AGC-4 Mk II, AGC-4

4189341263D

Voltage, var, or cos phi regulation

Option D1

Improve Tomorrow

1. Description of option

2. Function description

1. Description of option

1.1 Option D1

Option D1 is a combined software and hardware option. The specific hardware selection depends on the required interfacing to the automatic voltage regulator (AVR).

Functions

- Automatic regulation type selection
  - Option T2 (Digital AVR) is required for automatic voltage regulation with DEIF's Digital AVR's DVC 310, DVC 550 and/or Nidec's D510.
  - Option T3 (NIDEC D550 support) is required for Nidec's Digital AVR D550.
  - For more information, see DEIF's **DVC 550 Designer's handbook**.
- Voltage-dependent cos phi/Q control (y2(x2) droop)
- Power-dependent cos phi/Q control (y2(x2) droop)

1.2 ANSI numbers

Function	ANSI no.
Voltage synchronisation matching	25, 90
Constant voltage control for stand-alone generator	90
Constant reactive power control for paralleling generator	90
Constant cos phi control for paralleling generator	90
Reactive power load sharing for paralleling with other generators	90

1.3 Software version

This document is based on the AGC-4 Mk II software version 6.00 and the AGC-4 software version 4.79. Option D1 is included in the standard AGC-4 Mk II.

1.4 Parameters

The relevant parameters are included in the function descriptions. For more information, see the **Parameter list**.

There are also relevant settings under *Advanced Protection* in the utility software.

1.5 Warnings, legal information and safety

1.5.1 Warnings and notes

Throughout this document, a number of warnings and notes with helpful user information will be presented. To ensure that these are noticed, they will be highlighted as follows in order to separate them from the general text.

Warnings

DANGER!

This shows dangerous situations.

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

Notes

NOTE Notes provide general information, which will be helpful for the reader to bear in mind.

1.5.2 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.

1.5.3 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.

NOTE 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.

2. Function description

2.1 Regulation type (voltage/var/cos phi)

The controller uses one of the following to select the regulation type:

1. The generator breaker (GB) and mains breaker (MB) states
2. Digital inputs

2.1.1 Regulation type based on breaker states

Regulation type	GB open	GB closed, MB open	GB closed, MB closed
Fixed voltage	X	X	
var sharing		X	
Fixed cos phi			X

INFO
var sharing is a mix of fixed voltage and var sharing regulation, and requires option G3 or G5. (If hardware option M12 is selected, then option G3 is included in the standard AGC-4 Mk II.) The reactive load is shared equally between the gensets, AND the voltage is maintained at the nominal value.

2.1.2 Regulation type based on digital inputs

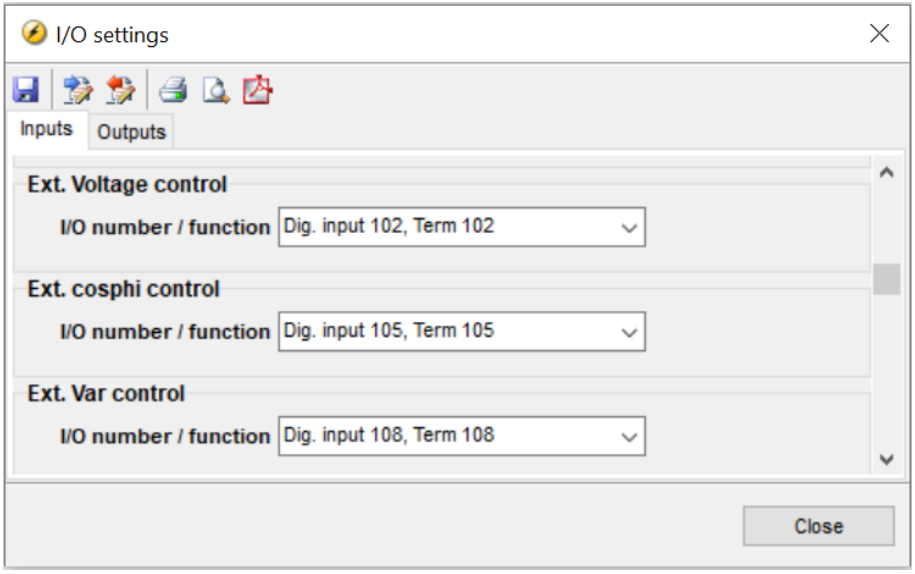
You can use digital inputs to select the regulation type. This allows the controller to use external set points, for example, from an external potentiometer or a PLC.

Regulation type	Comment	Analogue input relationship to external set point
Fixed voltage	Stand-alone generator or GB opened	+/-10 V DC input ~ nominal voltage +/-10 %
Fixed var	Fixed reactive power	0 to 10 V DC input ~ 0 to 100 % reactive power*
Fixed cos phi	Fixed cos phi	-10 to 0 to 10 V DC input ~ 0.6 capacitive to 1.0 to 0.6 inductive cos phi

*Note: 0 to 100 % relates to the nominal power of the generator.

Configuring the inputs

To use a digital input to activate an external set point, configure the digital input function *Ext. Voltage control*, *Ext. cosphi control* and/or *Ext. Var control* using the PC utility software (USW), as shown below.



INFO
It is not necessary to configure all three functions.

CIO external set points

The external set point(s) can also come from a CIO. The regulation type is activated using M-Logic. A digital input is not required.

More information
See **Option A10** for more information.

2.2 AVR regulation failure

The AVR regulation failure alarm is configured in menu 2680. When the regulation is activated but the set point cannot be reached within the configured time, the alarm is activated. The deviation is calculated in percent.

Example

U_{ACTUAL} = 400 V AC

$U_{NOMINAL}$ = 440 V AC

Difference in percent: (440 - 400) / 440 * 100 = 9.1 %

If the AVR regulation failure alarm set point is lower than 9.1 %, the alarm is activated.

INFO
Change the alarm set point to 100 % to deactivate the alarm.

2.3 Manual AVR control

More information
See **Manual governor and AVR control** in the **Designer's Handbook** for more information.

2.4 Voltage-dependent cos phi/Q control (y2(x2) droop)

2.4.1 Voltage support

The voltage support function is also called *Voltage-dependent cos phi/Q control (y2(x2) droop)* and *Droop curve 2*. The function changes the cos phi or the kvar set point of the generators if the mains voltage changes beyond certain values in order to support the mains voltage. The idea is that if the mains voltage drops, the generators increase their excitation and support the mains voltage. If the mains voltage increases, the excitation of the DGs decreases in order to produce less reactive power (var).

This function is used when the generators are paralleling to the mains and running *Fixed power*, *Mains power export* or *Peak shaving*. It cannot be used in island applications.

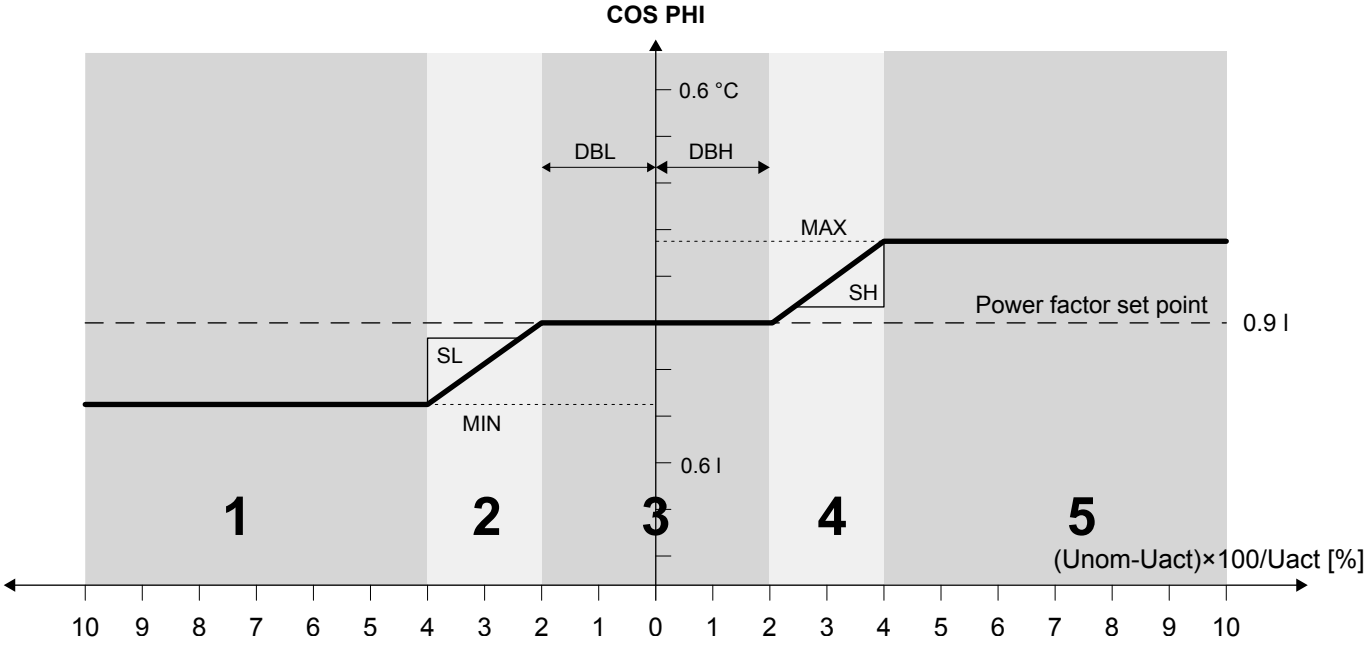
Voltage support principle

In a system that is parallel to mains, voltage-dependent cos phi control provides dynamic cos phi control, based on the mains voltage. The purpose is to support the mains voltage locally behind a transformer by minimising the reactive current flow to the mains.

The function is made with only one active regulator on the generator, and a variable curve defining the set point to the regulator. This ensures that there are no hunting problems with two to three regulators in cascade.

The diagram below shows the principle. The dotted line illustrates the x-axis (voltage deviation, *x2*), and the vertical line (cos phi, *y2*) is the y-axis. The cos phi set point is 0.90 in this example.

INFO
When the function is activated, the controller uses the actual power factor at that moment as the reference for the droop function. The controller uses this value for as long as the function is active.



The diagram has the following zones:

Zone	Description	Voltage	Advanced protection, Droop curve 2
1	Minimum cos phi	90 to 96 %	Cosphi min set (7171) [Pf] Cosphi min dir. (7172)
2	Decreasing slope	96 to 98 %	Cosphi Slope low (7175)
3	Deadband voltage (cos phi = 0.9 I)	98 to 102 %	Deadband low (7151) [%]

Zone	Description	Voltage	Advanced protection, Droop curve 2
			Deadband high (7152) [%]
4	Increasing slope	102 to 104 %	Cosphi Slope high (7176)
5	Maximum cos phi	104 to 110 %	Cosphi max set (7173) [Pf] Cosphi max. dir (7174)

INFO
The voltage-dependent droop curve is configured in **Advanced protections, Droop curve 2**. If full grid code rule compliance is required, you must add Option A10. For more information, see the **Option A10** documentation.

Parameters and settings

These parameters and settings are used by the voltage support function.

Name	Parameter	Default	Range
Contr. sett. cosphi	7052	0.9	0.1 to 1
Contr. sett. cosphi	7053	Inductive	Inductive, Capacitive

Advanced protection, Droop curve 2	Default	Range	Description
Deadband low (7151)	2.00 %	0 to 99.99 %	Deadband low, in percentage of nominal voltage.
Deadband high (7152)	2.00 %	0 to 99.99 %	Deadband high in percentage of nominal voltage.
Hysteresis low (7153)	2.1 %	0 to 99.99 %	Hysteresis low in percentage of nominal voltage. If HYSL is set above DBL, the hysteresis low is disabled. Hysteresis is not shown in the principle diagram.
Hysteresis high (7154)	2.1 %	0 to 99.99 %	Hysteresis high in percentage of nominal voltage. If HYSH is set above DBH, the hysteresis high is disabled. Hysteresis is not shown in the principle diagram.
Cosphi min set (7171)	0.8 Pf	0 to 1 Pf	Minimum output of droop handling, in combination with 7172.
Cosphi min dir. (7172)	Inductive (GEN)	Inductive (GEN), Capacitive (GEN)*	Direction for minimum output of droop handling.
Cosphi max set (7173)	1.00 Pf		Maximum output of droop handling, in combination with 7174.
Cosphi max dir. (7174)	Inductive (GEN)	Inductive (GEN), Capacitive (GEN)*	Direction for maximum output of droop handling.
Cosphi Slope low (7175)	-0.005 %/unit	-1 to 1 %/unit	Slope low. The setting determines the increase/ decrease of the cos phi reference per percent the actual voltage drops below nominal voltage.
Cosphi Slope high (7176)	0.005 %/unit	-1 to 1 %/unit	Slope high. The setting determines the increase/ decrease of the cos phi reference per percent the actual voltage rises above nominal voltage. For the ramp slope calculation, *unit* is V AC. For example, 10 %/u means 10 % increase of cos phi per volt AC deviation.
Curve select (7181)	Cosphi(X2)	Cosphi(X2), Q(X2)**	Output type for droop curve 2. Choose cos phi or reactive power.

Advanced protection, Droop curve 2	Default	Range	Description
Curve select (7182)	U	U, P	Input type for curve 2. Choose U for voltage-dependent cos phi control.
Curve enable (7183)	Disable	Disable, Enable	**Enable**: The selected settings are used for droop curve 2. **Disable**: Droop curve 2 is ignored.

*Note: The settings of *Cosphi min set* and *Cosphi max set* can be reversed, meaning that the reactive power will move in the inductive direction with increasing voltage. See **Capacitative range** below.

Note: If you select reactive power control (Q(X2)**) in *Curve select (7181)*, the function is similar to Cosphi (X2).

Deadband

The ramp has a configurable deadband that can be used with reference to the nominal voltage of the mains to deactivate the ramp functionality. This is to have a normal operation band where a normal voltage fluctuation does not create disturbance on the mains. If the deadband is set to 0, the deadband is removed and the ramp will be active at any time.

When the mains measurement is outside the deadband, the voltage deviation is taken into consideration and a new cos phi value is calculated. The cos phi regulator of the generator will then adjust the cos phi and thereby change the var import/ export of the plant. The calculation is based on the fixed cos phi set point value (parameter 7052).

Hysteresis

A hysteresis can be used. The cos phi set point is kept at the drooped value as the voltage returns towards nominal until the hysteresis is reached.

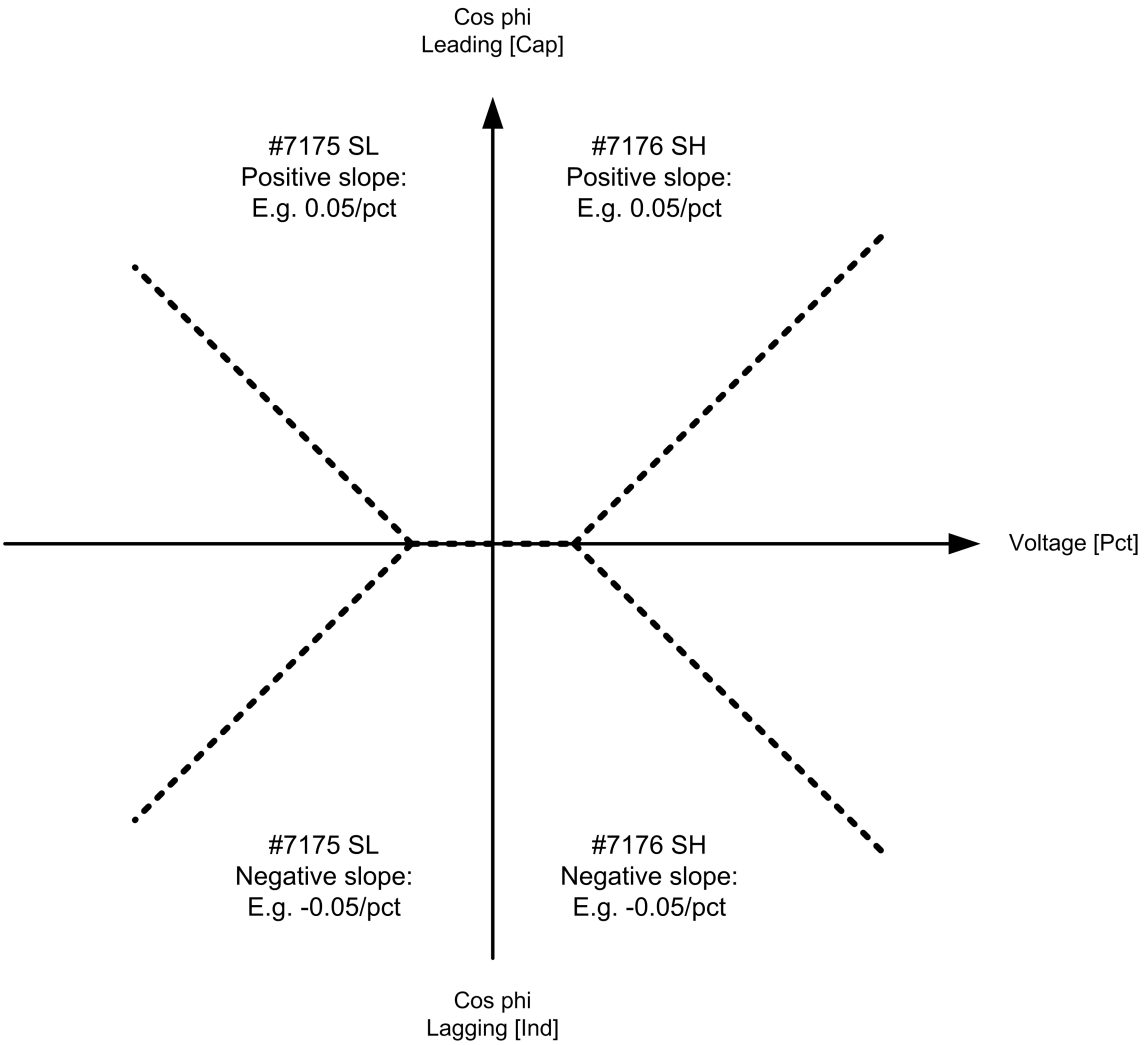
For example, for a 1 % hysteresis set point and a 0.90 cos phi set point, if the voltage drops, the cos phi set point follows the slope to, for example, 0.82. When the voltage recovers, the cos phi set point stays at 0.82 until the voltage reaches 99 %. After that, the cos phi set point moves back to 0.90.

INFO
To deactivate hysteresis, configure the hysteresis with a value larger than the deadband.

Slope

Two settings for the slope are available, namely the "Slope Low" (SL) and the "Slope High" (SH). The name of the settings refers to the voltage being lower or higher than the nominal voltage (100 %). The slope is adjusted with a sign (positive or negative). The positive sign is the leading (capacitive) range, and the negative sign is the lagging (inductive) range.

This coordinate system shows when to use a positive or negative sign.



When the requirement of the voltage support is known, it can be decided whether the slope is positive or negative. This is best illustrated with an example:

If the voltage drops compared to the nominal voltage, the generator is requested to increase the excitation and thereby the produced kvars (in order to support the grid). If the set point (SP) is 1.00 and a deadband setting is 1 %, the cos phi set point decreases from 1.00 to 0.90 (SL setting is -0.05). See the calculation and diagram below.

$SP_{NEW\ 388\ V\ AC}$ = 1.00 - (((396 - 388) / 400) * 100) × 0.05 = 0.90 (simplified)

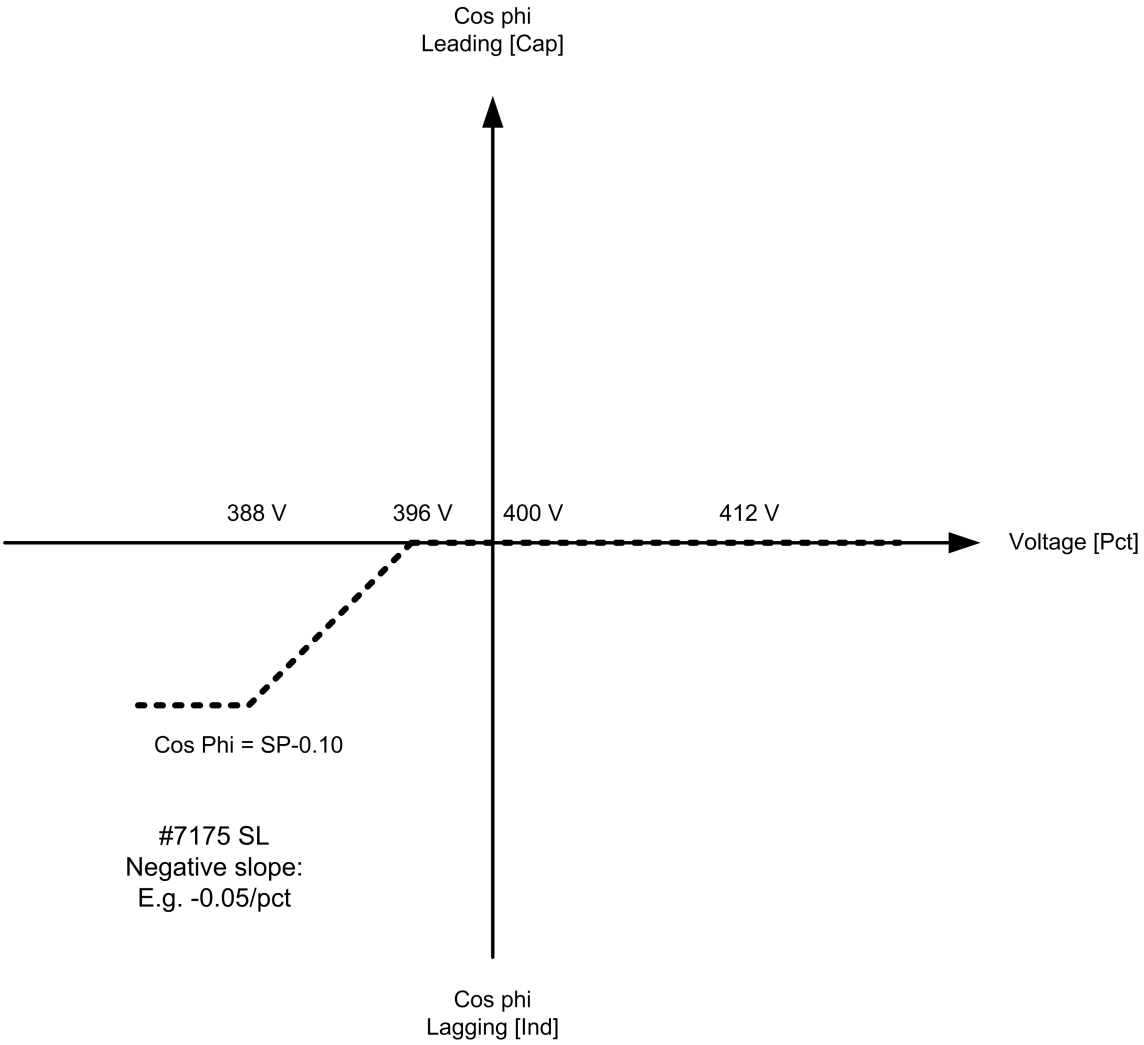
Slope calculation example

Values used in this example:

- UNormal = 400 V
- 7052 Cosphi set point = 1
- Deadband low = 2 %
- Deadband high = 3 %
- Umax: 448 V = Cosphi 0.95C
- Umin: 376 V = Cosphi 0.95I

Slope low calculation
Delta U high = Umax - (UNormal + Deadband low) = 448 V - 408 V = 40 V
Delta U high / UNormal = 40 V / 400 V = 0.1 = 10 %
Delta Cosphi low = 1 - 0.95 = 0.05
Slope low = 0.05 / 10 % = 0.005

	Slope high calculation Delta U low = Umin - (UNormal - Deadband low) = 376 V - 388 V = -12 V Delta U low / UNormal = -12 V / 400 V = -0.03 = -3 % Delta Cosphi high = 1 - 0.95 = 0.05 Slope high = 0.05 / -3 % = -0.017



Capacitive range

Even though the function is normally used to support a low mains voltage, it is possible to adjust the function to decrease the excitation if the voltage increases (leading cos phi).

CAUTION
To avoid pole slip and damage of the generators, make sure that the capability curve of the generators is respected and that the generators are not running under-excited or without excitation.

2.4.2 Example of voltage-dependent cos phi control

Parameters and settings for the example

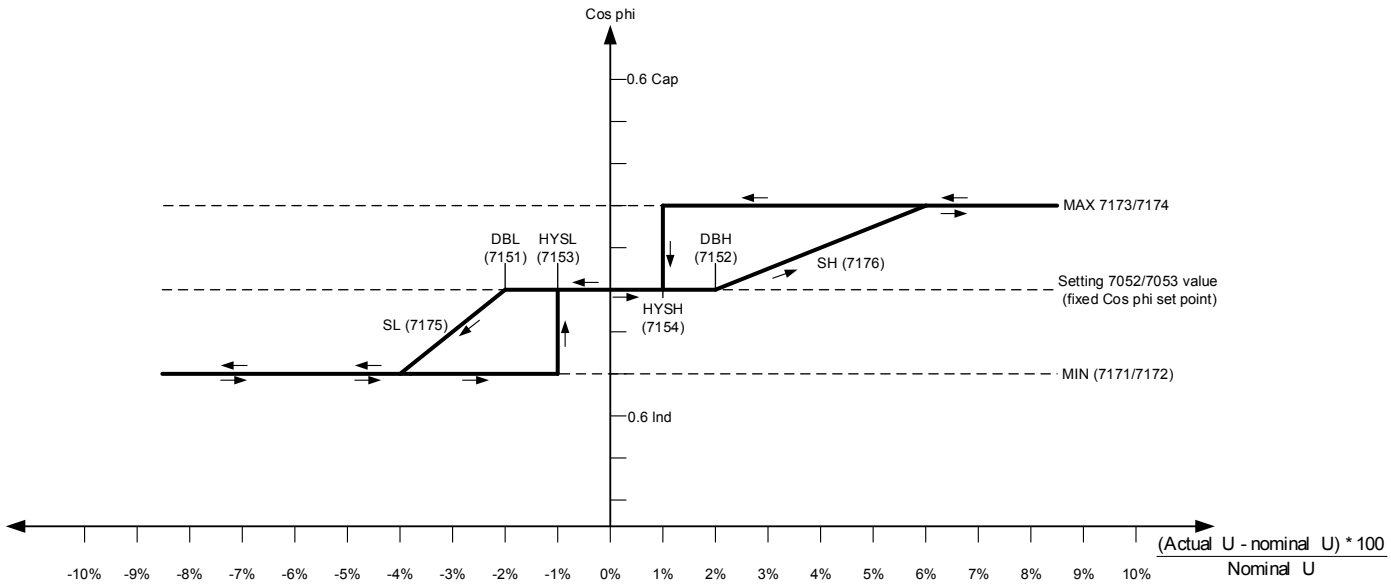
Name	Parameter	Settings
Contr. sett. cosphi	7052	0.9
Contr. sett. cosphi	7053	Inductive

Advanced protection, Droop curve 2	Setting
Deadband low (7151)	2.00 %
Deadband high (7152)	2.00 %
Hysteresis low (7153)	1.0 %
Hysteresis high (7154)	1.0 %
Cosphi min set (7171)	0.7 Pf
Cosphi min dir. (7172)	Inductive (GEN)
Cosphi max set (7173)	0.9 Pf
Cosphi max dir. (7174)	Capacitive (GEN)
Cosphi Slope low (7175)	-0.1 %/unit
Cosphi Slope high (7176)	0.05 %/unit
Curve select (7181)	Cosphi(X2)
Curve select (7182)	U
Curve enable (7183)	Enable

Scenario

With a nominal voltage of 400 V and an actual voltage of 412 V, there is a deviation of 12 V which is equal to a 3 % deviation from the nominal setting. Based on the parameters and settings above, the genset will then droop to a cos phi of 0.95 inductive.

Voltage-dependent cos phi droop curve



INFO

The output in the exact moment the droop is launched will be frozen and used as set point for the droop actions as long as the droop is active (shown as "fixed cos phi set point" in the diagram above).

2.5 Power-dependent cos phi/Q control (y2(x2) droop)

2.5.1 Power support

Power-dependent cos phi control gives a dynamic cos phi control in a parallel to mains system based on the generator-produced power. The purpose is to support the mains locally behind a transformer by minimising the reactive current flow in the grid.

The function measures and reacts based on the generator power measurement. The function calculates a dynamic power-dependent cos phi that is used to support the mains voltage/compensate the voltage impact of the power produced. The ramp has a configurable deadband that can be used with reference to the nominal power of the generator to deactivate the ramp functionality.

The power support function is also called *Power-dependent cos phi/Q control (y2(x2) droop)* and *Droop curve 2*.

This function is used when the generators are paralleling to the mains and running *Fixed power*, *Mains power export* or *Peak shaving*. It cannot be used in island applications.

Power support principle

In a system that is parallel to mains, power-dependent cos phi control provides dynamic cos phi control, based on the generator power.

The function is made with only one active regulator on the generator, and a variable curve defining the set point to the regulator. This ensures that there are no hunting problems with two to three regulators in cascade.

The principle is shown in by a diagram in the example. The horizontal x-axis is for the power deviation, *x2*, and the vertical y-axis is for cos phi, *y2*.

INFO
When the function is activated, the controller uses the actual power factor at that moment as the reference for the droop function. The controller uses this value for as long as the function is active.

INFO
The power-dependent droop curve is configured in **Advanced protections, Droop curve 2**. If full grid code rule compliance is required, you must add Option A10. For more information, see the **Option A10** documentation.

Parameters and settings

These parameters and settings are used by the power support function.

Name	Parameter	Default	Range
Contr. sett. cosphi	7052	0.9	0.1 to 1
Contr. sett. cosphi	7053	Inductive	Inductive, Capacitive

Advanced protection, Droop curve 2	Default	Range	Description
Deadband low (7151)	2.00 %	0 to 99.99 %	Deadband low, in percentage of genset nominal power.
Deadband high (7152)	2.00 %	0 to 99.99 %	Deadband high in percentage of genset nominal power. This should be high, to deactivate the droop when the actual generator power exceeds the nominal power.
Hysteresis low (7153)	2.1 %	0 to 99.99 %	Hysteresis low in percentage of nominal power. If HYSL is set above DBL, the hysteresis low is disabled.
Hysteresis high (7154)	2.1 %	0 to 99.99 %	Hysteresis high in percentage of nominal power. If HYSH is set above DBH, the hysteresis high is disabled.
Cosphi min set (7171)	0.8 Pf	0 to 1 Pf	Minimum output of droop handling, in combination with 7172.
Cosphi min dir. (7172)	Inductive (GEN)	Inductive (GEN), Capacitive (GEN)*	Direction for minimum output of droop handling.

Advanced protection, Droop curve 2	Default	Range	Description
Cosphi max set (7173)	1.00 Pf		Maximum output of droop handling, in combination with 7174.
Cosphi max dir. (7174)	Inductive (GEN)	Inductive (GEN), Capacitive (GEN)*	Direction for maximum output of droop handling.
Cosphi Slope low (7175)	-0.005 %/unit	-1 to 1 %/unit	Slope low. The setting determines the increase/ decrease of the cos phi reference per percent the actual power drops below nominal power. For the ramp slope calculation, see Example of power-dependent cos phi control.
Cosphi Slope high (7176)	0.005 %/unit	-1 to 1 %/unit	Slope high. The setting determines the increase/ decrease of the cos phi reference per percent the actual power rises above nominal power.
Curve select (7181)	Cosphi(X2)	Cosphi(X2), Q(X2)**	Output type for droop curve 2. Choose cos phi or reactive power.
Curve select (7182)	U	U, P	Input type for curve 2. **Choose P for power-dependent cos phi control.**
Curve enable (7183)	Disable	Disable, Enable	**Enable**: The selected settings are used for droop curve 2. **Disable**: Droop curve 2 is ignored.

*Note: The settings of *Cosphi min set* and *Cosphi max set* can be reversed, meaning that the reactive power will move in the inductive direction with increasing power. See **Capacitative range** below.

Note: If you select reactive power control (Q(X2)**) in *Curve select (7181)*, the function is similar to frequency droop (y1(x1)). See the **Designer's Reference Handbook** explanation of frequency droop.

Deadband

The ramp has a configurable deadband that can be used with reference to the generator nominal power to deactivate the ramp functionality. This is to have a normal operation band where a normal power fluctuation does not create disturbance on the mains. If the deadband is set to 0, the deadband is removed and the ramp will be active at any time.

When the generator measurement is outside the deadband, the power deviation is taken into consideration and a new cos phi value is calculated. The cos phi regulator of the generator will then adjust the cos phi and thereby change the var import/export of the plant. The calculation is based on the fixed cos phi set point value.

Hysteresis

A hysteresis can be used. The cos phi set point is kept at the drooped value as the power returns towards nominal until the hysteresis is reached.

For example, for a 1 % hysteresis set point and a 0.90 cos phi set point, if the power drops, the cos phi set point follows the slope to, for example, 0.82. When the power recovers, the cos phi set point stays at 0.82 until the power reaches 99 %. After that, the cos phi set point moves back to 0.90.

INFO
To deactivate hysteresis, configure the hysteresis with a value larger than the deadband.

Slope

Two settings for the slope are available, namely the "Slope Low" (SL) and the "Slope High" (SH). The name of the settings refers to the power being lower or higher than the nominal power (100 %). The slope is adjusted with a sign (positive or negative). The positive sign is the leading (capacitive) range, and the negative sign is the lagging (inductive) range.

See **Voltage support** for more details.

Capacitive range

It is possible to adjust the function to decrease the excitation if the power increases (leading cos phi).

CAUTION
To avoid pole slip and damage of the generators, make sure that the capability curve of the generators is respected and that the generators are not running under-excited or without excitation.

2.5.2 Example of power-dependent cos phi control

Parameters and settings for the example

Name	Parameter	Settings
Contr. sett. cosphi	7052	1.0
Contr. sett. cosphi	7053	Inductive

Advanced protection, Droop curve 2	Setting
Deadband low (7151)	0 %
Deadband high (7152)	50 %
Hysteresis low (7153)	1.0 %
Hysteresis high (7154)	51.0 %*
Cosphi min set (7171)	1.0 Pf**
Cosphi min dir. (7172)	Inductive (GEN)
Cosphi max set (7173)	0.95 Pf
Cosphi max dir. (7174)	Capacitive (GEN)
Cosphi Slope low (7175)	0.001 %/unit
Cosphi Slope high (7176)	0 %/unit***
Curve select (7181)	Cosphi(X2)
Curve select (7182)	P
Curve enable (7183)	Enable

*Note: This value disables the hysteresis.

**Note: For this value, if the power increases above 100 %, the cos phi is kept at 1.0.

***Note: For this value, the cos phi is kept at the nominal cos phi when the power is above 100 %.

Slope calculation example

Cosphi Delta low = 1 - 0.95 = 0.05
Slope in % of P = 100 % - 50 % = 50 %
Slope = 0.05 / 50 % = 0.001

Power-dependent cos phi droop curve