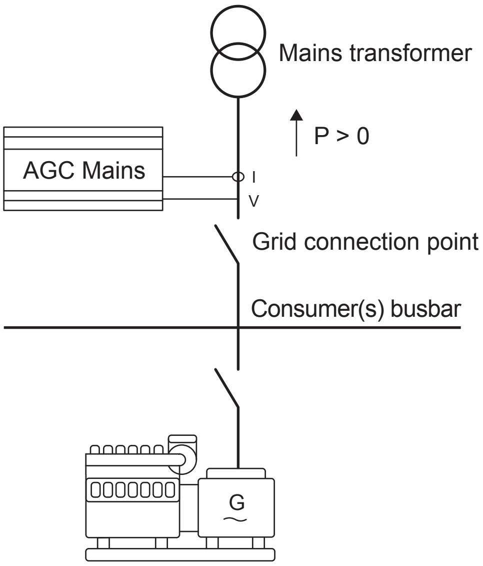
Several functions are based on the nominal power.

The nominal power is defined in *Nom. P 1*, parameter 6002; *Nom. P 2*, parameter 6012; *Nom. P 3*, parameter 6022; or *Nom. P 4*, parameter 6032. *Enable nom. set*, parameter 6006, determines which value is used.

4.2.1 Power direction

For option A10, for all the protections, cos phi regulation, and the RRCR set points, the controller treats the power to the grid as positive*.

Positive power to the mains



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

NOTE * The controller only treats the power to the grid as positive for option A10 code compliance. However, whether or not option A10 is active, the controller always displays power to the grid as negative. That is, power to the grid is always shown as negative on the display unit, in the utility software, and in the Modbus values.

4.3 Reactive power regulation

For option A10, there are six types of reactive power regulation in the mains controller. Select the regulation type under *Advanced Protection*, *var(Q) grid support*:

Reactive power regulation variants

Setting	Default	Range	Description
Variant type	Default	Default	Reactive power regulation uses *Droop Curve 2* if this is activated. Otherwise, if *Off* is selected in 7055, reactive power regulation uses parameter 7052 (cosphi) as the set point. If *Fixed Q* is selected in 7055, reactive power regulation uses parameter 7054 (Q) as the set point.
		Variant A: Q(U) U-Shift	Reactive power regulation uses *Type 1: Q(U) U-shift*.
		Variant B: Q(P) 10pts reg-curve	Reactive power regulation uses *Type 2: Q(P) Regulation*.
		Variant C: Q(U) Q-Shift	Reactive power regulation uses *Type 3: Q(U) Q shift*.
		Variant D: Cosphi (fixed)	Reactive power regulation uses *Type 4: Cosphi (fixed)*.
		Variant E: Q (fixed)	Reactive power regulation uses *Type 5: Q (fixed)*.

The default control type is compatible with the BDEW rules. The variant can be selected using the setting, a digital input or M-Logic (*Output, Grid Support, Var Reg Type ...*).

Example of M-Logic to activate a regulation type

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, the ramp is disabled.

Ramp timer setting

Setting	Default	Range	Description
Switching ramp timer	240 s	0 to 600 s	Time to the new set point when the regulation type is changed.

4.3.1 Default reactive power regulation

If *Default* is selected, select the reactive power regulation set points in the parameter list.

The controller uses the curves under *Advanced Protection, Droop curve 2*.

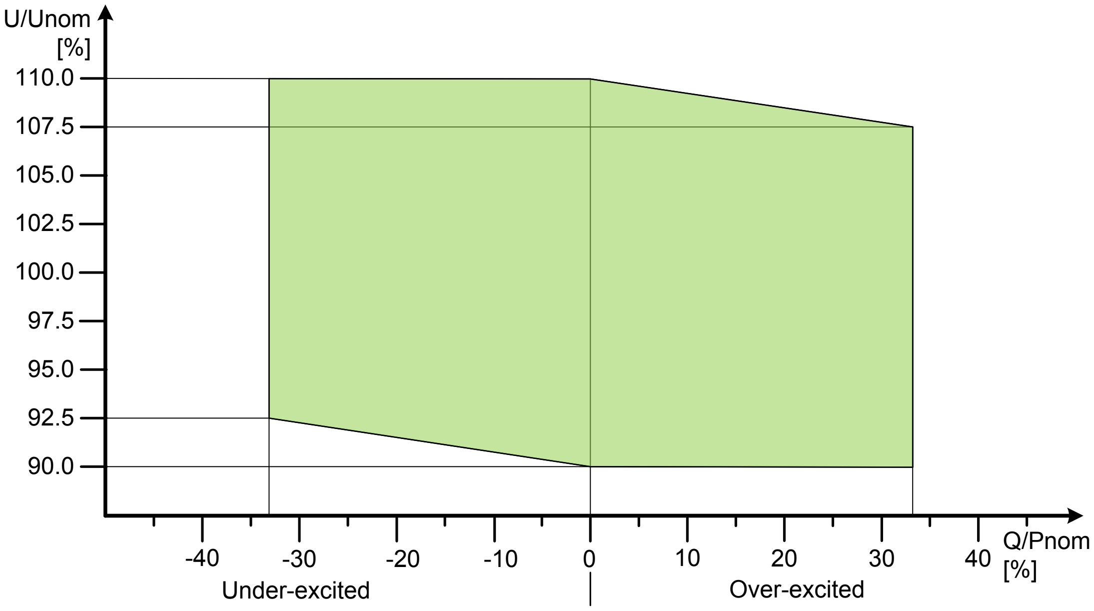
Text	Parameter	Default	Range	Description
Contr. sett. cosphi	7052	0.9	0.10 to 1.00	Cos phi set point with 2 decimals
Contr. sett. cosphi	7053	Inductive	Inductive Capacitive	Cos phi inductive or capacitive
Contr. sett. cosphi	7054	Off	Off Fixed for DG(s) Fixed for imp/exp	**Off**: Cos phi internal set point (that is, parameter 7052). **Fixed for DG(s)**: The genset(s) are regulated to achieve the cos phi set point* at the genset(s). The cos phi at the mains connection point is ignored. **Fixed for imp/exp**: The genset(s) are regulated to achieve the cos phi set point* at the mains connection point.

NOTE * The mains controller determines the cos phi set point.

4.3.2 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 (that is, Type 1, 2, 3, 4 or 5). When the *Variant type* is *Default* (under *Advanced Protection*, *var(Q) grid support*), 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.

4.3.3 Settings for grid voltage-dependent reactive power limiting

Configure the settings under *Advanced Protection*, *var(Q) grid support*.

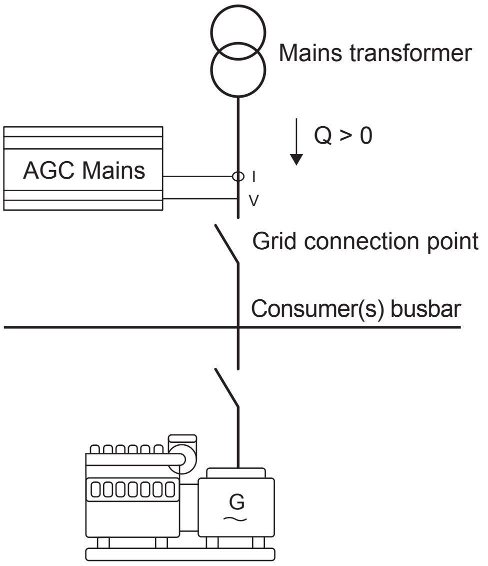
Setting	Default	Range	Description
Q-Limitation at U/Uc < 0.925 (under-excited)	OFF	OFF	The function* does not limit the reactive power during low grid voltage.
		ON	The function* limits the reactive power during low grid voltage.
Q-Limitation at U/Uc > 1.075 (over-excited)	OFF	OFF	The function* does not limit the reactive power during high grid voltage.
		ON	The function* limits the reactive power during high grid voltage.

NOTE * The function = Grid voltage-dependent reactive power limiting.

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

For variants A, B, C and E (reactive power regulation types 1, 2, 3 and 5), the reactive power (Q) from the grid is positive. That is, positive reactive power is from the grid to the consumer.

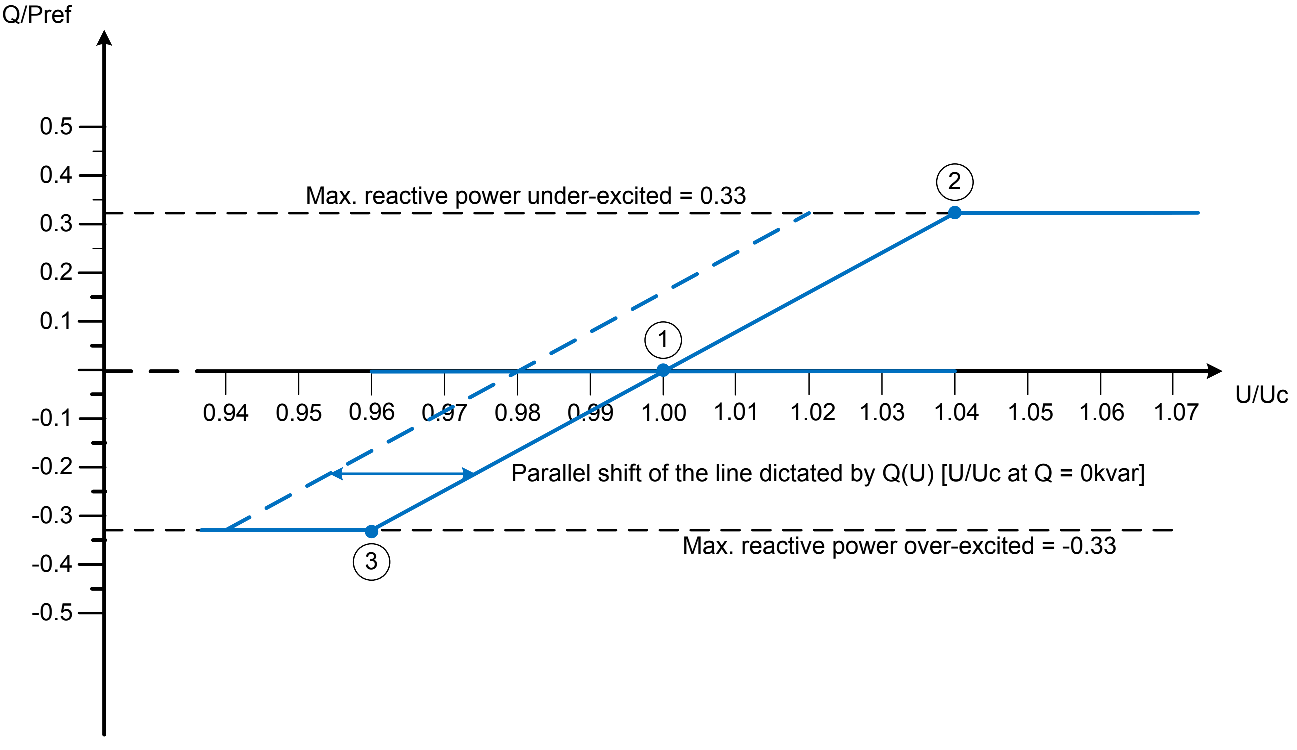
Positive reactive power from the grid



4.3.5 Type 1: Variant A) Q(U) U-Shift

If the *Q(U) U-shift* curve 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.

Default settings for *Q(U) U-Shift*



The *Q(U) U-shift* curve is defined under *Advanced Protection*, *var(Q) grid support*.

Point 1 is defined by *Q(U) [U/Uc at Q=0kvar]*.

Point 2 is defined by *Q(U) [U/Uc at Q max]* and *Q(U) [Q/Pref max]* (over-excited).

Point 3 is defined by *Q(U) [U/Uc at Q max]*, and *Q(U) [Q/Pref min]* (under-excited). The voltage level for point 3 is defined automatically.

Point 1 can be moved horizontally using *Q(U) shift X-axis [U/Uc]*, Modbus or an analogue input (4 to 20 mA). The movement of point 1 affects points 2 and 3.

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

The analogue signal for offset control must come from CIO 308 input 1.23.

Wire break monitoring and fallback function

When using an analogue input, the CIO 308 input 1.23 wire break monitoring function must be activated. This can be done in the USW. Select the CIO icon, then select the CIO 308. Select I23. Under *Wire break detection*, select *Enabled*.

One of the three other reactive power regulation functions must also be selected (using M-Logic) as the fallback function if the input fails.

M-Logic example: Use fixed cos phi regulation if the input fails

4.3.6 Settings for Type 1: Variant A

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 1: Q(U) U-shift*.

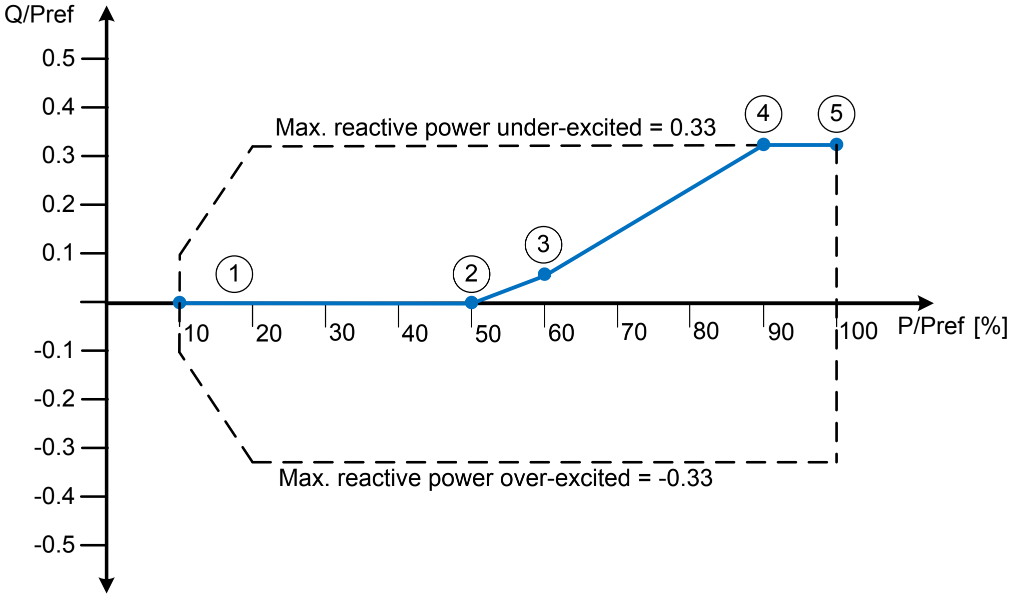
Setting	Default	Range	Description
Q(U) deadband	0 %	0 to 50 %	Voltage deadband
Q(U) [U/Uc at Q = 0kvar]	1	0.5 to 1.5	Reference voltage at Q= 0 kvar
Q(U) [U/Uc at Q max]	1.04	0.5 to 1.5	Maximum voltage at maximum Q
Q(U) [Q/Pref max]	0.33	0 to 0.4	Maximum Q during over-voltage
Q(U) [Q/Pref min]	-0.33	-0.4 to 0	Minimum Q during under-voltage
Q(U) shift X-axis [U/Uc]	0	-0.2 to 0.2	Offset value for reference voltage at Q=0 kvar
Q(U) Ext control	OFF	OFF Modbus Analogue	External control of the offset value for reference voltage at Q=0.

4.3.7 Type 2: 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.

Example for *Type 2: Variant B) Q(P) curve*



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

4.3.8 Settings for Type 2: Variant B

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 2: Q(P) Regulation*.

Curve settings

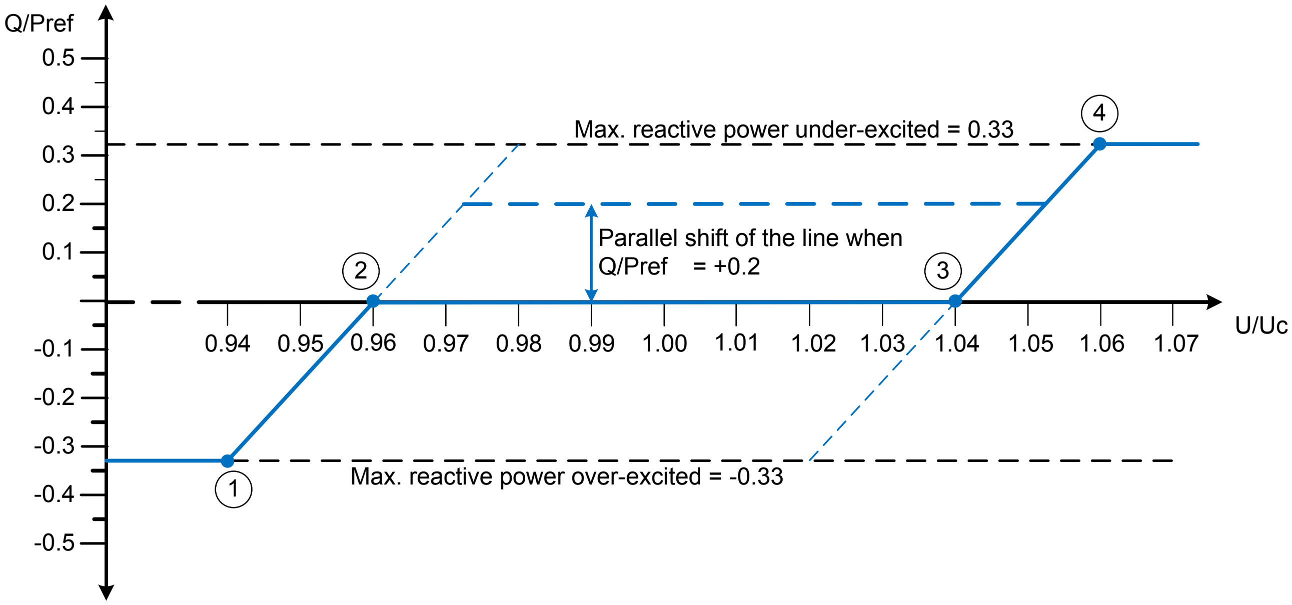
Active power	Default	Reactive power	Default
[%P/Pref] set-point 1	10	[Q/Pref] set-point 1	0
[%P/Pref] set-point 2	50	[Q/Pref] set-point 2	0
[%P/Pref] set-point 3	60	[Q/Pref] set-point 3	0.05
[%P/Pref] set-point 4	90	[Q/Pref] set-point 4	0.33
[%P/Pref] set-point 5	100	[Q/Pref] set-point 5	0.33
[%P/Pref] set-point 6	100	[Q/Pref] set-point 6	0.33
[%P/Pref] set-point 7	100	[Q/Pref] set-point 7	0.33
[%P/Pref] set-point 8	100	[Q/Pref] set-point 8	0.33
[%P/Pref] set-point 9	100	[Q/Pref] set-point 9	0.33
[%P/Pref] set-point 10	100	[Q/Pref] set-point 10	0.33

The ratio of Q to Pref assumes that Q is in kvar and P is in kW. For example, for Pref = 480 kW, if the Q/Pref ratio is 0.05, then Q is 24 kvar. If Q/Pref is -0.05, then Q is -24 kvar.

4.3.9 Type 3: 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.

Example for *Type 3: Variant C) 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 setting, Modbus or analogue input. The offset is added to the actual reactive power.

The offset setting is *Q(U) shift Y-axis [Q/Pref]*.

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

The analogue signal for offset control must come from CIO 308 input 1.23.

Wire break monitoring and fallback function

When using an analogue input, the CIO 308 input 1.23 wire break monitoring function must be activated. This can be done in the USW. Select the CIO icon, then select the CIO 308. Select I23. Under *Wire break detection*, select *Enabled*.

One of the three other reactive power regulation functions must also be selected (using M-Logic) as the fallback function if the input fails.

M-Logic example: Use fixed cos phi regulation if the input fails

4.3.10 Settings for Type 3: Variant C

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 3: Q(U) Q-shift*.

Curve settings

Voltage	Default	Reactive power	Default
[U/Unom] set-point 1	0.94	[Q/Pref] set-point 1	-0.33
[U/Unom] set-point 2	0.96	[Q/Pref] set-point 2	0
[U/Unom] set-point 3	1.04	[Q/Pref] set-point 3	0
[U/Unom] set-point 4	1.06	[Q/Pref] set-point 4	0.33

Other settings

Setting	Default	Range	Description
Q(U) shift Y-axis [Q/Pref]	0	-0.4 to 0.4	Offset value for Qref/Pref
Q(U) Ext Control	OFF	OFF Modbus Analogue	External control of the offset value for Qref/Pref

The ratio of Q to Pref assumes that Q is in kvar and P is in kW. For example, for Pref = 480 kW, if the Q/Pref ratio is 0.05, then Q is 24 kvar. If Q/Pref is -0.05, then Q is -24 kvar.

4.3.11 Type 4: 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**.

4.3.12 Settings for Type 4: Variant D

Configure the settings under *Advanced Protection*, *var(Q) grid support*, *Type 4: Cosphi (fixed)*.

Setting	Default	Range	Description
Cosphi set-point	1	0.900 to 1.000	Cos phi set point with 3 decimals
Cosphi direction	Inductive (GEN)	Inductive (GEN) Capacitive (GEN)	Cos phi inductive or capacitive
Cosphi offset	0	-0.1 to 0.1	Offset for the set point
Cosphi Ext control	OFF	OFF ON	External control of the offset for cos phi

4.3.13 Type 5: Variant E) fixed Q

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

Settings for Type 5: Variant E

Configure the settings under *Advanced Protection, var(Q) grid support, Type 5: Q (fixed)*.

Setting	Default	Range	Description
Q set point [% of Pref]	0	-100 to 100	

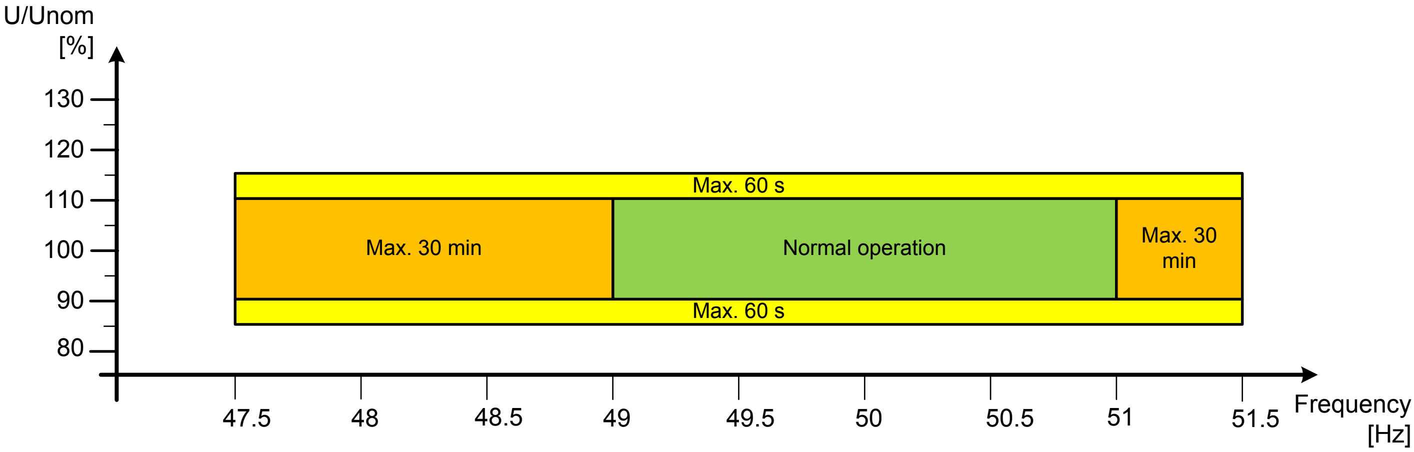
5. General functions

These functions are supported by both genset and mains controllers. Unless otherwise noted, the functions are the same in both controller types.

5.1 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



5.1.1 Parameters for quasi-stationary operation

Quasi-stationary operation is configured using fail classes for busbar voltage and frequency parameters.

To have the long times required for quasi-stationary operation, you must use the group 3 and/or 4 parameters (see the table below). Configure the set points and timers to define the area and duration for quasi-stationary operation. For Option A10, the timers can be up to 2000 seconds. This covers both VDE and G99 requirements. (Without Option A10, the timers are a maximum of 99.99 seconds.)

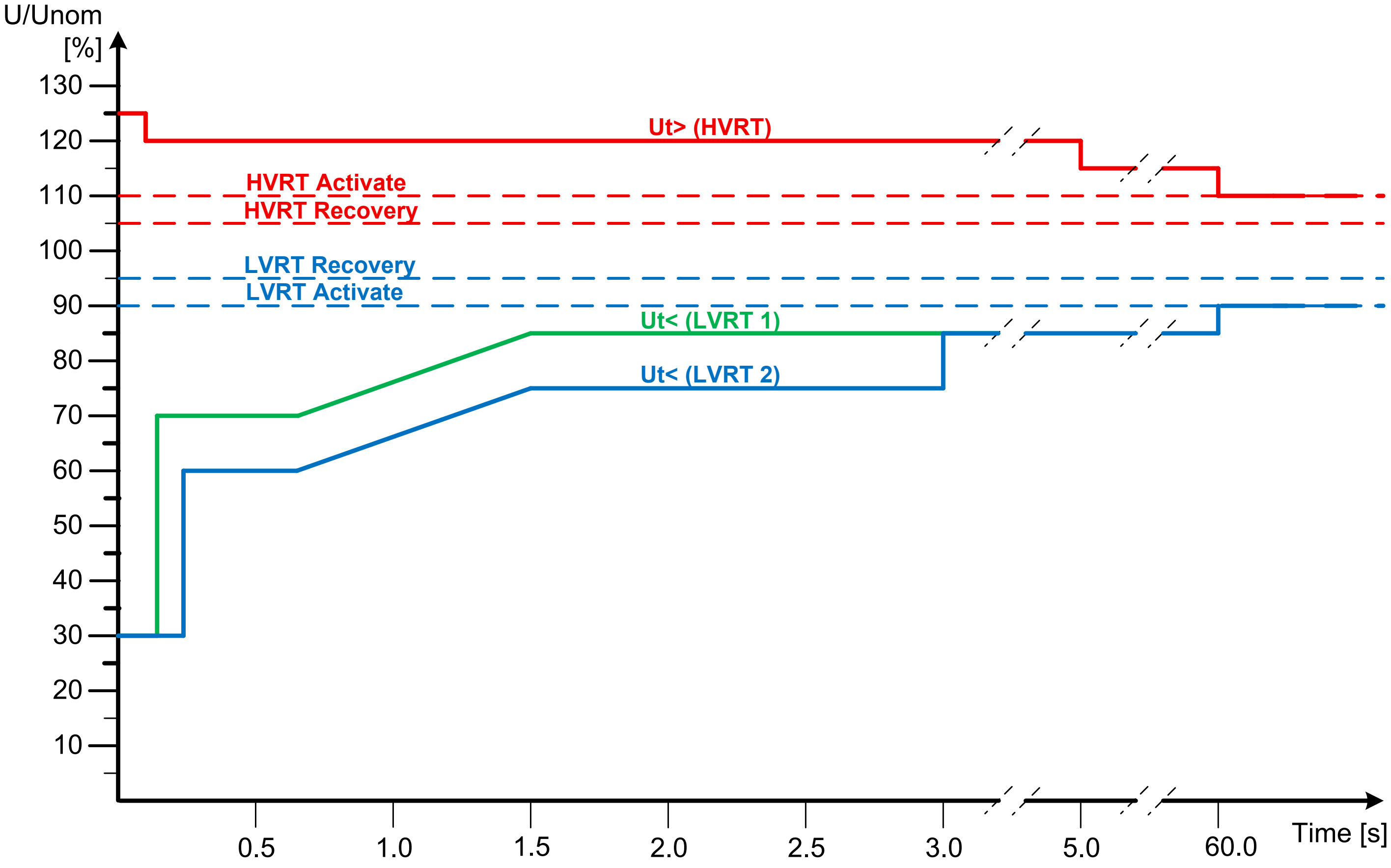
Text	Parameter	Default	Range
BB U> 3	1290	105 %, 50 s	100 to 130 %, 0 to 2000 s
BB U< 3	1320	97 %, 100 s	40 to 100 %, 0 to 2000 s
BB U< 4	1330	95 %, 50 s	40 to 100 %, 0 to 2000 s
BB f> 3	1370	105 %, 50 s	100 to 120 % (50 to 60 Hz), 0 to 2000 s
BB f< 3	1400	97 %, 100 s	80 to 100 % (40 to 50 Hz), 0 to 2000 s
BB f< 4	1410	95 %, 50 s	80 to 100 % (40 to 50 Hz), 0 to 2000 s

5.2 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 for up to 5 seconds during FRT.

The controller counts FRT activations. In the USW, select the *Counters* icon Σ to open the *Counters* window, then select *LVRT/HVRT*. For each curve, the number of activations and trips are shown.

External FRT for genset controllers

If the genset controller includes option M12, you can configure an *External FRT active* input on inputs 43 to 55. When the input is activated, the genset controller activates the FRT curve.

5.2.1 Settings for FRT curves

FRT setup settings

Configure these settings under *Advanced Protection*, *FRT setup*.

Activation Mode: Number of phases

Setting	Default	Range	Description
Activation Mode	Number of Phases	Number of Phases Symmetrical - Asymmetrical	**Number of Phases**: The FRT activation counts the number of phases that exceed the set point.
LVRT 1 type select LVRT 2 type select HVRT 1 type select	Any phase-phase	Any phase-phase 1 phase-phase 2 phase-phase 3 phase-phase 1 phase-neutral	The measurements to exceed the set point to activate the fault ride through curve.

Setting	Default	Range	Description
		2 phase-neutral 3 phase-neutral Any phase-neutral	

Activation Mode: Symmetrical - Asymmetrical

Setting	Default	Range	Description
Activation Mode	Select **Symmetrical - Asymmetrical**	Number of Phases Symmetrical - Asymmetrical	**Symmetrical - Asymmetrical**: The FRT activation is based on the detection of a symmetrical fault, an asymmetrical fault, or any fault type.
LVRT 1 type select LVRT 2 type select	Any phase-phase	Symmetrical phase-phase Asymmetrical phase-phase Any phase-phase Symmetrical phase-neutral Asymmetrical phase-neutral Any phase-neutral	The fault type for which the measurements have to exceed the set point to activate the fault ride through curve.
HVRT1 type select	phase-phase	phase-phase phase-neutral	The fault type for which the measurements have to exceed the set point to activate the fault ride through curve.
Linking	Linked	Individual Linked	**Individual**: Each FRT curve is activated and handled independently of the other FRT curves. **Linked**: The FRT curves are activated based on the same incident, and the recovery is co-ordinated.

There are configurable settings to stop GOV and/or AVR regulation for up to 5 seconds during LVRT.

Suspend GOV and AVR (only genset controllers)

Setting	Default	Range	Description
Suspend GOV regulation	Disable	Disable Enable	*Disable*: GOV regulation is not affected when an FRT curve is activated. *Enable*: GOV regulation is stopped when any FRT curve is activated.
GOV reg suspension timer	5 s	0 to 5 s	Time duration for stopping the GOV, when an FRT curve is activated.
Suspend AVR regulation	Disable	Disable Enable	*Disable*: AVR regulation is not affected when an FRT curve is activated. *Enable*: AVR regulation is stopped when any FRT curve is activated.
AVR reg suspension timer	5 s	0 to 5 s	Time duration for stopping the AVR, when an FRT curve is activated.

LVRT 1 settings

Configure these settings under *Advanced Protection*, *LVRT 1*.

LVRT 1 curve

Voltage	Default*	Timer	Default**
Ut< U SP1	30 %	Ut< t SP1	0 s
Ut< U SP2	30 %	Ut< t SP2	0.15 s
Ut< U SP3	70 %	Ut< t SP3	0.15 s
Ut< U SP4	70 %	Ut< t SP4	0.7 s
Ut< U SP5	85 %	Ut< t SP5	1.5 s
Ut< U SP6	85 %	Ut< t SP6	60 s
Ut< U SP7	90 %	Ut< t SP7	60 s

Voltage	Default*	Timer	Default**
Ut< U SP8	90 %	Ut< t SP8	70 s
Ut< U SP9	90 %	Ut< t SP9	70 s
Ut< U SP10	90 %	Ut< t SP10	70 s

NOTE * The range is 4 to 120 % of nominal voltage.
NOTE ** The range is 0 to 70 s.

LVRT 2 settings

Configure these settings under *Advanced Protection*, *LVRT 2*.

LVRT 2 curve

Voltage	Default*	Timer	Default**
Ut< U SP1	30 %	Ut< t SP1	0 s
Ut< U SP2	30 %	Ut< t SP2	0.22 s
Ut< U SP3	60 %	Ut< t SP3	0.22 s
Ut< U SP4	60 %	Ut< t SP4	0.7 s
Ut< U SP5	75 %	Ut< t SP5	1.5 s
Ut< U SP6	75 %	Ut< t SP6	3 s
Ut< U SP7	85 %	Ut< t SP7	3 s
Ut< U SP8	85 %	Ut< t SP8	60 s
Ut< U SP9	90 %	Ut< t SP9	60 s
Ut< U SP10	90 %	Ut< t SP10	70 s

NOTE * The range is 4 to 120 % of nominal voltage.
NOTE ** The range is 0 to 70 s.

HVRT 1 settings

Configure these settings under *Advanced Protection*, *HVRT 1*.

HVRT 1 curve

Voltage	Default*	Timer	Default**
Ut> U SP1	125 %	Ut> t SP1	0 s
Ut> U SP2	125 %	Ut> t SP2	0.1 s
Ut> U SP3	120 %	Ut> t SP3	0.1 s
Ut> U SP4	120 %	Ut> t SP4	5 s
Ut> U SP5	115 %	Ut> t SP5	5 s
Ut> U SP6	115 %	Ut> t SP6	60 s
Ut> U SP7	110 %	Ut> t SP7	60 s
Ut> U SP8	110 %	Ut> t SP8	70 s
Ut> U SP9	110 %	Ut> t SP9	70 s
Ut> U SP10	110 %	Ut> t SP10	70 s

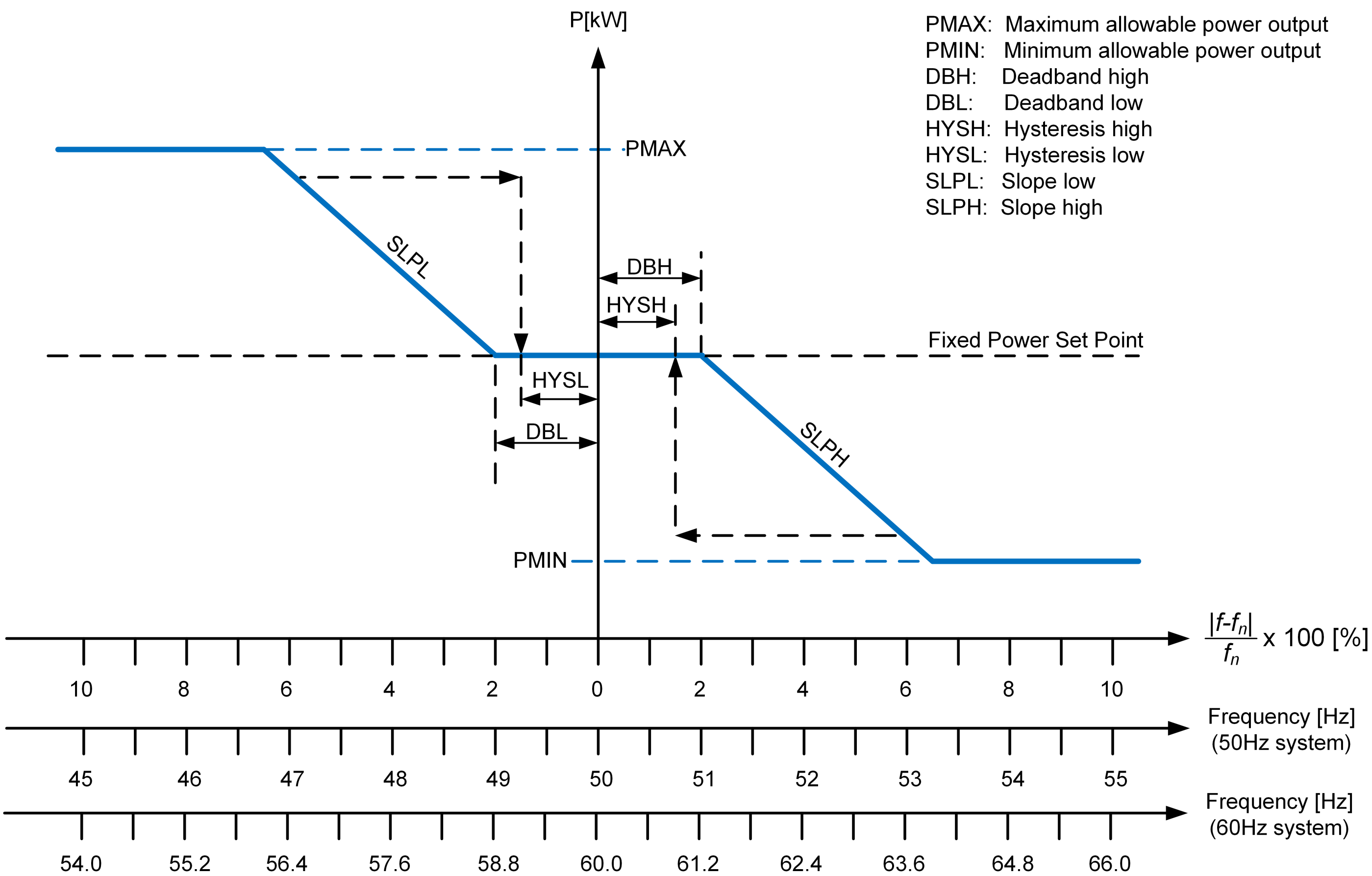
NOTE * The range is 100 to 130 % of nominal voltage.
NOTE ** The range is 0 to 70 s.

Parameters
Configure these parameters in the parameter list.

Text	Parameter	Default	Range	Description
HVRT Activate 1	1631	110 %	30 to 130 %	Threshold for activation of the HVRT curve
HVRT Recovery 1	1632	105 %, 1 s	30 to 130 %, 0 to 320 s	Threshold for de-activation of the HVRT curve, with time delay
HVRT Activate 1	1634	OFF	-	Alarm, when parameter 1631 is active
HVRT 1	1640	OFF	-	Alarm, when the HVRT curve is exceeded (trip area)
Ut< Activate 1	1651	90 %	30 to 120 %	Threshold for activation of the LVRT 1 curve
Ut< Recovery 1	1652	95 %, 1 s	30 to 120 %, 0 to 320 s	Threshold for de-activation of LVRT 1 curve, with time delay
Ut< Activate 1	1654	OFF	-	Alarm, when parameter 1651 is active
Ut< 1	1660	OFF	-	Alarm, when the LVRT 1 curve is exceeded (trip area)
Ut< Activate 2	1691	90 %	30 to 120 %	Threshold for activation of the LVRT 2 curve
Ut< Recovery 2	1692	95 %, 1 s	30 to 120 %, 0 to 320 s	Threshold for de-activation of LVRT 2 curve, with time delay
Ut< Activate 2	1694	OFF	-	Alarm, when parameter 1691 is active
Ut< 2	1700	OFF	-	Alarm, when the LVRT 2 curve is exceeded (trip area)

5.3 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 1* 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).

More information
External set points for power from the Radio Ripple Control Receiver (RRCR) inputs have a higher priority than over- and under-frequency-dependent active power regulation, and all other set points are ignored (for example, Modbus). See the **Designer's Handbook** for more information on RRCR.

Scaling can be changed in parameter 9030. There are four selections for the different measuring ranges for *Droop curve 1*.

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

The slope can be based on absolute value or %.

More information
See Requirements for Generators frequency droop for information on how option A10 complies with Regulation (EU) 2016/631 (also known as RfG).

5.3.1 Settings and parameters

Configure these settings under *Advanced Protection*, *Droop curve 1*.

Basic

Setting	Default	Range	Description
Curve select	P(X1)	P(X1) N.A.	P(X1): The X-Axis is power. N.A.: Do not select this.
Curve select	f	f U N.A.	f: The Y-Axis is frequency. U: The Y-Axis is voltage. N.A.: Do not select this.
Curve enable	Disable	Disable Enable	Function ON/OFF selection
Recovery delay	600 s	0 to 3600 s	The timer starts when the grid frequency returns to the deadband. The controller uses power ramp 3 until this timer runs out, or the frequency moves out of the deadband.
Calculation method	P installed	P momentary P installed Mains controller only: P momentary (CP) Mains controller only: Pb inst. (CP)*	Selection of actual P or nominal P is to be used as base for the calculations. See the example. **P momentary (CP)**: The slope settings must be in %. **Pb inst. (CP)**: Related to *P installed*.

NOTE * This is at the connection point. This is **not** related to *Advanced Protection > var(Q) grid support > Pnom reference (Pref): Pb inst.* (dynamic).

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 *P 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 *P installed*, the calculation uses the value in *Slope low (7133)*.

Curve control

Setting	Default	Range	Description
Deadband low (7121)	0.4 %	0 to 99.99 %	Deadband for grid under-frequency or under-voltage
Deadband high (7122)	0.4 %	0 to 99.99 %	Deadband for grid over-frequency or over-voltage
Hysteresis low (7123)	99.89 %	0 to 99.99 %	Hysteresis for grid under-frequency or under-voltage
Hysteresis high (7124)	99.89 %	0 to 99.99 %	Hysteresis for grid over-frequency or over-voltage

Scaling, parameter 9030, determines which *P curve* the controller uses. The setting for the default scaling is shown below.

P curve for *100-25000V*

Setting	Default for 100-25000V	Range for 100-25000V	Description
P min	24 kW	0 to 20000 kW	Limit, minimum active power
P max	480 kW	0 to 20000 kW	Limit maximum active power
Slope low	96 kW/%	-20000 to 20000 kW/%	Gradient during grid under-frequency or under-voltage. See the example.
Slope high	-96 kW/%	-20000 to 20000 kW/%	Gradient during grid over-frequency or over-voltage

Slope calculation

Setting	Default	Range	Description
Droop slope calculation method	Absolute	Absolute Percentage	Calculation method for the gradient.
Slope low	5 % power/% f/U	-100 to 100	Gradient during grid under-frequency or under-voltage
Slope high	-5 % power/% f/U	-100 to 100	Gradient during grid over-frequency or over-voltage

Parameters (only genset controller)

Configure these parameters in the parameter list.

Text	Parameter	Default	Range	Description
Power ramp up 3	2801	0.1 %/s	0.1 to 20 %/s	Power increase rate while in the deadband during recovery after a grid under- or over-frequency, or under- or over-voltage.
Power ramp down 3	2802	0.1 %/s	0.1 to 20 %/s	Power decrease rate while in the deadband during recovery after a grid under- or over-frequency, or under- or over-voltage.
Power ramp up 4	2803	0.1 %/s	0.1 to 20 %/s	Power increase rate after a disconnection from the grid due to a grid protection (the *Recovery timer* is running).
Power ramp down 4	2804	0.1 %/s	0.1 to 20 %/s	Power decrease rate after a disconnection from the grid due to a grid protection (the *Recovery timer* is running).

Frequency off-set for testing

To use a 4 to 20 mA signal as the frequency offset, configure these parameters.

Text	Parameter	Default	Range	Description
f offset Tmax	7291	0 Hz	0.0 to 2.5 Hz	The frequency offset for 20 mA.
f offset Tmin	7292	0 Hz	-2.5 to 0.0 Hz	The frequency offset for 4 mA.
f offset meas	7293	Multi input 102 (transducer)	Multi input 102 (transducer) Multi input 105 (transducer) Multi input 108 (transducer)	Select the transducer for the frequency offset.

5.4 Q-U protection

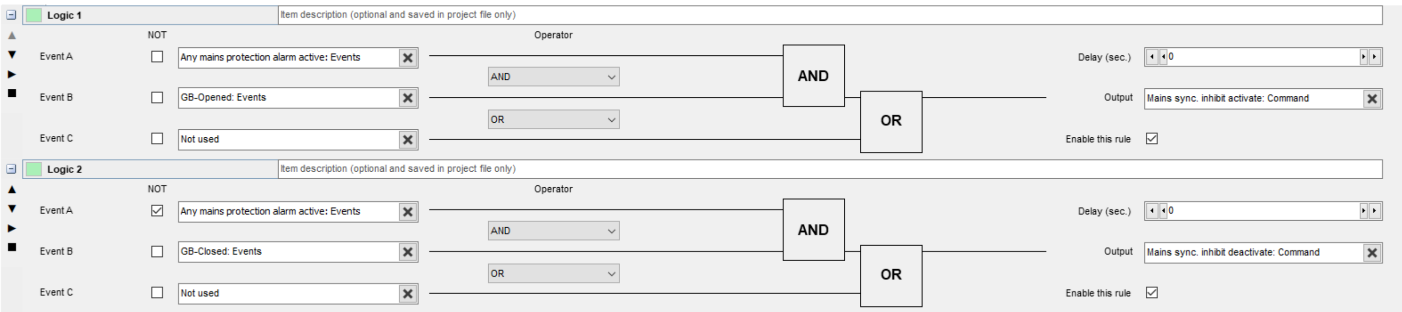
See the **Option A1 Mains protection package**.

5.5 Connection after trip caused by grid protections

For this function, the *Mains sync. Inhibit* is used.

For a detailed description, see the **Designer's Handbook**.

Example of M-Logic for implementation

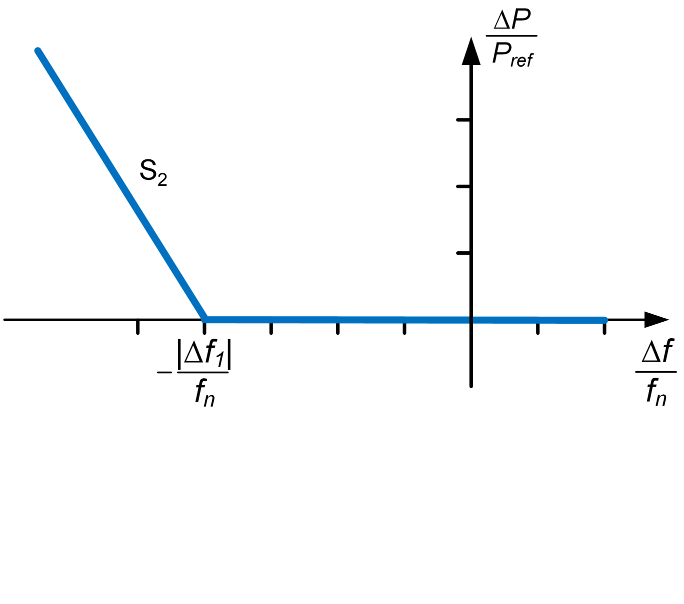


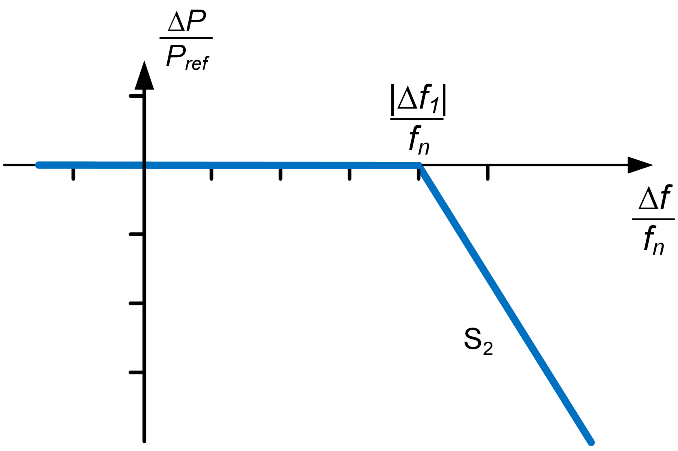
6. Appendix

6.1 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 option A10 functions used to meet the Requirements for Generators.





This formula defines the droop (S_2):

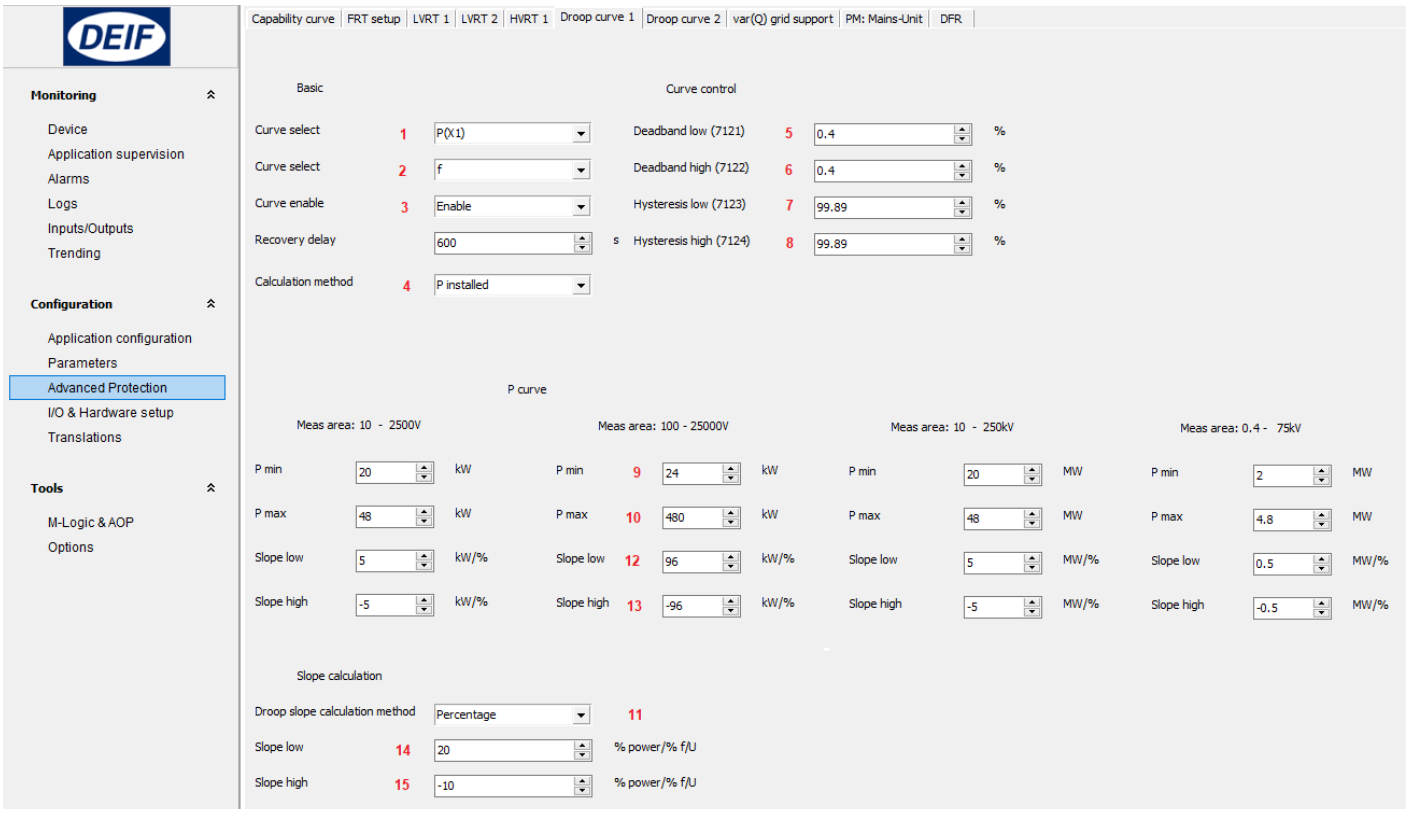
$$S_2\ [\%] = 100 \cdot \frac{|\Delta f| - |\Delta f_1|}{f_n} \cdot \frac{P_{ref}}{|\Delta P|}$$

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 (parameter 60×1).
P_{ref}	[W]	The reference active power. This corresponds to the controller nominal power (parameter 60×2) (the maximum capacity of the generator). ΔP is based on P_{ref}.
ΔP	[W]	The change in active power output from the generator.

6.1.1 Option A10 droop curve parameters for RfG

General settings

In the utility software, on the *Advanced protection* page, use *Droop curve 1* to meet the "active power frequency response capability of power-generating modules", seen in Requirements for Generators.



The numbers marked in red are shown in the # columns in the tables below.

Variables used in the following 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 (parameter 60×2).

Use the following settings for RfG frequency droop:

Setting	#	Value	Notes
Curve select	1	P(X1)	This ensures that the response is active power.
Curve select	2	f	This ensures that the response is based on the actual system frequency.
Curve enable	3	Enable	Enable droop curve 1.
Calculation method	4	P installed	This ensures that the droop response is based on the controller's nominal power (parameter 60×2). See P_{ref} above.

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

Curve control settings

Setting	Unit	#	Notes
Deadband low (DBL)	%	5	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 = $\lvert 49.8 - 50 \rvert$ / 50 · 100 = 0.4 %
Deadband high (DBH)	%	6	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 = $\lvert 50.2 - 50 \rvert$ / 50 · 100 = 0.4 %
Hysteresis low (HYSL)	%	7	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 (HYSH)	%	8	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. **For RfG:** Hysteresis is not relevant. Disable it by setting HYSH above DBH.
P_{min} (MIN)	W	9	The minimum active power. This limits the change in the active power output. **For RfG:** Configure P_{min} according to the system capabilities.
P_{max} (MAX)	W	10	The maximum active power. This limits the change in the active power output. **For RfG:** Configure P_{max} according to the system capabilities.

Slope settings

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	11	Absolute	The slope is configured using absolute power values (see # 12 and 13).
	11	Percentage	The slope is configured using percentage power values (see # 14 and 15).

Absolute method for droop slope calculation

Setting	#	Unit	Notes
Slope low (SLPL) LFSM-U	12	W/%	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 (SLPH) LFSM-O	13	W/%	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 % Nominal power (P_n) = 480 kW SLPH [W/%] = -480 kW / 5 % = -96 kW/%

Percentage method for droop slope calculation

Setting	#	Unit	Notes
Slope low (SLPL) LFSM-U	14	-	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}.

Setting	#	Unit	Notes
			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 (SLPH) LFSM-O	15	-	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 [-]

6.1.2 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} Slope low (SLPL) - LFSM-U	The active power output change when the network frequency is decreasing. **Using absolute frequency values:** $\Delta P\,[W] = -SLPL \cdot \frac{f - f_{DBL}}{f_n} \cdot 100$ 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:

Frequency range	Calculation and notes
	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)

Frequency range	Calculation and notes
	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 %