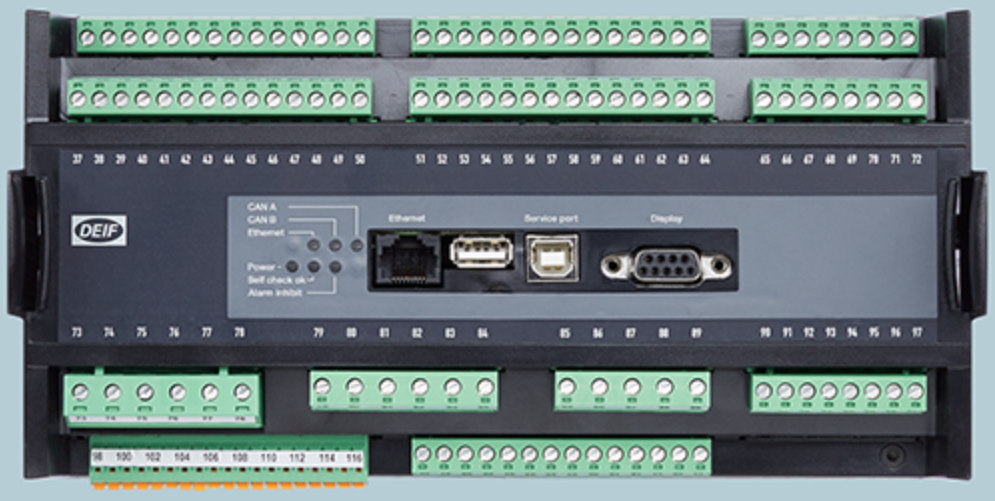
AGC-4

Option A10
VDE AR-N 4110/4105 and G99 grid protection



DEIF A/S · Frisenborgvej 33 · DK-7800 Skive
Tel.: +45 9614 9614 · Fax: +45 9614 9615
info@deif.com · www.deif.com

Document no.: 4189341213B

1. Option description

2. External measurements, inputs and outputs

3. Function descriptions

1. Option description

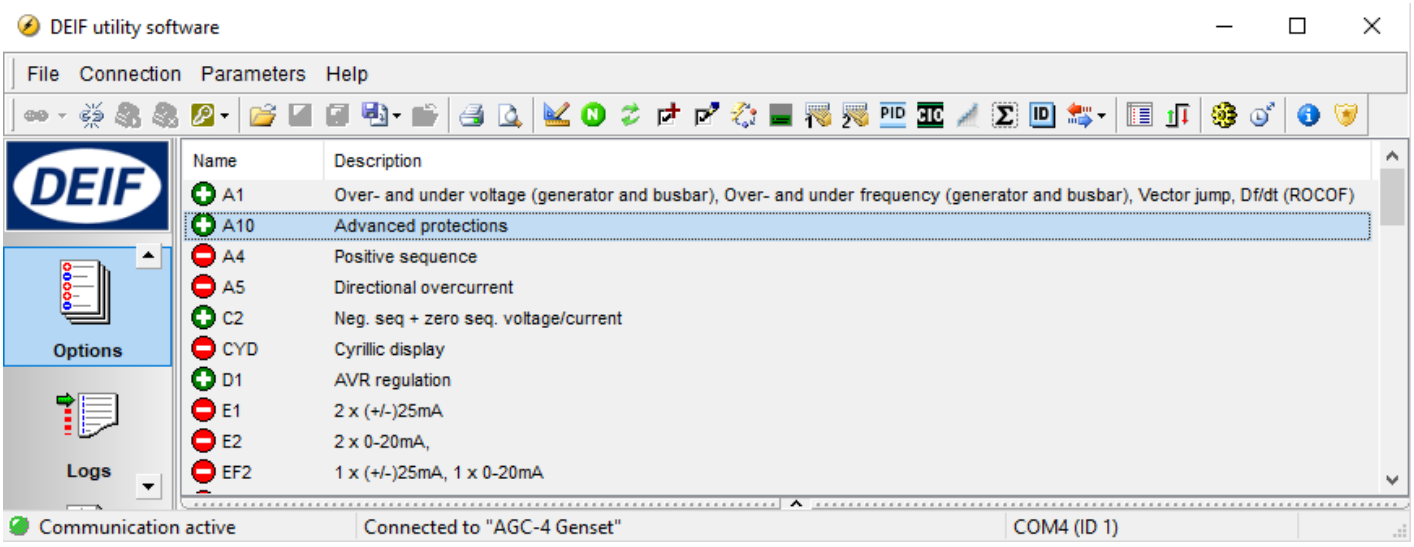
1.1 Option A10

Option A10 is a software option. Option A10 automatically activates Options A1 (Mains protection package), C2 (Generator add-on protection package). Option D1 (AVR regulation) is required for running the generator parallel to the grid. Option D1 is not included in Option A10, and must be ordered separately.

DEIF recommends selecting Option Q1 (Verified class 0.5) when you order the controller. Option Q1 requires improved calibration during the controller's production.

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

Figure 1.1 Example of activated options for Option A10



1.2 VDE requirements

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

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.

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.

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.

1.3 G99 requirements

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

CAUTION
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.

df/dt: To meet the G99 requirements, choose *G99 df/dt* in parameter 1205. You can then configure df/dt in menu 1670.

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.

1.4 Software version

This document is based on the following software:

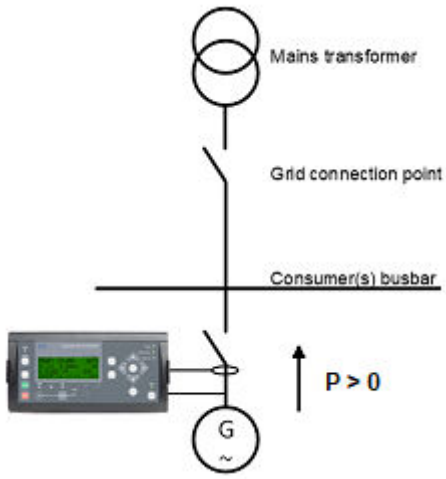
Software type	Software version
ML-2 firmware	4.76 and later
PC Utility Software	3.45.2 and later

INFO
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 Power direction

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

Figure 1.2 Positive power from the genset



INFO
For reactive power (Q) regulation, the Q from the grid is positive.

1.6 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.

1.7 Nominal grid voltage and scaling

Several functions are based on the nominal grid voltage.

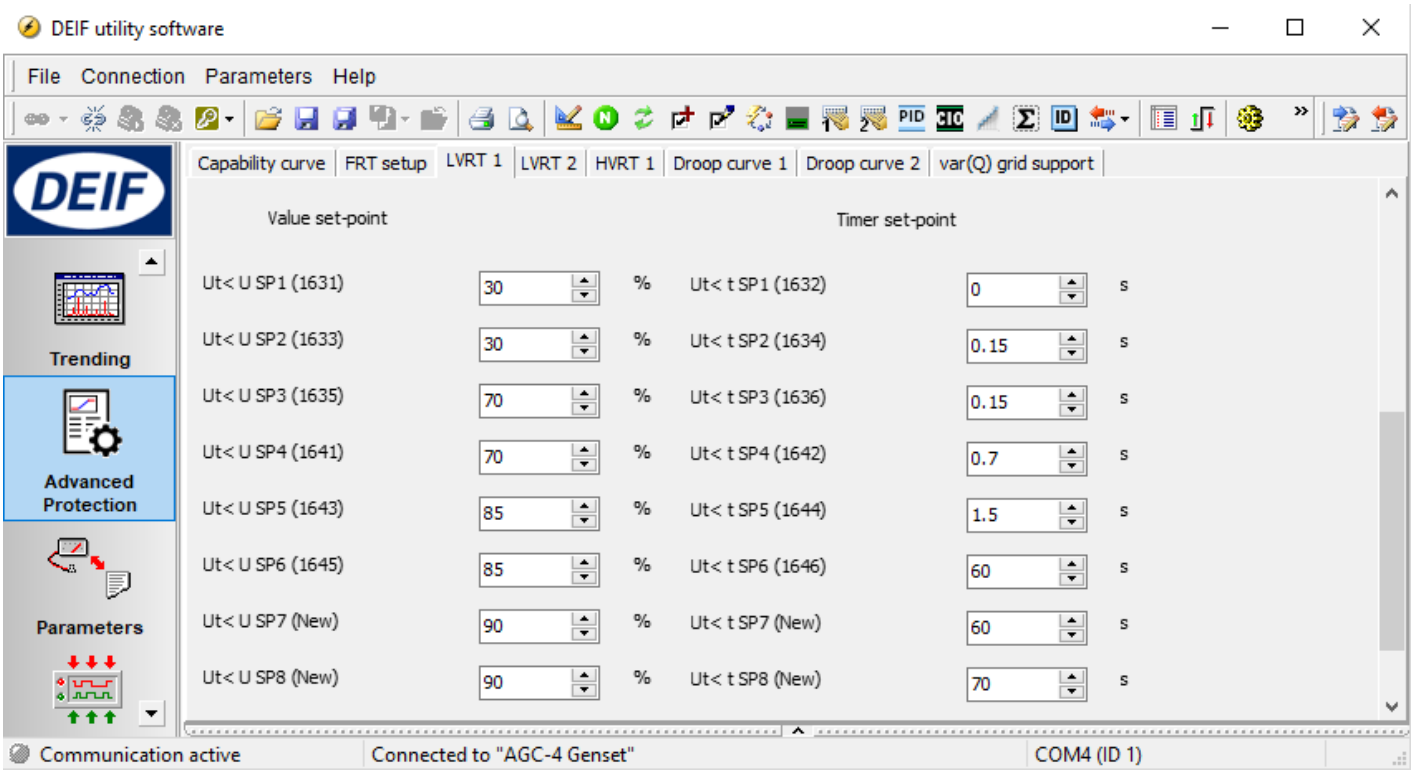
The nominal grid voltage is defined in *BB Nominal U 1*, parameter 6053, or *BB Nominal U 2*, parameter 6063. *Bus nom. set*, parameter 6052, determines which value is used.

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 Parameters and settings

Some configurable settings, which previously had parameter numbers, have been moved to *Advanced Protection*. These settings no longer appear in the parameter list. To help the user, the old parameter number is shown in brackets. Where a new configurable setting has been created, this is shown by *(New)*.

Figure 1.3 Example of configurable settings with numbers



1.9 Abbreviations and glossary

Table 1.1 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
P %	Active power (P) as a percentage of the nominal power (Pnom)

Abbreviation	Explanation
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

Table 1.2 Glossary

Term	Explanation
controller	DEIF AGC-4 genset controller
genset	An electricity generating set with controllable speed (governor) and excitation (AVR).
grid	The national electricity supply. Also called *mains*.
plant	The power producing facility where the genset is located.

1.10 Warnings, legal information and safety

1.10.1 Legal information and disclaimer

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 Multi-line 2 unit, the company responsible for the installation or the operation of the set must be contacted.

INFO
The Multi-line 2 unit is not to be opened by unauthorised personnel. If opened anyway, the warranty will be lost.

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.

1.10.2 Safety issues

Installing and operating the Multi-line 2 unit may imply work with dangerous currents and voltages. Therefore, the installation should only be carried out by authorised personnel who understand the risks involved in working with live electrical equipment.

DANGER!
Be aware of the hazardous live currents and voltages. Do not touch any AC measurement inputs as this could lead to injury or death.

1.10.3 Factory settings

The Multi-line 2 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.

2. External measurements, inputs and outputs

2.1 AC measurements at the grid connection

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

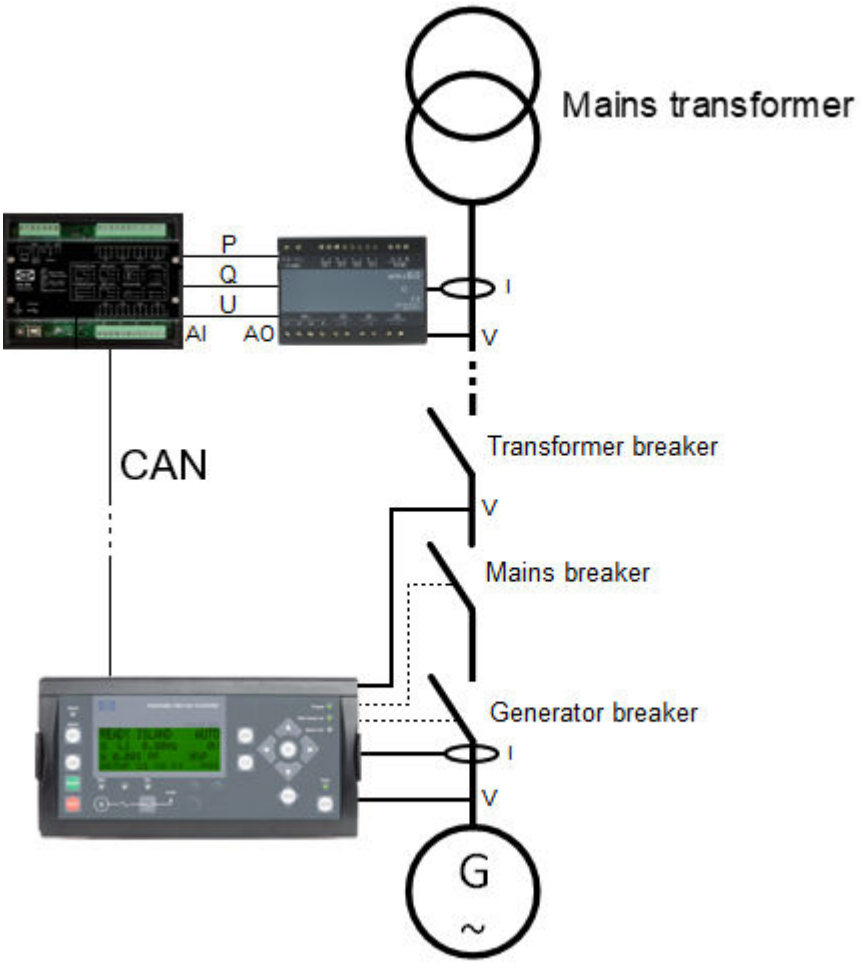
2.1.1 Grid connection point too distant

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.

INFO
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.

Figure 2.1 Example for AC measurements from a distant grid connection point



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

2.1.2 Using a transducer for voltage measurements

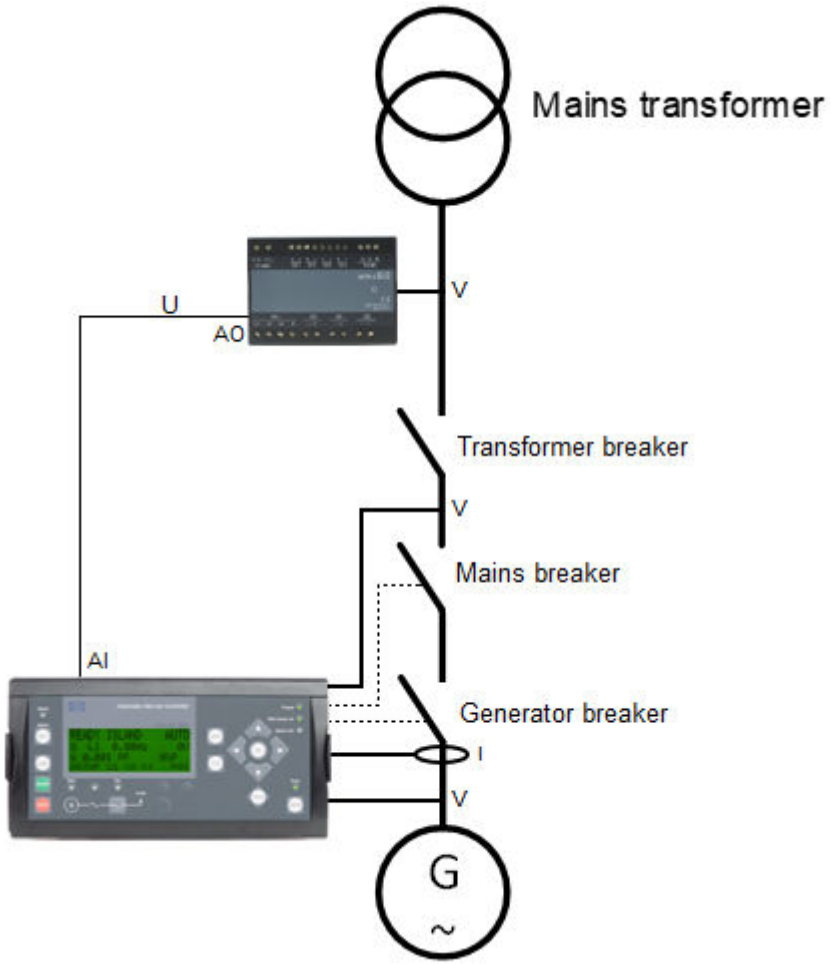
The *Q(U) U-shift* and *Q(U) Q-shift* functions can be based on a 4 to 20 mA grid voltage signal from a DEIF MTR at the grid connection point. This is useful if there is a significant voltage drop between the connection point and the controller.

INFO
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.

Figure 2.2 Example for voltage measurement as an analogue input from the grid connection point

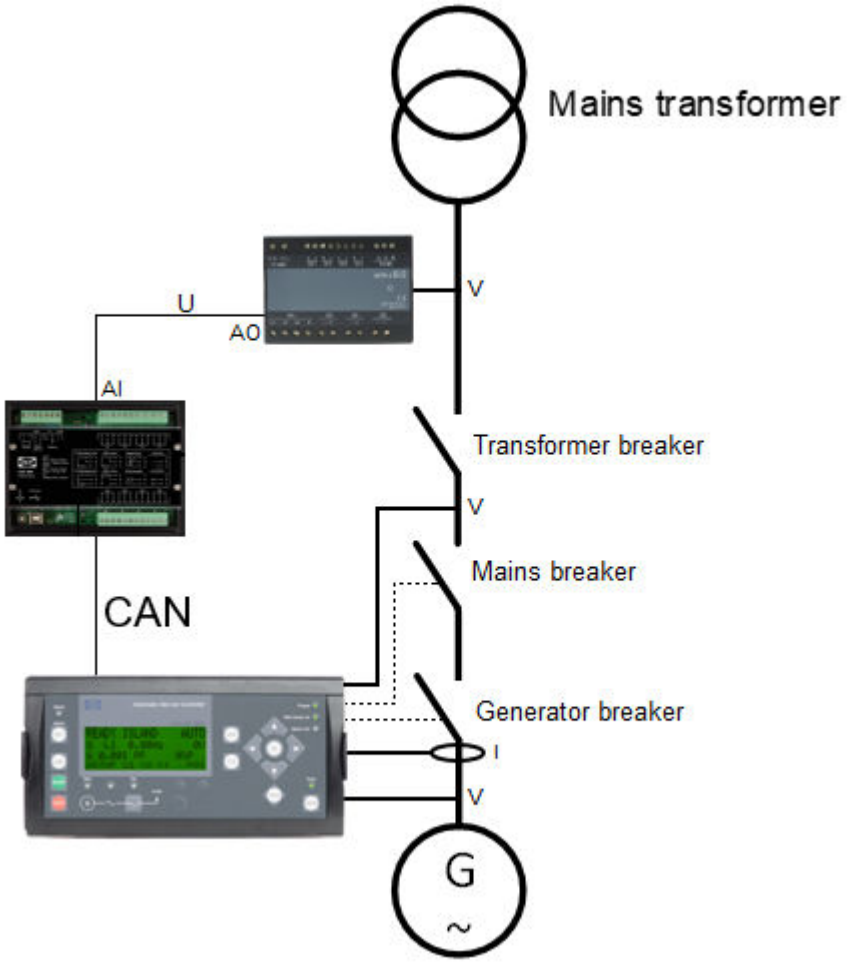


To activate the U function, use M-Logic and parameters.

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 ID1 terminal 20 input (that is, CIO 308 1.20).

Figure 2.3 Example for voltage measurement over CAN from the grid connection point



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

2.1.3 Using M-Logic for external AC measurements

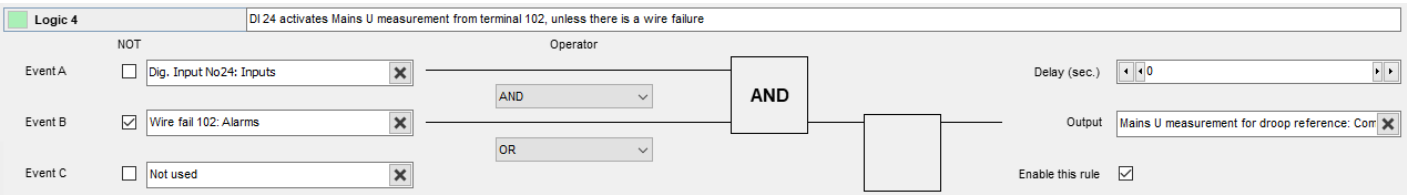
The controller uses the M-Logic configuration to link the analogue input to the requirement measurement. For safety, include the analogue input wire break monitoring in the M-Logic configuration.

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*.

Figure 2.4 Example of M-Logic for U measurement from a transducer

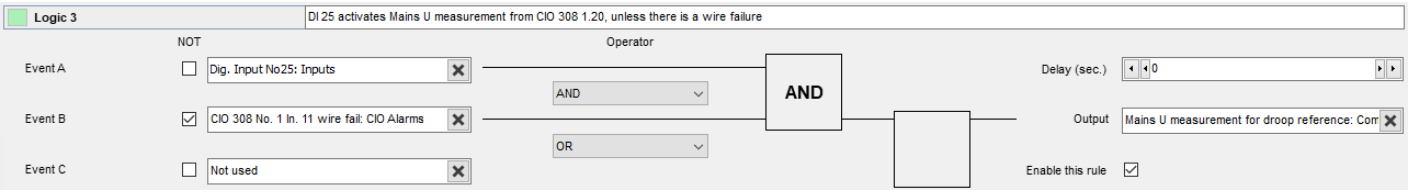


U measurement from a CIO

To activate the U measurement from a CIO:

- In *Mains U measure*, parameter 7283, select *CIO 308 1.20 (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 In. 20 wire fail*.
  - To activate the function, use *Output, Command, Mains U measurement for droop reference*.

Figure 2.5 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.

2.1.4 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.

Table 2.1 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)	Selection of the analogue input
Mains U Ext Nom	7284	400 V	100 to 25000 V	Nominal grid voltage for the transducer

Table 2.2 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) CIO308 1.14 (transducer)	Selection of the analogue input

Table 2.3 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)	Selection of the analogue input

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

2.3 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 Reference Handbook** for more information.

2.4 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*).

The reactive power set point can only be chosen if *Fixed Q* is chosen in *ContrSet cosphi or Q*, parameter 7055.

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)

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

2.5 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

2.6 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	Output for the *Power* set point. Select the AGC analogue output under *Transducer A* and/or *B*.

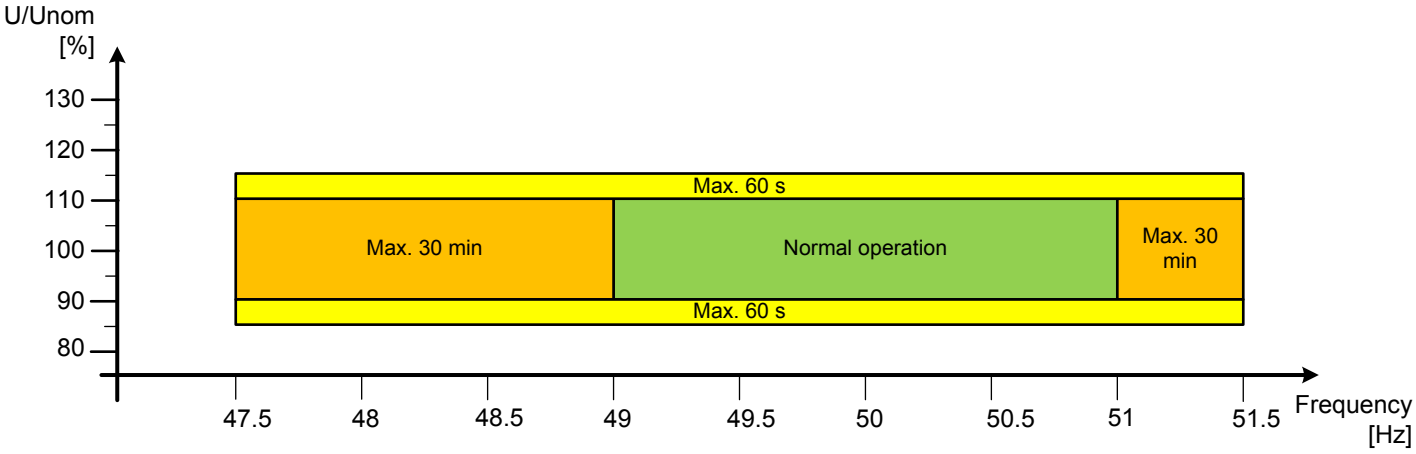
Text	Parameter	Default	Range	Description
			-10V-0-10V	
P ref Output max	5694	500 kW	0 to 20000 kW	The maximum of the range for the power set point.
P ref Output min	5695	0 kW	-9999 to 20000 kW	The minimum of the range for the power set point.
Q ref Output Type	5703	Disabled	Disabled 0-20mA 4-20mA 0-10V -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. Function descriptions

3.1 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).

Figure 3.1 Example for VDE quasi-stationary operation



3.1.1 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.)

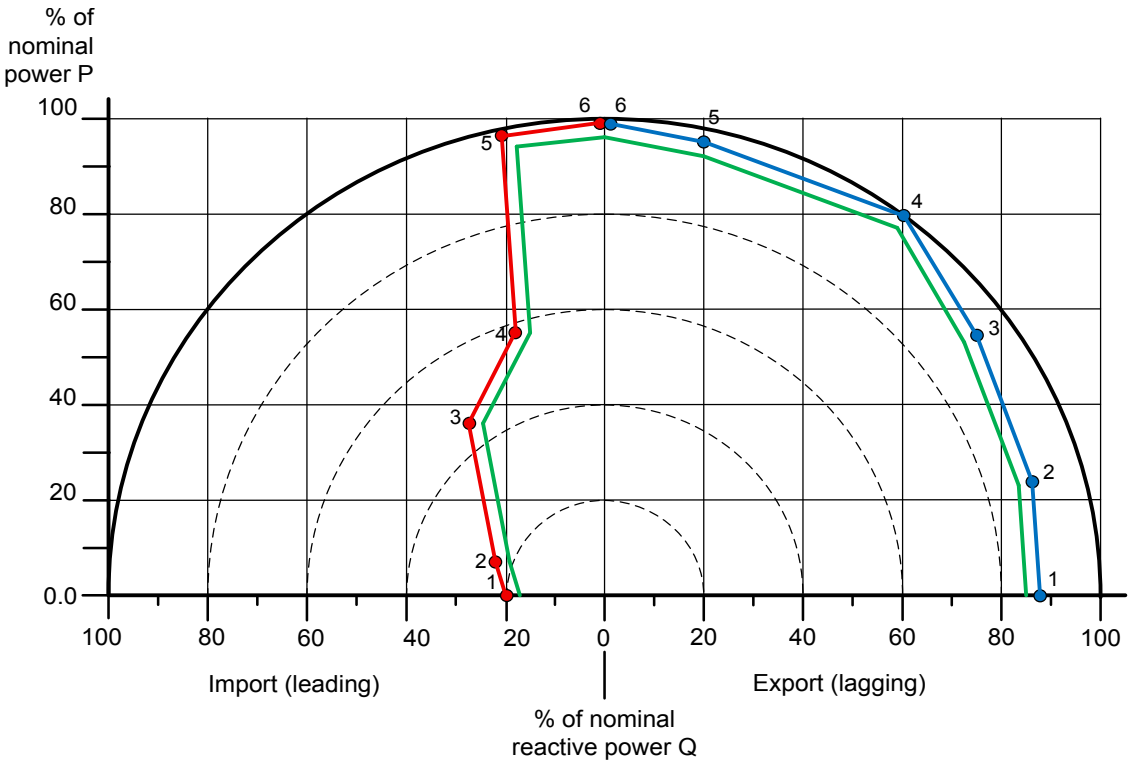
Text	Parameter	Default	Range
BB U> 3	1290	105 %, 50 s	100 to 130 %, 0 to 2000 s
BB U< 3	1320	97 %, 100 s	40 to 100 %, 0 to 2000 s
BB U< 4	1330	95 %, 50 s	40 to 100 %, 0 to 2000 s
BB f> 3	1370	105 %, 50 s	100 to 120 % (50 to 60 Hz), 0 to 2000 s
BB f< 3	1400	97 %, 100 s	80 to 100 % (40 to 50 Hz), 0 to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

3.2 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.

Figure 3.2 Example of generator capability curve with limiting



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

INFO
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.

If the set point for reactive power is outside the limiting curve, the controller stops reactive power (or cos phi) regulation. 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.

3.2.1 Parameters and settings

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

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

Table 3.1 *Set-point for Leading* (under-excited) (red curve)

Reactive power	Default	Active power	Default
G P dep Q<Q1 (1741)	20 %	G P dep P<P1 (1742)	0 %
G P dep Q<Q2 (1743)	22 %	G P dep P<P2 (1744)	7 %
G P dep Q<Q3 (1745)	27 %	G P dep P<P3 (1746)	12 %
G P dep Q<Q4 (1751)	18 %	G P dep P<P4 (1752)	55 %
G P dep Q<Q5 (1753)	21 %	G P dep P<P5 (1754)	97 %
G P dep Q<Q6 (1755)	1 %	G P dep P<P6 (1756)	99 %

Table 3.2 *Set-point for Lagging* (over-excited) (blue curve)

Reactive power	Default	Active power	Default
G P dep Q>Q1 (1771)	88 %	G P dep P>P1 (1772)	0 %
G P dep Q>Q2 (1773)	86 %	G P dep P>P2 (1774)	24 %
G P dep Q>Q3 (1775)	77 %	G P dep P>P3 (1776)	53 %
G P dep Q>Q4 (1781)	60 %	G P dep P>P4 (1782)	80 %
G P dep Q>Q5 (1783)	33 %	G P dep P>P5 (1784)	95 %
G P dep Q>Q6 (1785)	1 %	G P dep P>P6 (1786)	99 %

Table 3.3 *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	X	Depending on which regulator is active, the controller limits the regulation. For cos phi, the controller uses settings 7171 and 7173 (under *Advanced Protection*, *Droop curve 2*, *Cosphi curve*). For reactive power, the controller uses settings 7161 and 7162 (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.

Table 3.4 *AVR lim. setpoint*, parameter 2812 (green curve)

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 *Q curve* the controller uses.

Table 3.5 *Q curve* for *10-2500V*

Setting	Default for 10-2500V	Range for 10-2500V	Description
S nominal(import) (1766)	60 kVA	1 to 3200 kVA	Nominal apparent power import
S nominal(export) (1796)	60 kVA	1 to 3200 kVA	Nominal apparent power export

3.3 Reactive power regulation

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

Table 3.6 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)*.

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 ...*).

Figure 3.3 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.

Table 3.7 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.

3.3.1 Default reactive power regulation

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

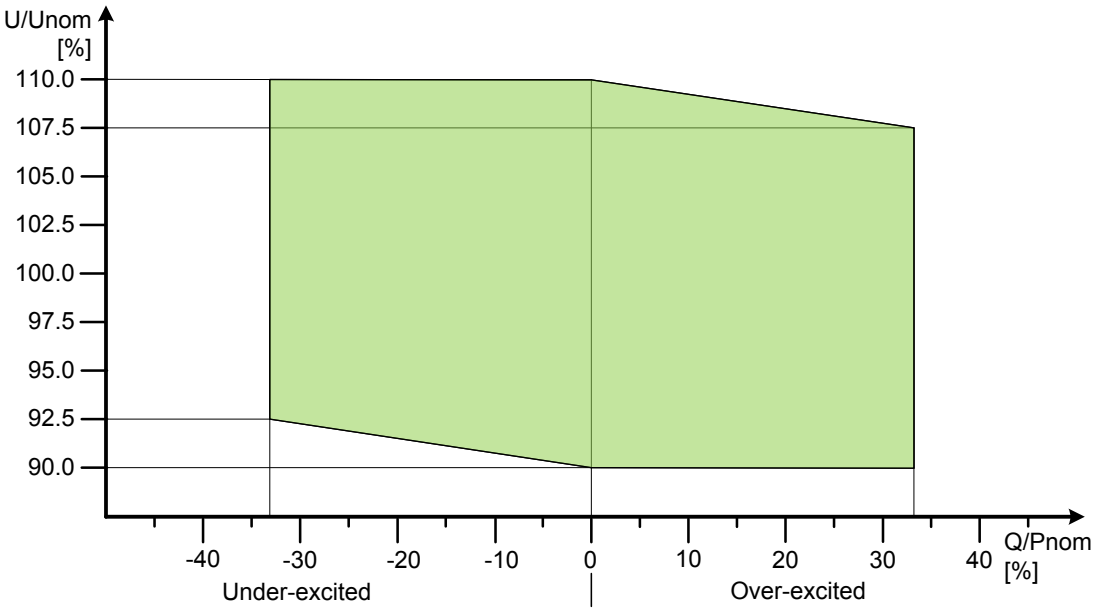
The controller uses the curves under *Advanced Protection, Droop curve 2*.

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. 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). Alternatively, you can use *M-Logic, Output, Grid support, Droop curve 2: Activate cosphi reference*. Superior = Set point from AGC-4 Mains in G5 applications (that is, the AGC-4 Main parameter 7052 or 7054) Fixed Q = Reactive power internal set point (that is, parameter 7054). Alternatively, you can use *M-Logic, Output, Grid support, Droop curve 2: Activate Q reference*.

3.3.2 Grid voltage-dependent reactive power limiting

If the function is activated, the controller uses grid-voltage dependent reactive power limitation when one of the four types of reactive power regulation is activated (that is, Type 1, 2, 3 or 4). 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.

Figure 3.4 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.

3.3.3 Settings for grid voltage-dependent reactive power limiting

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

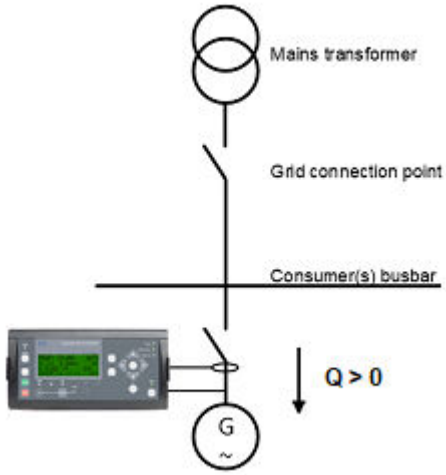
Setting	Default	Range	Description
Q-Limitation at U/Uc < 0.925 (under-excited)	OFF	OFF	The function* does not limit the reactive power during low grid voltage.
		ON	The function* limits the reactive power during low grid voltage.
Q-Limitation at U/Uc > 1.075 (over-excited)	OFF	OFF	The function* does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

3.3.4 Reactive power direction for variants A, B and C

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

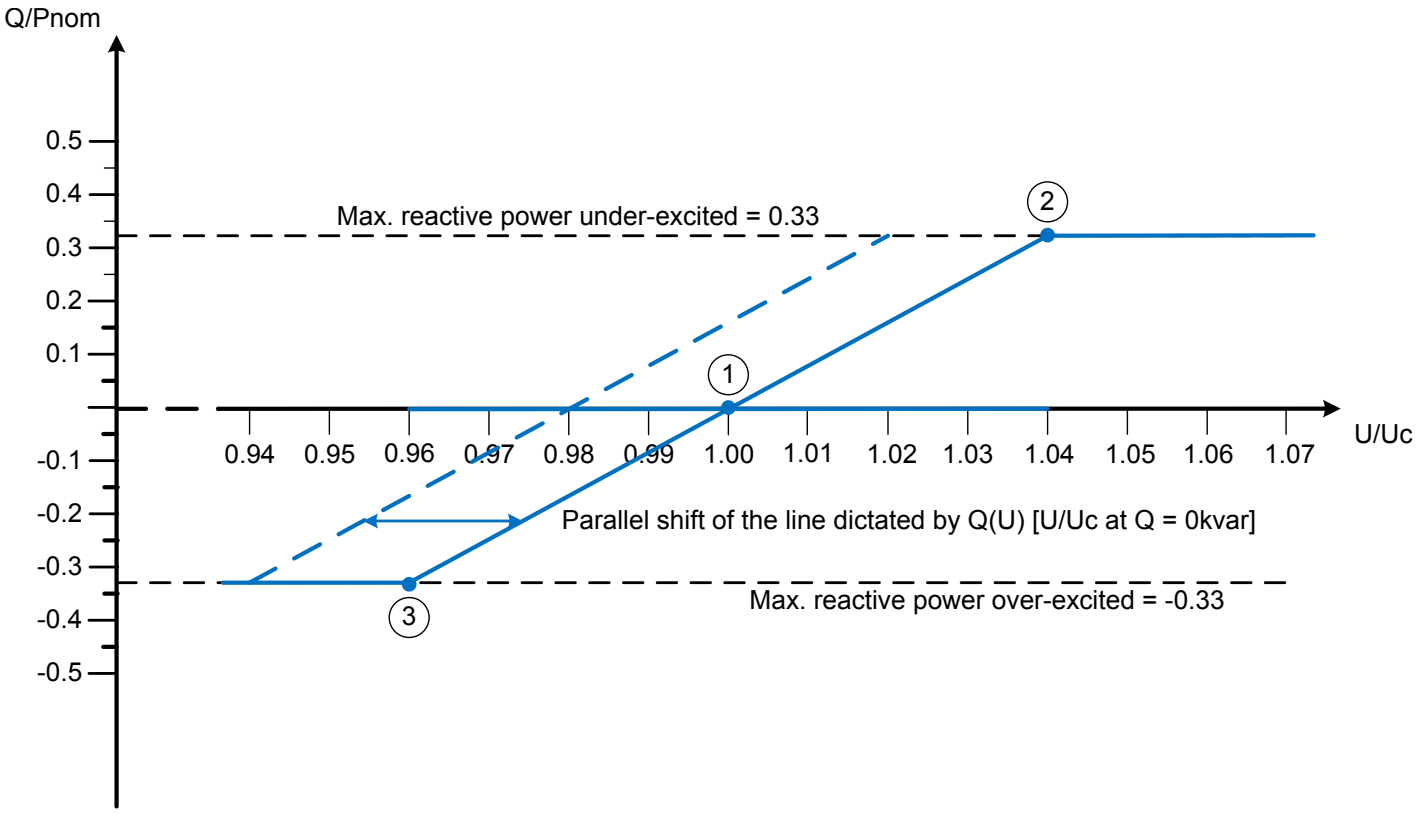
Figure 3.5 Positive reactive power to the genset



3.3.5 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.

Figure 3.6 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.

Figure 3.7 M-Logic example: Use fixed cos phi regulation if the input fails

3.3.6 Settings for Type 1: Variant A

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

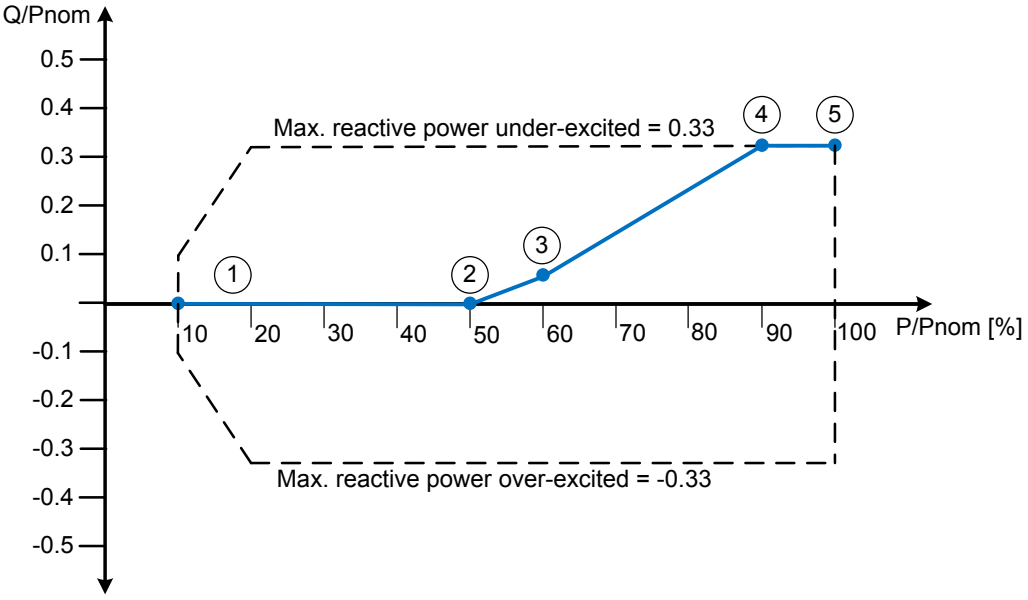
Setting	Default	Range	Description
Q(U) deadband	0 %	0 to 50 %	Voltage deadband
Q(U) [U/Uc at Q = 0kvar]	1	0.5 to 1.5	Reference voltage at Q= 0 kvar
Q(U) [U/Uc at Q max]	1.04	0.5 to 1.5	Maximum voltage at maximum Q
Q(U) [Q/Pnom max]	0.33	0 to 0.4	Maximum Q during over-voltage
Q(U) [Q/Pnom min]	-0.33	-0.4 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.

3.3.7 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.

Figure 3.8 Example for *Type 2: Variant B) Q(P) curve*



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

3.3.8 Settings for Type 2: Variant B

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

Table 3.8 Curve settings

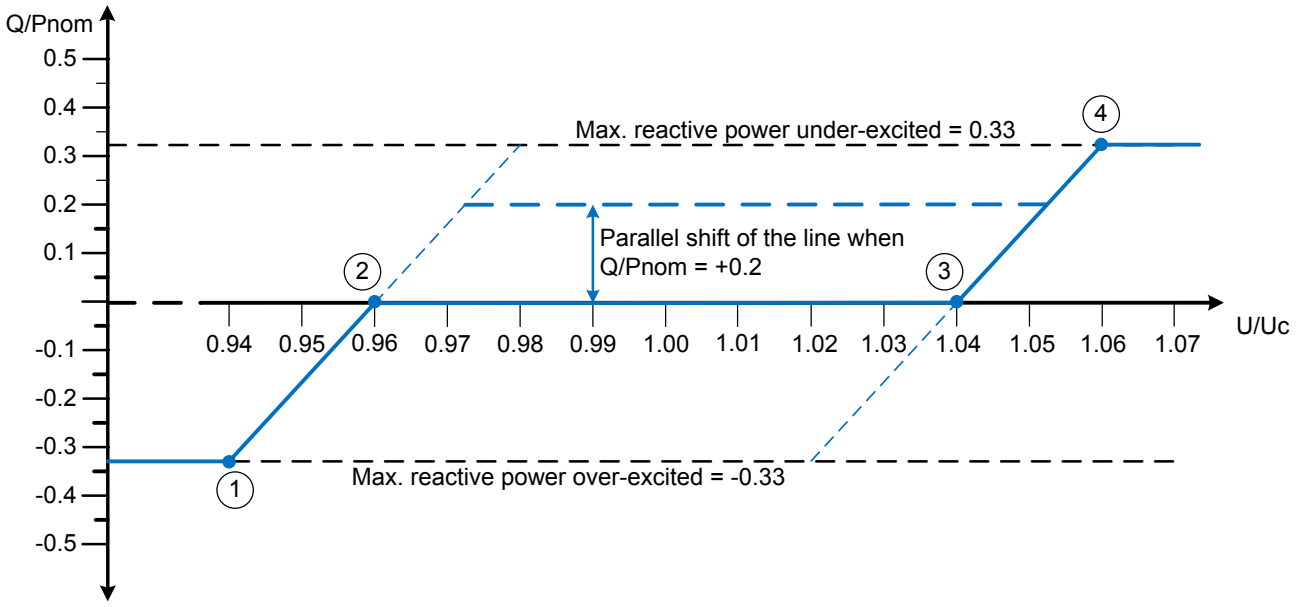
Active power	Default	Reactive power	Default
[%P/Pnom] set-point 1	10	[Q/Pnom] set-point 1	0
[%P/Pnom] set-point 2	50	[Q/Pnom] set-point 2	0
[%P/Pnom] set-point 3	60	[Q/Pnom] set-point 3	0.05
[%P/Pnom] set-point 4	90	[Q/Pnom] set-point 4	0.33
[%P/Pnom] set-point 5	100	[Q/Pnom] set-point 5	0.33
[%P/Pnom]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

3.3.9 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.

Figure 3.9 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**.

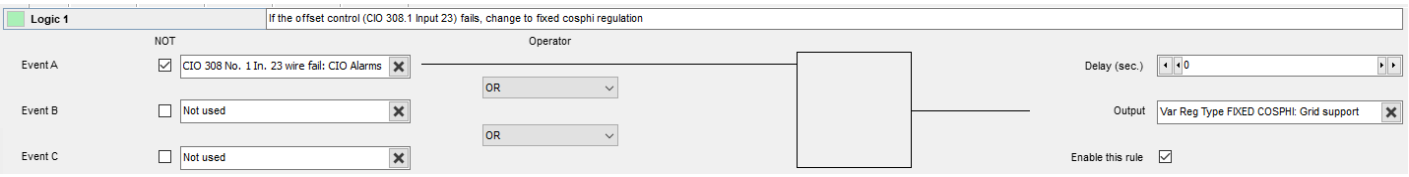
The analogue signal for offset control must come from CIO 308 input 1.23.

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.

Figure 3.10 M-Logic example: Use fixed cos phi regulation if the input fails



3.3.10 Settings for Type 3: Variant C

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

Table 3.9 Curve settings

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

Table 3.10 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.

3.3.11 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**.

3.3.12 Settings for Type 4: Variant D

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

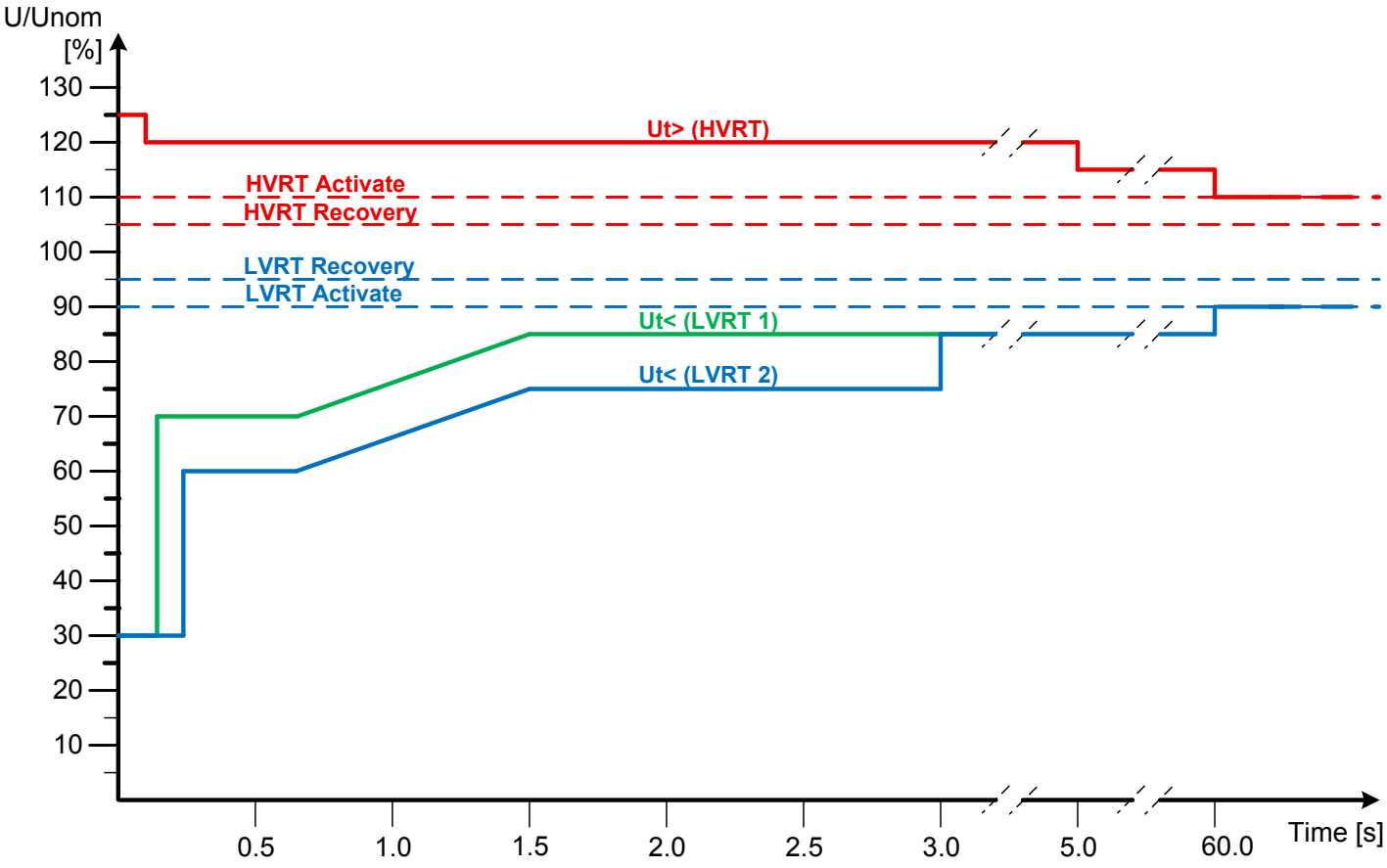
Setting	Default	Range	Description
Cosphi set-point	1	0.900 to 1.000	Cos phi set point with 3 decimals
Cosphi direction	Inductive (GEN)	Inductive (GEN) Capacitive (GEN)	Cos phi inductive or capacitive
Cosphi offset	0	-0.1 to 0.1	Offset for the set point
Cosphi Ext control	OFF	OFF ON	External control of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

3.4 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.

Figure 3.11 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.

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.

3.4.1 Settings for FRT curves

FRT setup settings

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

Table 3.11 LVRT and HVRT trip type

Setting	Default	Range	Description
LVRT 1 trip type select LVRT 2 trip type select HVRT 1 trip type select	Any phase-phase fault	Any phase-phase fault 1 phase-phase fault 2 phase-phase fault 3 phase-phase fault 1 phase-neutral fault 2 phase-neutral fault 3 phase-neutral fault Any phase-neutral fault	The measurement type for the fault ride through curve

Table 3.12 Suspend GOV and AVR

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 reg	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*.

Table 3.13 LVRT 1 curve

Voltage	Default*	Timer	Default**
Ut< U SP1 (1631)	30 %	Ut< t SP1 (1632)	0 s
Ut< U SP2 (1633)	30 %	Ut< t SP2 (1634)	0.15 s
Ut< U SP3 (1635)	70 %	Ut< t SP3 (1636)	0.15 s
Ut< U SP4 (1641)	70 %	Ut< t SP4 (1642)	0.7 s
Ut< U SP5 (1643)	85 %	Ut< t SP5 (1644)	1.5 s
Ut< U SP6 (1645)	85 %	Ut< t SP6 (1646)	60 s
Ut< U SP7 (New)	90 %	Ut< t SP7 (New)	60 s
Ut< U SP8 (New)	90 %	Ut< t SP8 (New)	70 s
Ut< U SP9 (New)	90 %	Ut< t SP9 (New)	70 s
Ut< U SP10 (New)	90 %	Ut< t SP10 (New)	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*.

Table 3.14 LVRT 2 curve

Voltage	Default*	Timer	Default**
Ut< U SP1 (1671)	30 %	Ut< t SP1 (1672)	0 s
Ut< U SP2 (1673)	30 %	Ut< t SP2 (1674)	0.22 s
Ut< U SP3 (1675)	60 %	Ut< t SP3 (1676)	0.22 s
Ut< U SP4 (1681)	60 %	Ut< t SP4 (1682)	0.7 s
Ut< U SP5 (1683)	75 %	Ut< t SP5 (1684)	1.5 s
Ut< U SP6 (1685)	75 %	Ut< t SP6 (1686)	3 s
Ut< U SP7 (New)	85 %	Ut< t SP7 (New)	3 s
Ut< U SP8 (New)	85 %	Ut< t SP8 (New)	60 s
Ut< U SP9 (New)	90 %	Ut< t SP9 (New)	60 s
Ut< U SP10 (New)	90 %	Ut< t SP10 (New)	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*.

Table 3.15 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

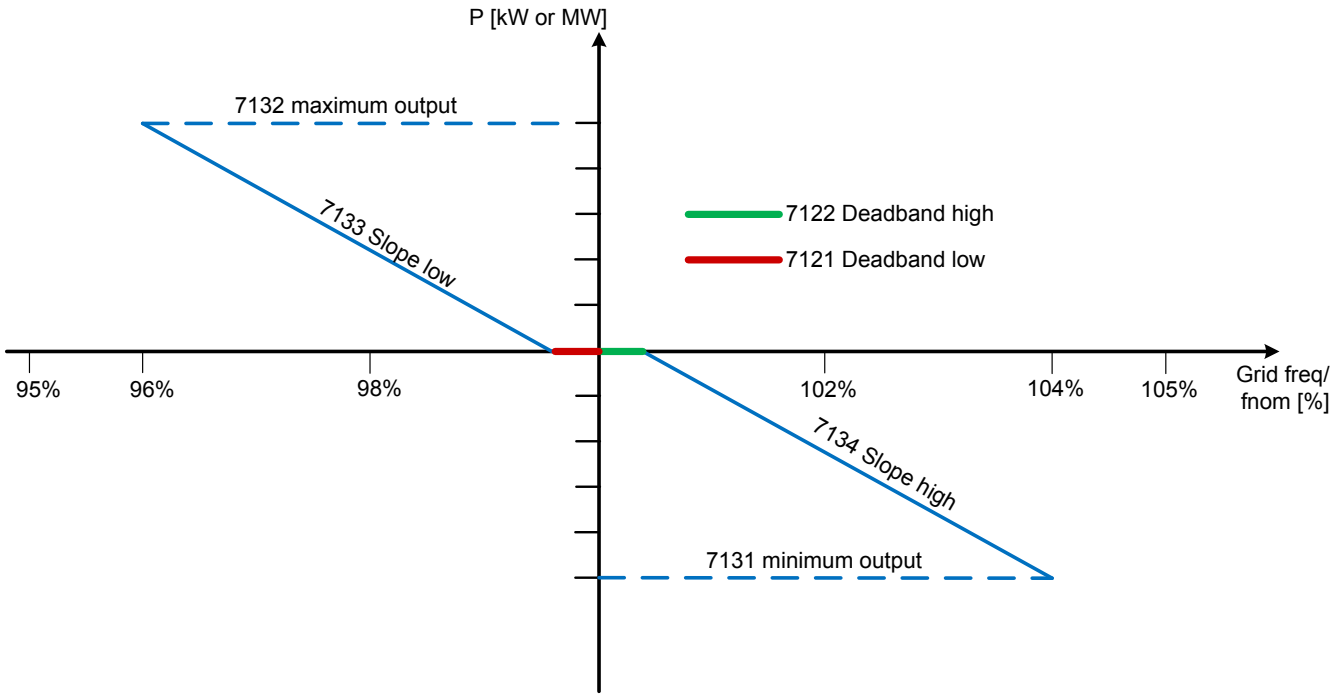
Configure these parameters in the parameter list.

Table 3.16 Parameters

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)

3.5 Over- and under-frequency-dependent active power

During a critical grid condition (+/- 200 mHz) 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).

INFO
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 Reference 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 gradient can be based on absolute value or %.

3.5.1 Settings and parameters

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

Table 3.17 Basic

Setting	Default	Range	Description
Curve select (7141)	P(X1)	P(X1) N.A.	P(X1): The X-Axis is power. N.A.: Do not select this.
Curve select (7142)	f	f N.A.	f: The Y-Axis is frequency. N.A.: Do not select this.
Curve enable (7143)	Disable	Disable Enable	Function ON/OFF selection
Recovery delay (new)	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	Selection of actual P or nominal P is to be used as base for the calculations. See the example.

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 <f (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 <f (7133)*.

Table 3.18 Curve control

Setting	Default	Range	Description
Deadband <f (7121)	0.4 %	0 to 99.99 %	Deadband for grid under-frequency
Deadband >f (7122)	0.4 %	0 to 99.99 %	Deadband for grid over-frequency
Hysteresis <f (7123)	99.89 %	0 to 99.99 %	Hysteresis for grid under-frequency
Hysteresis >f (7124)	99.89 %	0 to 99.99 %	Hysteresis for grid over-frequency

Scaling, parameter 9030, determines which *P curve* the controller uses.

Table 3.19 *P curve* for *10-2500V*

Setting	Default for 10-2500V	Range for 10-2500V	Description
P min (7131)	20 kW	0 to 2000 kW	Limit, minimum active power
P max (7132)	48 kW	0 to 2000 kW	Limit maximum active power
Slope <f (7133)	5 kW/%	-2000 to 2000 kW/%	Gradient during grid under-frequency. See the example.
Slope >f (7134)	-5 kW/%	-2000 to 2000 kW/%	Gradient during grid over-frequency

Table 3.20 Slope calculation

Setting	Default	Range	Description
Droop slope calculation method	Absolute	Absolute Percentage	Calculation method for the gradient.
Slope <f	5 % power/% f		Gradient during grid under-frequency
Slope >f	-5 % power/% f		Gradient during grid over-frequency

Configure these parameters in the parameter list.

Table 3.21 Parameters

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.
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.
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).

3.6 Q-U protection

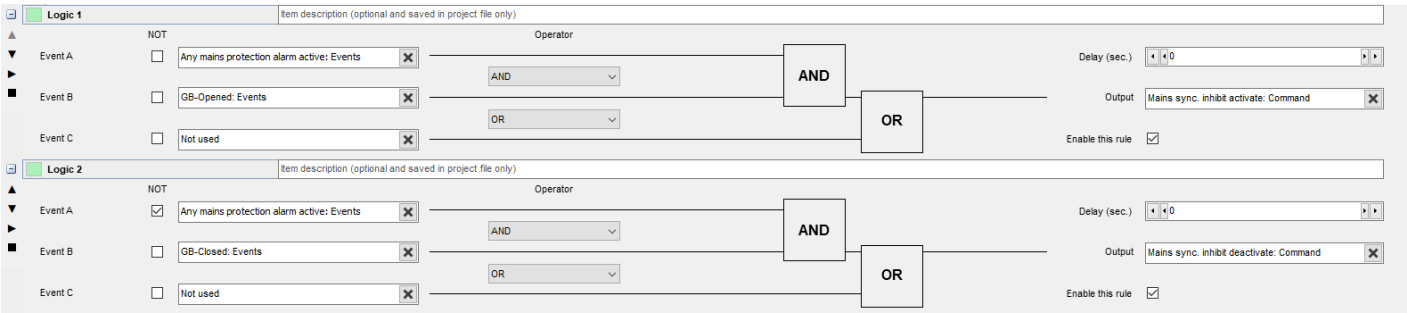
See the **Option A1 Mains protection package**.

3.7 Connection after trip caused by grid protections

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

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

Figure 3.12 Example of M-Logic for implementation



3.8 Q ramp

A ramp function for reactive power regulation can be activated. This ramp is used when the controller increases or decreases the reactive power. Configure these parameters in the parameter list.

Table 3.22 Parameters

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	ON OFF	Activation/deactivation of the function

INFO
There is no ramp for cos phi regulation.

3.9 df/dt (ROCOF)

The **Option A1 Mains protection package** has a detailed description of the df/dt function.

Standard df/dt

df/dt type (parameter 1205): Select *Standard df/dt*.

For Option A10, *df/dt (ROCOF), Timer* (menu 1420) delays the df/dt activation. The range is 0 to 3 s, and the default is 0 s.

INFO
For standard df/dt, the parameters are configured in *df/dt ROCOF* (menu 1420 and parameter 1422). Menu 1670 is not visible.

G99 df/dt

df/dt type (parameter 1205): Select *G99 df/dt*.

INFO
For G99 df/dt, the parameters are configured in *df/dt ROCOF G99* (menu 1670 and parameter 1672). Menu 1420 is not visible.