MULTI-LINE 2

Option D1
Voltage, var, or cos phi regulation

- Description of option
- Function description

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1. Delimitation

1.1 Scope of option D1

This description of options covers the following products:

AGC-3	SW version 3.5x.x or later
AGC-4	SW version 4.4x.x or later
All GPC-3 variants, all GPU-3 variants, PPM-3, PPU-3	SW version 3.0x.x or later

Table 1.1 Functions by product

Function	AGC-3	AGC-4	GPC-3	GPU-3	PPU-3	PPM-3
Automatic regulation type selection	•	•				•
Manual regulation type selection			•	-*	•	
Voltage-dependent cos phi/Q control (y2(x2) droop)		•	•			

*Note: Voltage regulation requires Option G2.

2. General information

2.1 Warnings, legal information and safety

2.1.1 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.

2.1.2 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.

3. Description of option

3.1 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

3.2 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).

4. Function description

4.1 Automatic regulation type selection, AGC/PPM

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

1. The GB and MB states (MB for AGC only).
2. The regulation type digital inputs.

4.1.1 Regulation type based on breaker states

Table 4.1 AGC breaker states and regulation types

Regulation type	Generator breaker OFF	Generator breaker ON, Mains breaker OFF	Generator breaker ON, Mains breaker ON
Fixed voltage	X	X	
Fixed cos phi			X
var sharing (requires option G3 or G5)		X	

Table 4.2 PPM breaker states and regulation types

Regulation type	Generator breaker OFF	Generator breaker ON, Shaft generator/ Shore connection breaker OFF	Generator breaker ON, Shaft generator/ Shore connection breaker ON
Fixed voltage	X	X	
Fixed cos phi			X
var sharing		X	

INFO
var sharing is a mix of fixed voltage and var sharing regulation. The reactive load is shared equally between the gensets, AND the voltage is maintained at the nominal value.

4.1.2 Regulation type based on digital inputs

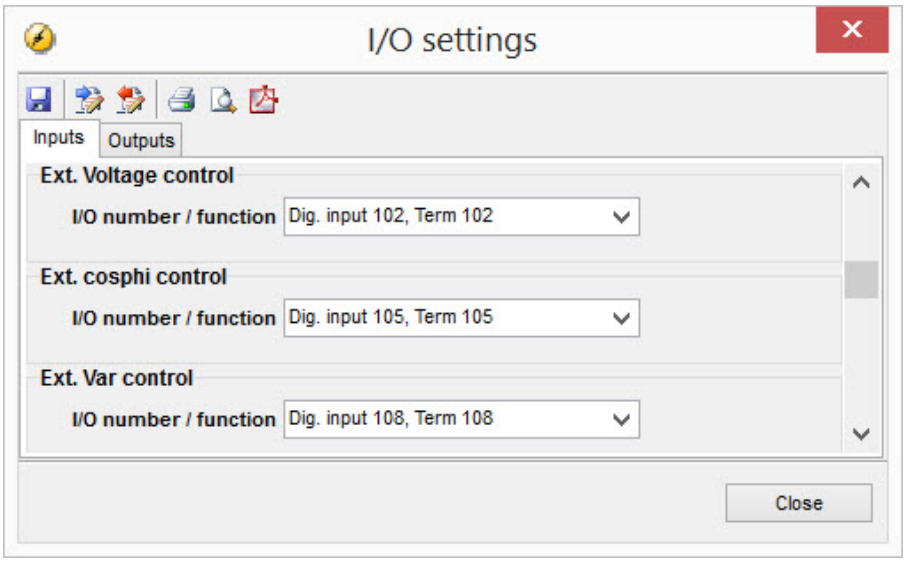
You can use digital inputs to select the regulation type. This allows the controller to use external set points, for example, from an external potentiometer or a PLC.

Regulation type	Comment	Terminal "ext. U/Q 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

INFO
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. U control", "Ext. cos phi control" or "Ext. Q control" using the PC utility software (USW), as shown below.



INFO
Only one of the functions needs to be configured.

4.2 Manual regulation type selection, GPC/PPU

The regulation type selection is done in the GPC/PPU using digital inputs, M-Logic or external communication, for example, Modbus.

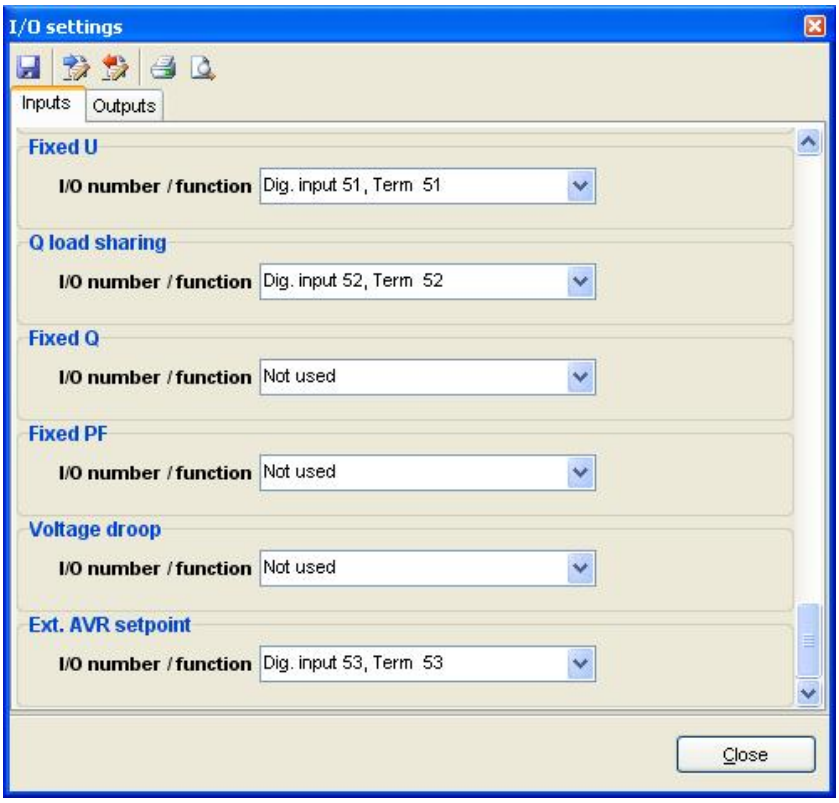
The regulation type is used to control the AVR when the GB is closed. With the GB open, the regulation type is fixed voltage and frequency (unless manual or SWBD mode is activated).

Table 4.3 Available regulation types with option D1

Regulation types	Comment
Fixed voltage	For example, stand-alone generator
Fixed Q	Fixed reactive power
Fixed cos phi	For example, parallel with mains
Q load sharing	Reactive load sharing
Voltage droop	Voltage will drop with rising reactive power

4.2.1 Input selection

The regulation type inputs must be configured in the PC utility software (USW) as shown below (default settings).



INFO
Only one of the functions needs to be configured.

4.2.2 Regulators

INFO
The working principle of the PID regulator is described in the Designer's Reference Handbook.

The outputs for the AVR can be either analogue or digital. Please refer to the data sheet for further information about possible selections.

4.2.3 External set point

The external set points can be used if the set point comes from another source, for example, a PLC. The input "Ext. AVR set point" is used to activate the external set point. When the input is high, the external set point is used. When it is low, the internal set point is used.

The inputs for the external set points are terminal 41 (common) and 42 (+) and the signal level is +/-10 V DC.

The available regulation types and their respective adjustment ranges are described in the table below:

Regulation type	"Ext. AVR set point" = ON	Comment
Fixed voltage	+/-10 V DC input ~ nominal voltage +/-10 %	Stand-alone generator or GB opened
Fixed Q	0 to 10 V DC input ~ 0 to 100 % reactive power	Fixed reactive power
Fixed cos phi	0 to 10 V DC input ~ 1 to 0.6 inductive cos phi	Fixed cos phi
Q load sharing	+/-10 V DC input ~ nominal voltage +/-10 %	Reactive power sharing
Voltage droop	+/-10 V DC input ~ nominal voltage +/-10 %	

INFO
0 to 100 % relates to the nominal power [P] of the generator.

4.2.4 AVR mode undefined (menu 2750)

After the breaker is closed, one AVR regulation type must be selected. If no regulation type is selected, or more than one regulation type is selected, then the controller responds as follows (regardless of the fail class selected for "AVR mode undef." in menu 2750):

1. No regulation type input active: The controller is changed to manual regulation (regulator OFF) and an "AVR mode undef." alarm is activated after the delay has expired.
2. More than one regulation type input active: The controller uses the first selected regulation type and an "AVR mode undef." alarm is activated.

4.3 Regulation type selection, GPU

There is no regulation type selection available for the GPU. The GPU always uses fixed voltage control when the GB is open, it matches the voltage during synchronisation, and after closing of the GB, the regulation is turned OFF.

INFO
To activate the regulation in a GPU, option G2 is required.

4.4 AVR regulation failure

The AVR regulation failure in menu 2230 is part of option D1. The alarm occurs when the regulation is activated but the set point cannot be reached.

The alarm will appear when the set point is reached. The deviation is calculated in per cent:

Example:

U_{ACTUAL} = 400 V AC

$U_{NOMINAL}$ = 440 V AC

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

If the alarm setting is lower than 9.1 % in this example, the alarm appears.

INFO
Adjust the alarm setting "Deadband" to 100 % to deactivate the alarm.

4.5 Manual AVR control

Regarding manual control of the AVR, please refer to the chapter "Manual governor and AVR control" in the Designer’s Reference Handbook.

4.6 Voltage-dependent cos phi/Q control (y2(x2) droop) for AGC

4.6.1 Voltage support (AGC)

For the AGC-4, the voltage support function is also referred to as "Voltage-dependent cos phi/Q control (y2(x2) droop)" or "Droop curve 2". The function changes the cos phi or the kvar set point of the generators if the mains voltage changes beyond certain

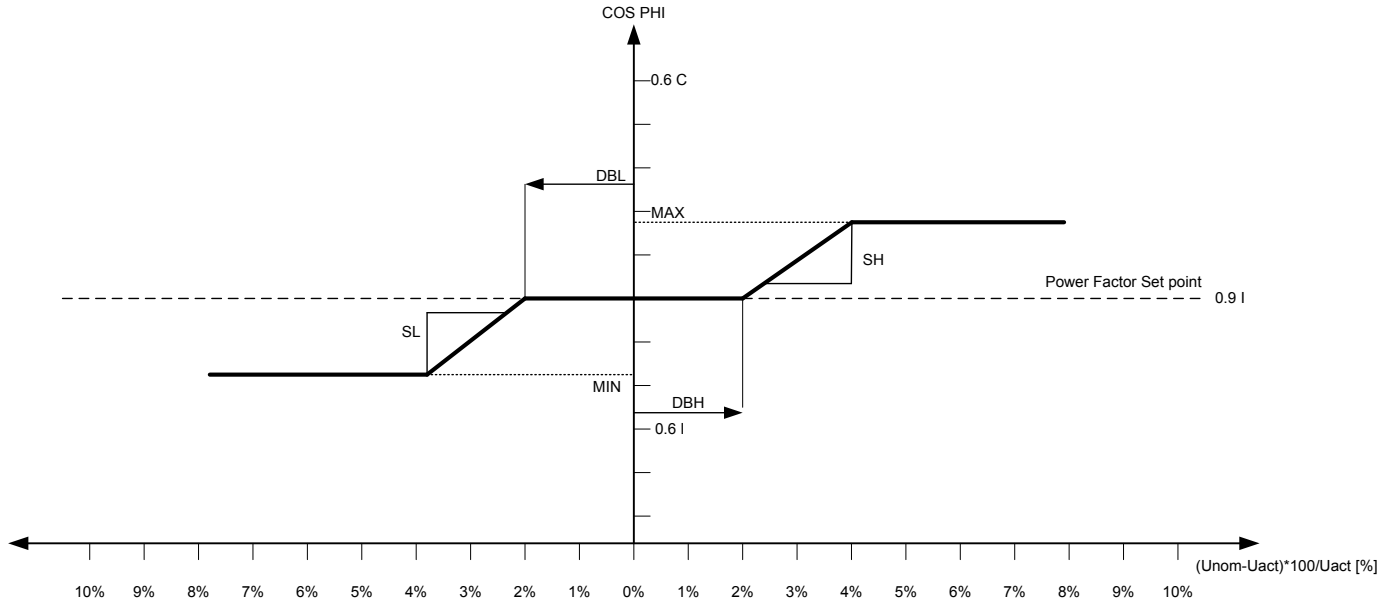
values in order to support the mains voltage. The idea is that if the mains voltage drops, the generators increase their excitation and support the mains voltage. If the mains voltage increases, the excitation of the DGs decreases in order to produce a smaller amount of var.

This function is used when the generators are paralleling to the mains and running one of the following: "fixed power", "mains power export" or "peak shaving". It cannot be used in island applications.

Function description

The diagram below shows the principle. The dotted line illustrates the x-axis (voltage deviation), and the vertical line (cos phi) is the y-axis. The cos phi set point is 0.90 in this example, but the voltage support works around any set point that is adjusted.

INFO
From SW version 4.54.x and onwards: 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 illustrates the following areas:

Zone	Voltage	cos phi	USW: Advanced protection, Droop curve 2
Minimum cos phi - Limit	90 to 96 %	Min. limit	(7171)
Decreasing slope - Low (SL)	96 to 98 %	Sloping	(7175)
Deadband	98 to 102 %	0.90	(7151-7152)
Increasing slope - High (SH)	102 to 104 %	Sloping	(7176)
Maximum cos phi - Limit	104 to 110 %	Max. limit	(7173)

Parameters

The above diagram is configured with the following settings:

Name	Parameter	Settings	Description
Contr. sett. cosphi	7052	0.9	cos phi set point 0.6 to 1.
Contr. sett. cosphi	7053	Inductive	Inductive/capacitive.

Name	USW: Advanced protection, Droop curve 2	Settings	Description
Deadband low	(7151)	2.00 %	Deadband low in percentage of nominal X2.
Deadband high	(7152)	2.00 %	Deadband high in percentage of nominal X2.
Hysteresis low	(7153)	1.00 %	Hysteresis low in percentage of nominal X2. If HYSL is set above DBL, the hysteresis low is disabled. (Not shown in the diagram).
Hysteresis high	(7154)	1.00 %	Hysteresis high in percentage of nominal X2. If HYSH is set above DBH, the hysteresis high is disabled. (Not shown in the diagram).
Cosphi min set	(7171)	0.8	Minimum output of droop handling. This setting is related to the setting in 7172.
Cosphi min dir.	(7172)	Inductive	Minimum output of droop handling.
Cosphi max set	(7173)	1.00	Maximum output of droop handling. This setting is related to the setting in 7174.
Cosphi max dir.	(7174)	Inductive	Maximum output of droop handling.
Cosphi Slope low	(7175)	-0.05	Slope low. The setting determines the increase/decrease of cos phi reference per percent the actual X2 drops below nominal X2.
Cosphi Slope high	(7176)	0.05	Slope high. The setting determines the increase/decrease of cos phi reference per percent the actual X2 rises above nominal X2.
Curve select	(7181)	cos phi(X2)	Output type for curve 2. Selections currently available “Reactive Power” and “cos phi”.
Curve select	(7182)	U	Input type for curve 2. Selections currently available “Power” and “Voltage”.
Curve enable	(7183)	ON	Enable/disable of curve 2.

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.

Hysteresis

In addition to the mentioned settings, a hysteresis can also be used. The function of the hysteresis is that the cos phi set point stays at the drooped value if the voltage returns towards nominal until the adjusted hysteresis is reached.

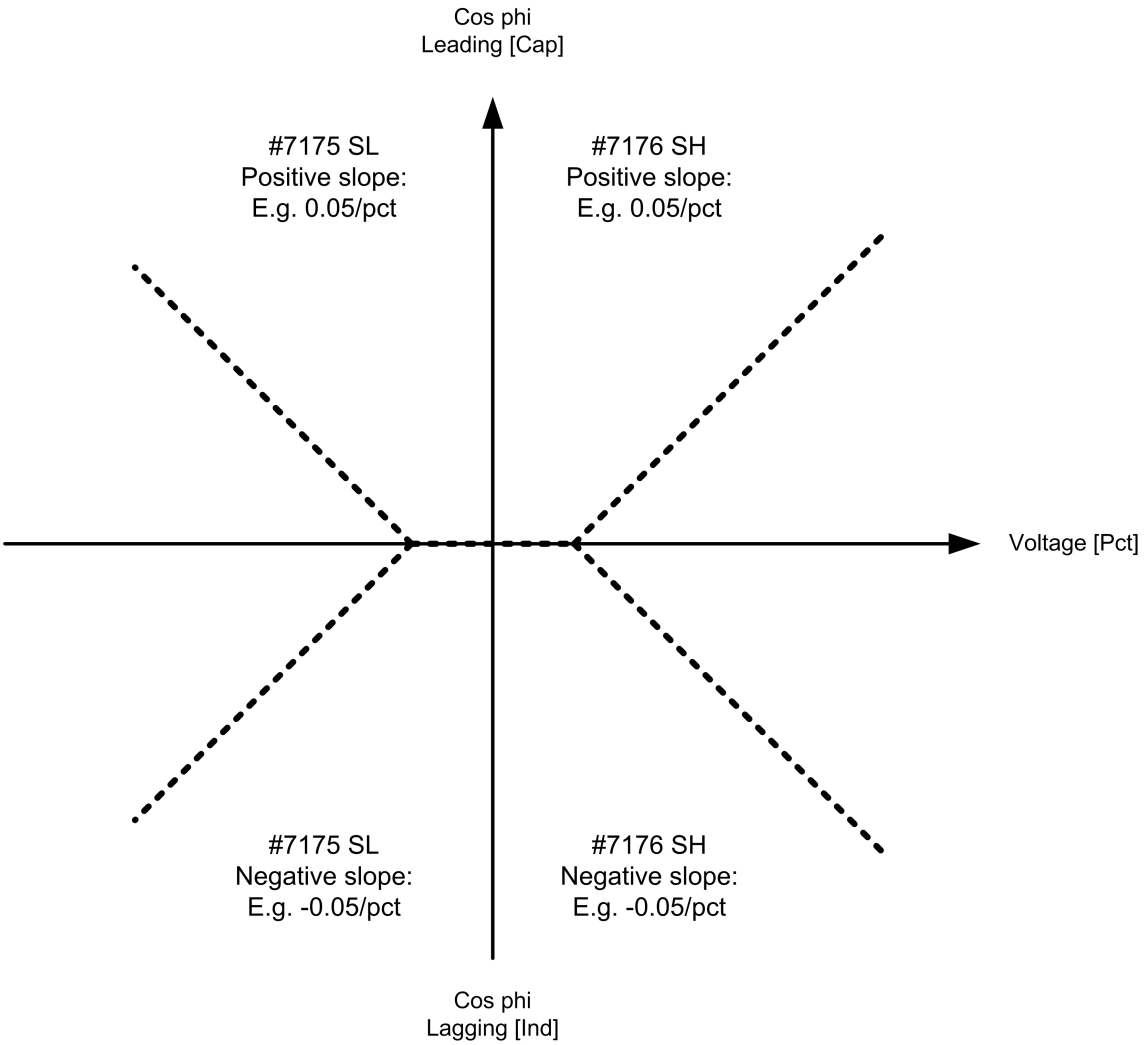
If for example the voltage drops, the cos phi set point follows the slope to for example 0.82. If the voltage now recovers, the cos phi set point stays at the mentioned 0.82 (in our example) until the voltage reaches 99 %, and then it moves back to our set point of 0.90. (1 % is the set point of the hysteresis).

If the hysteresis is adjusted at a higher value than the deadband, it is not in effect. Therefore, if the hysteresis is not used, please adjust it higher than the DB.

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.

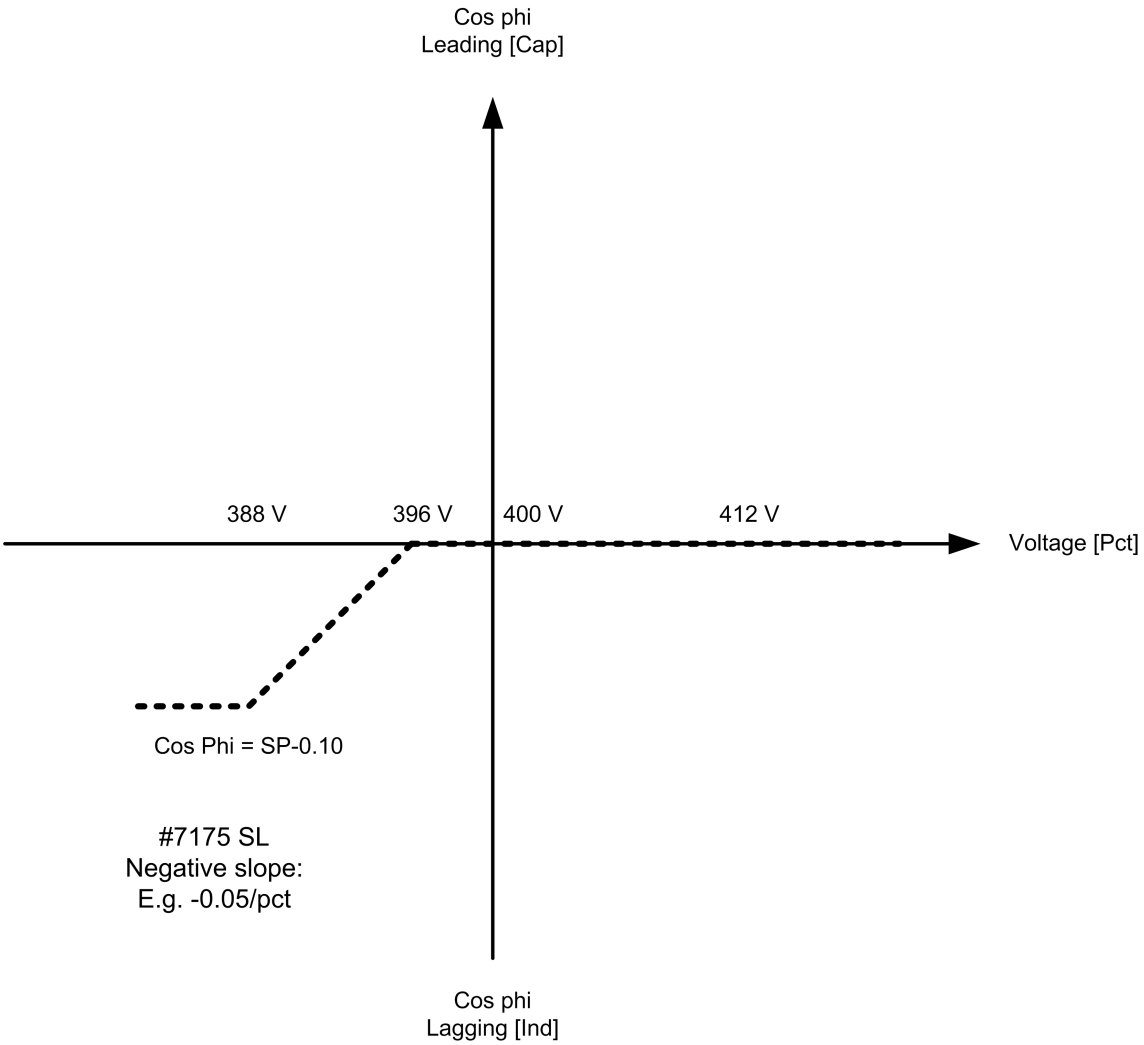
In order to explain when to adjust positive or negative sign, the following coordinate system is used.



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 will decrease 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)



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.

4.6.2 Example of voltage-dependent cos phi (AGC)

For AGC-4, voltage-dependent cos phi control is a function that gives a dynamic cos phi control in a parallel to mains system 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.

INFO
These settings are only relevant if **Advanced Protection, Droop curve 2** *Curve select (7182)* is **U**, and *Curve enable (7183)* is **Enable**.

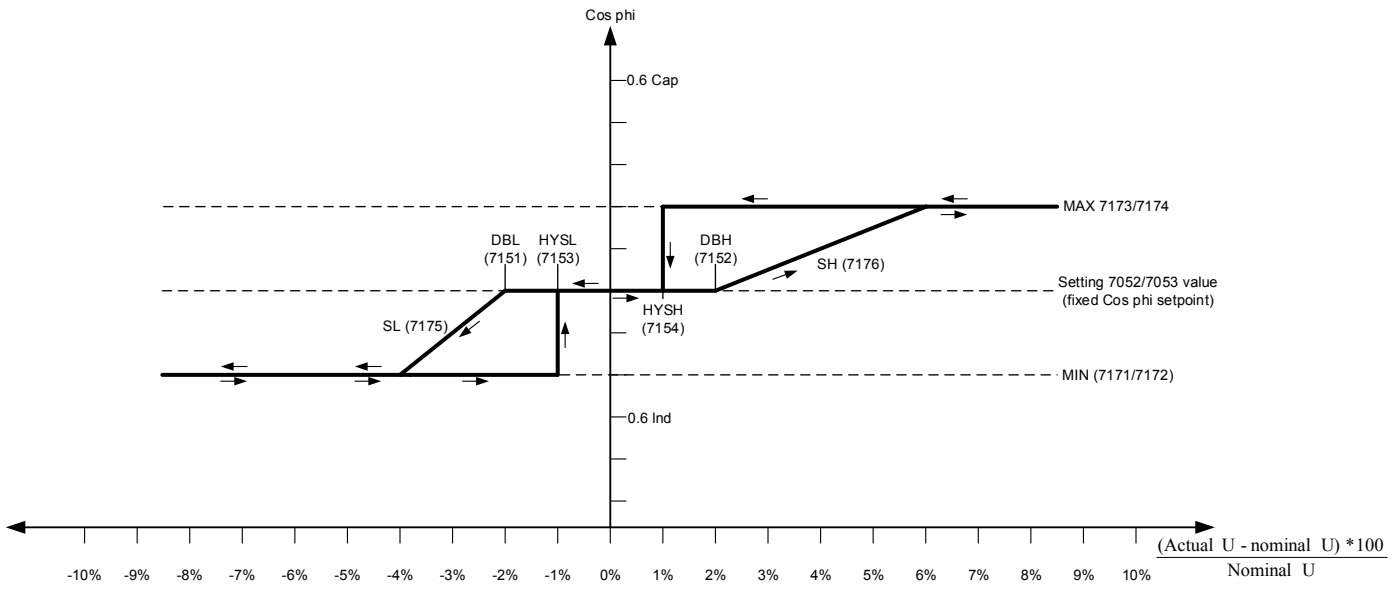
Name	Parameter	Settings	Description
Contr. sett. cosphi	7052	0.9	Fixed cos phi set point 0.6 to 1.
Contr. sett. cosphi	7053	Inductive	Fixed cos phi inductive/capacitive selection.

Name	USW: Advanced protection, Droop curve 2	Settings	Description
Deadband low	(7151)	2 %	Deadband low in percentages of nominal voltage.
Deadband high	(7152)	2 %	Deadband high in percentages of nominal voltage.
Hysteresis low	(7153)	1.0 %	Hysteresis low in percentages nominal voltage. If this is set to 0 or above the value of Deadband low (7151), the hysteresis low is disabled.
Hysteresis high	(7154)	1.0 %	Hysteresis high in percentages nominal voltage. If this is set to 0 or above the value of Deadband high (7152), the hysteresis high is disabled.
Cosphi min set	(7171)	0.7	Minimum output of droop handling (voltage decreasing). This setting is related to the setting in (7172).
Cosphi min dir.	(7172)	Inductive (GEN)	Minimum output of droop handling (Inductive (GEN)/Capacitive (GEN)).
Cosphi max set	(7173)	0.9	Maximum output of droop handling (voltage increasing). This setting is related to the setting in (7174).
Cosphi max dir.	(7174)	Capacitive (GEN)	Maximum output of droop handling (Inductive (GEN)/Capacitive (GEN)).
Cosphi Slope low	(7175)	-0.1	Slope low. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage drops below nominal.
Cosphi Slope high	(7176)	0.05	Slope high. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage rises above nominal.
Curve select	(7181)	Cosphi(X2)	Output type for curve 2. The other setting is **Q(X2)**.

INFO
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.

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. The genset will then droop to a cos phi of 0.95 inductive according to the above settings.

Figure 4.1 Voltage-dependent cos phi droop curve



INFO
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.

The system measures and reacts based on the mains voltage measurement. The function will make a dynamic voltage-dependent cos phi that is used to support the mains voltage. 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.

INFO
From SW version 4.54.x: 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. (Illustrated as "fixed cos phi set point" in the diagram above).

The system is able to run the generator with a capacitive and an inductive cos phi lowering or raising the mains voltage.

The system 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 ramp slope is set in % per unit [%/u] where the unit is in V AC, meaning that the nominal setting for slope low, 10 %/u means 10 % increase of cos phi per volt AC deviation.

INFO
This function is only active when generator is parallel to grid.

4.6.3 Example of power-dependent cos phi control (AGC)

For AGC-4, power-dependent cos phi control is a function that 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 voltage locally behind a transformer by minimising the reactive current flow in the grid.

INFO
These settings are only relevant if **Advanced Protection, Droop curve 2**: *Curve select (7182)* is **P**, and *Curve enable (7183)* is **Enable**.

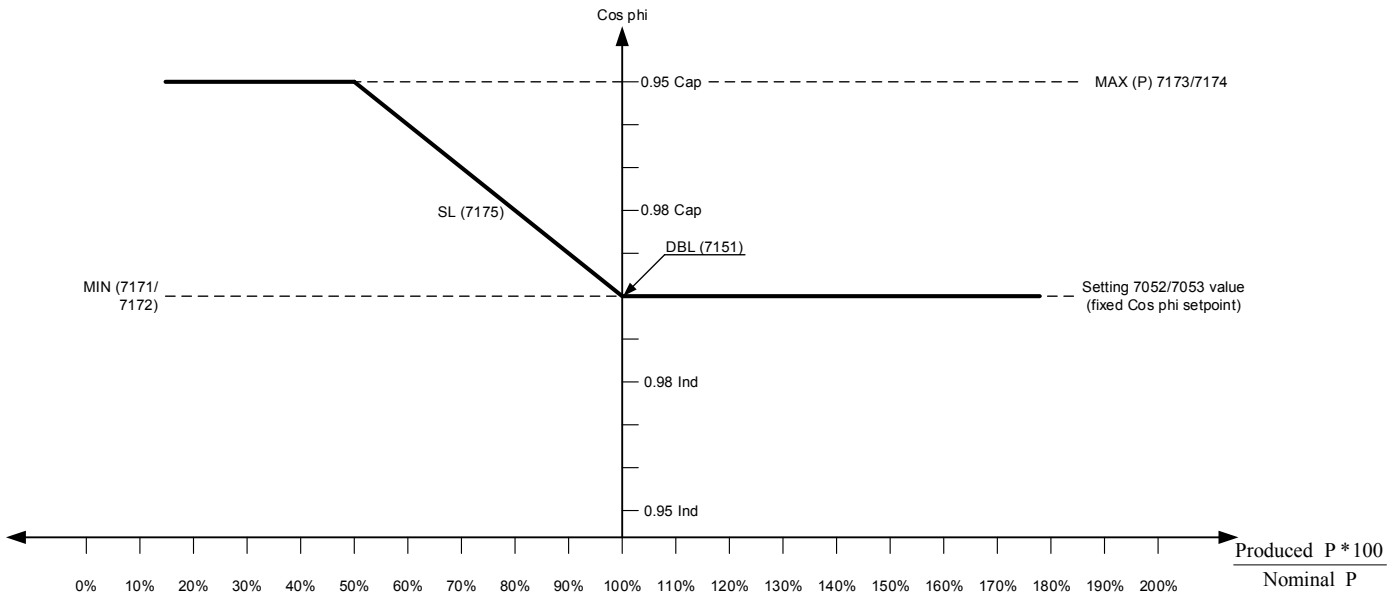
Name	Parameter	Settings	Description
cos phi	7052	1.0	Fixed cos phi set point 0.6 to 1.
cos phi	7053	Inductive	Fixed cos phi inductive/capacitive selection.

Name	USW: Advanced protection, Droop curve 2	Settings	Description
Deadband low	(7151)	0.00 %	Deadband low in percentages of nominal power. In this example set to 0 to disable the deadband.
Deadband high	(7152)	50.00 %	Deadband high in percentages of nominal power. In this example, the deadband is set high as the droop is not expected to be used.

Name	USW: Advanced protection, Droop curve 2	Settings	Description
Hysteresis low	(7153)	1.00 %	Hysteresis high in percentages of nominal power. If this is set above the value of *Deadband low (7151)*, the hysteresis low is disabled.
Hysteresis high	(7154)	51.00 %	Hysteresis high in percentages of nominal power. If this is set above the value of *Deadband high (7152)*, the hysteresis high is disabled. In this example the hysteresis is disabled.
Cosphi min set	(7171)	1.0	Minimum output of droop handling (voltage decreasing). This setting is related to the setting in (7172). If the power increases above 100 %, the cos phi is kept at 1.0.
Cosphi min dir.	(7172)	Inductive (GEN)	Minimum output of droop handling (Inductive (GEN)/Capacitive (GEN)).
Cosphi max set	(7173)	0.95	Maximum output of droop handling (voltage increasing). This setting is related to the setting in (7174).
Cosphi max dir.	(7174)	Capacitive (GEN)	Maximum output of droop handling (Inductive (GEN)/Capacitive (GEN)).
Cosphi Slope low	(7175)	0.001	Slope low. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage drops below nominal.
Cosphi Slope high	(7176)	0.000	Slope high. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage rises above nominal. In this example, the cos phi is kept at the nominal cos phi when the power is increasing above 100 %.
Curve select	(7181)	Cosphi(X2)	Output type for curve 2. The other setting is **Q(X2)**.

INFO
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.

Figure 4.2 cos phi droop curve



The system measures and reacts based on the generator power measurement. The function will make 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 (Deadband high (7152)) that can be used with reference to the nominal power of the generator to deactivate the ramp functionality.

This is to have a normal operation band where a normal power variation 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 power measurement is outside the deadband, the power production 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.

INFO
From SW version 4.54.x: 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. (Illustrated as "fixed cos phi set point" in the diagram above).

The system is able to run the generator with a capacitive and an inductive cos phi to compensate for mains voltage.

The system 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.

INFO
This function is only active when generator is parallel to grid.

4.7 Voltage-dependent cos phi/Q control (y2(x2) droop) for GPC-3

4.7.1 Voltage support (GPC-3)

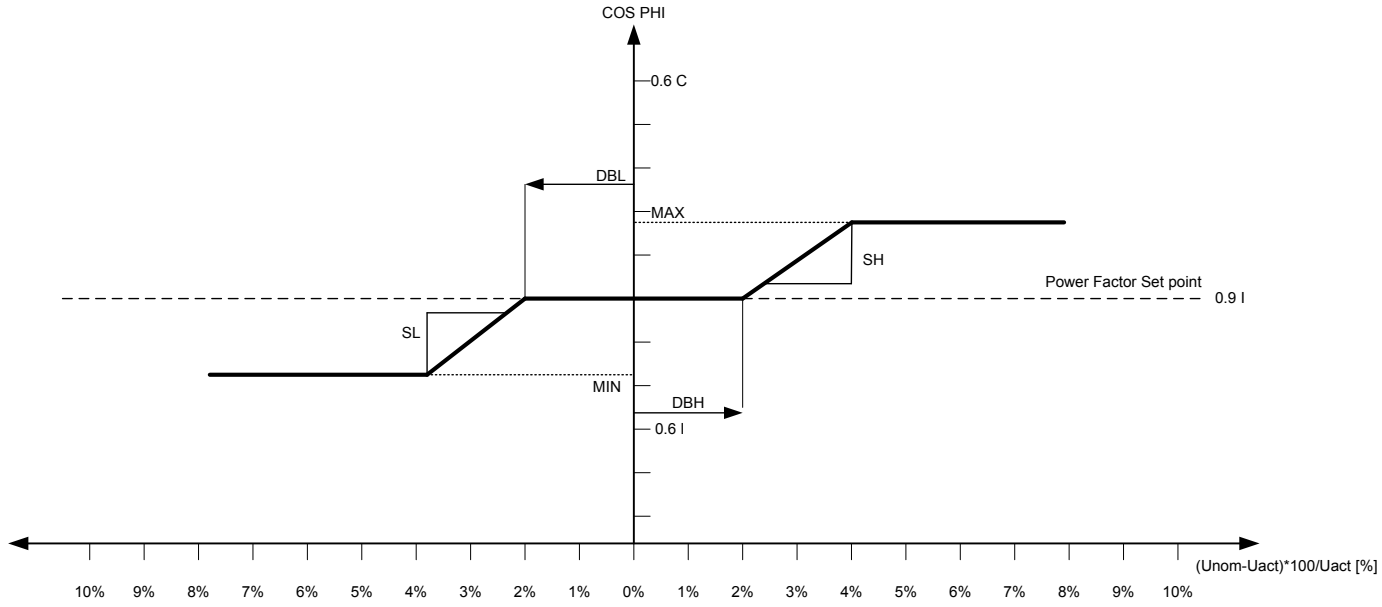
For GPC-3, the voltage support function is also referred to as "Voltage-dependent cos phi/Q control (y2(x2) droop)". The function changes the cos phi or the kvar set point of the generators if the mains voltage changes beyond certain values in order to support the mains voltage. The idea is that if the 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 a smaller amount of var.

This function is used when the generators are paralleling to the mains and running one of the following: "fixed power", "mains power export" or "peak shaving". It cannot be used in island applications.

Function description

The diagram below shows the principle. The dotted line illustrates the x-axis (voltage deviation), and the vertical line (cos phi) is the y-axis. The cos phi set point is 0.90 in this example, but the voltage support works around any set point that is adjusted.

INFO
GPC-3 from version 3.20.x: 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. (Illustrated as "power factor set point" in the diagram below).



The diagram illustrates the following areas:

Zone	Voltage	cos phi	Parameter
Minimum cos phi - Limit	90 to 96 %	Min. limit	7171
Decreasing slope - Low (SL)	96 to 98 %	Sloping	7175
Deadband	98 to 102 %	0.90	7151-7152
Increasing slope - High (SH)	102 to 104 %	Sloping	7176
Maximum cos phi - Limit	104 to 110 %	Max. limit	(7173)

Parameters

The above diagram is configured with the following settings:

Name	Parameter	Settings	Description
cos phi	7052	0.9	cos phi set point 0.6 to 1.
cos phi	7053	Inductive	Inductive/capacitive.
DBL [%]	7151	2.00	Deadband low in percentage of nominal X2.
DBH [%]	7152	2.00	Deadband high in percentage of nominal X2.
HYSL [%]	7153	1.00	Hysteresis low in percentage of nominal X2. If HYSL is set above DBL, the hysteresis low is disabled. (Not shown in the diagram).
HYSH [%]	7154	1.00	Hysteresis high in percentage of nominal X2. If HYSH is set above DBH, the hysteresis high is disabled. (Not shown in the diagram).
MI	7171	0.8	Minimum output of droop handling. This setting is related to the setting in 7172.
I/C	7172	Inductive	Minimum output of droop handling.
MA	7173	1.00	Maximum output of droop handling. This setting is related to the setting in 7174.
I/C	7174	Inductive	Maximum output of droop handling.
SL [cos phi/%]	7175	-0.05	Slope low. The setting determines the increase/decrease of cos phi reference per percent the actual X2 drops below nominal X2.
SH [cos phi/%]	7176	0.05	Slope high. The setting determines the increase/decrease of cos phi reference per percent the actual X2 rises above nominal X2.

Name	Parameter	Settings	Description
Y2(X2)	7181	cos phi(X2)	Output type for curve 2. Selections currently available “Reactive Power” and “cos phi”.
X2	7182	U	Input type for curve 2. Selections currently available “Power” and “Voltage”.
ENA	7183	ON	Enable/disable of curve 2.

Hysteresis

In addition to the mentioned settings, a hysteresis can also be used. The function of the hysteresis is that the cos phi set point stays at the drooped value if the voltage returns towards nominal until the adjusted hysteresis is reached.

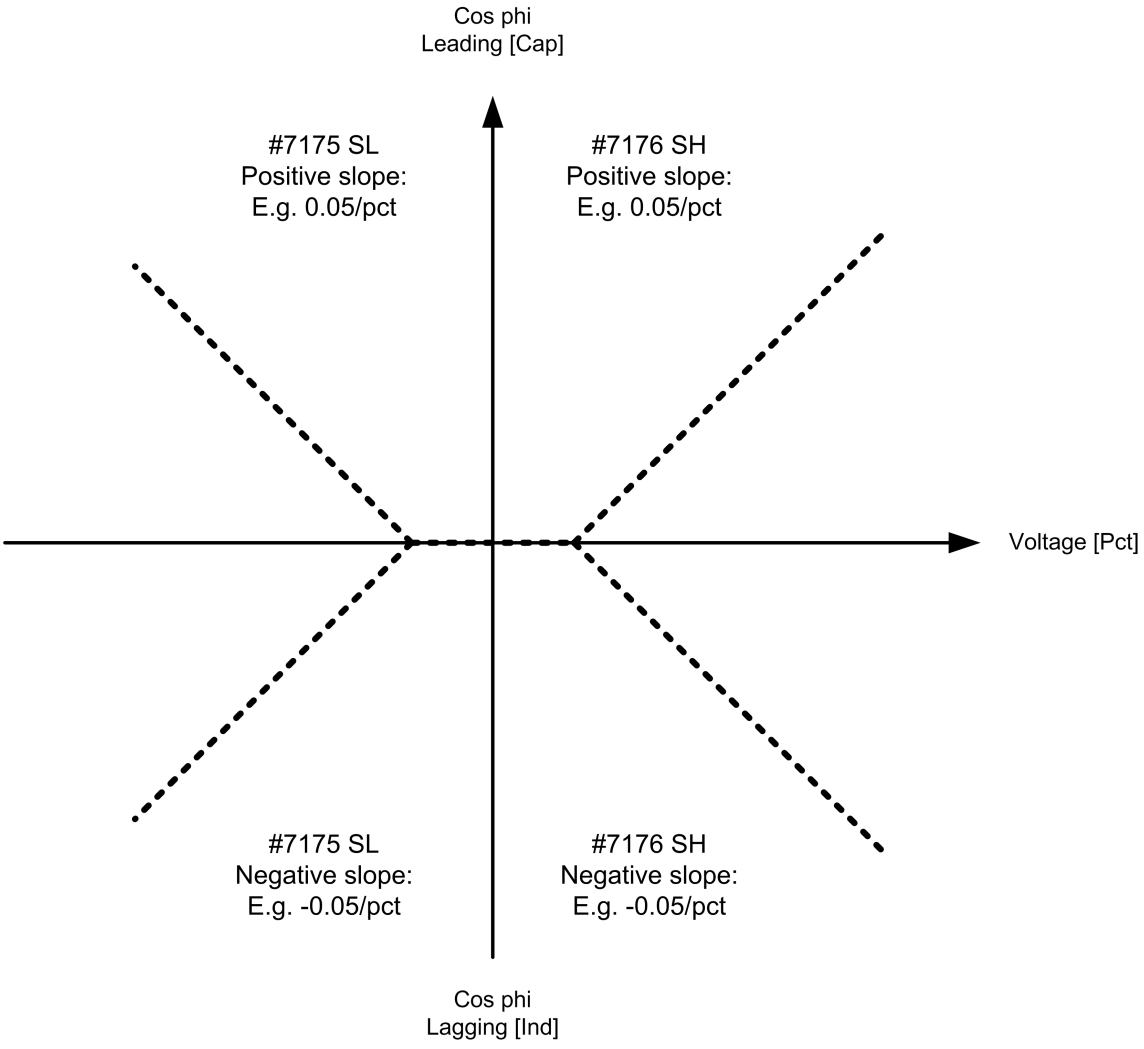
If for example the voltage drops, the cos phi set point follows the slope to for example 0.82. If the voltage now recovers, the cos phi set point stays at the mentioned 0.82 (in our example) until the voltage reaches 99 %, and then it moves back to our set point of 0.90. (1 % is the set point of the hysteresis).

If the hysteresis is adjusted at a higher value than the deadband, it is not in effect. Therefore, if the hysteresis is not used, please adjust it higher than the DB.

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.

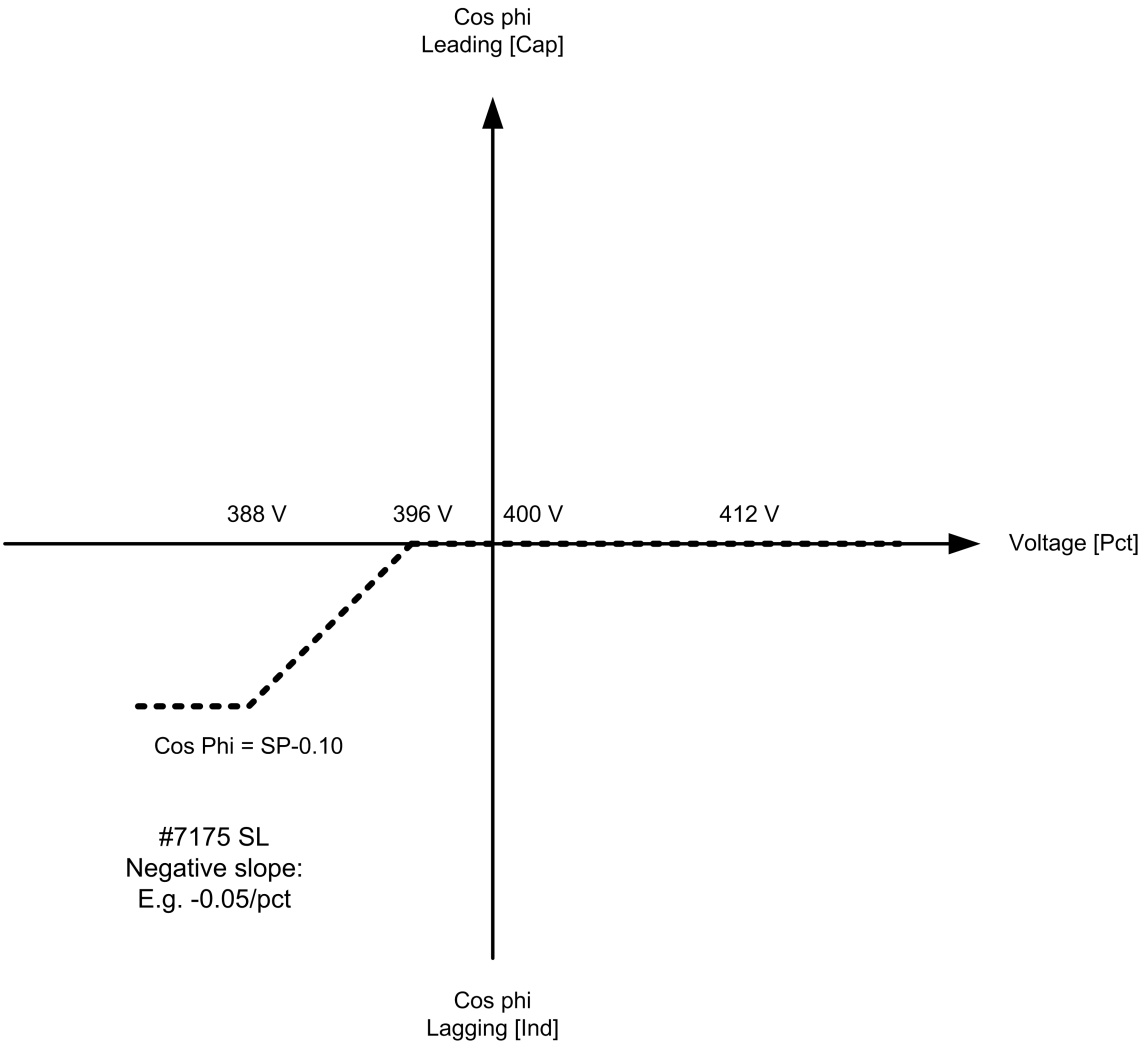
In order to explain when to adjust positive or negative sign, the following coordinate system is used.



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 will decrease 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)



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.

4.7.2 Example of voltage-dependent cos phi (GPC-3)

For GPC-3, voltage-dependent cos phi control is a function that gives a dynamic cos phi control in a parallel to mains system 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.

INFO

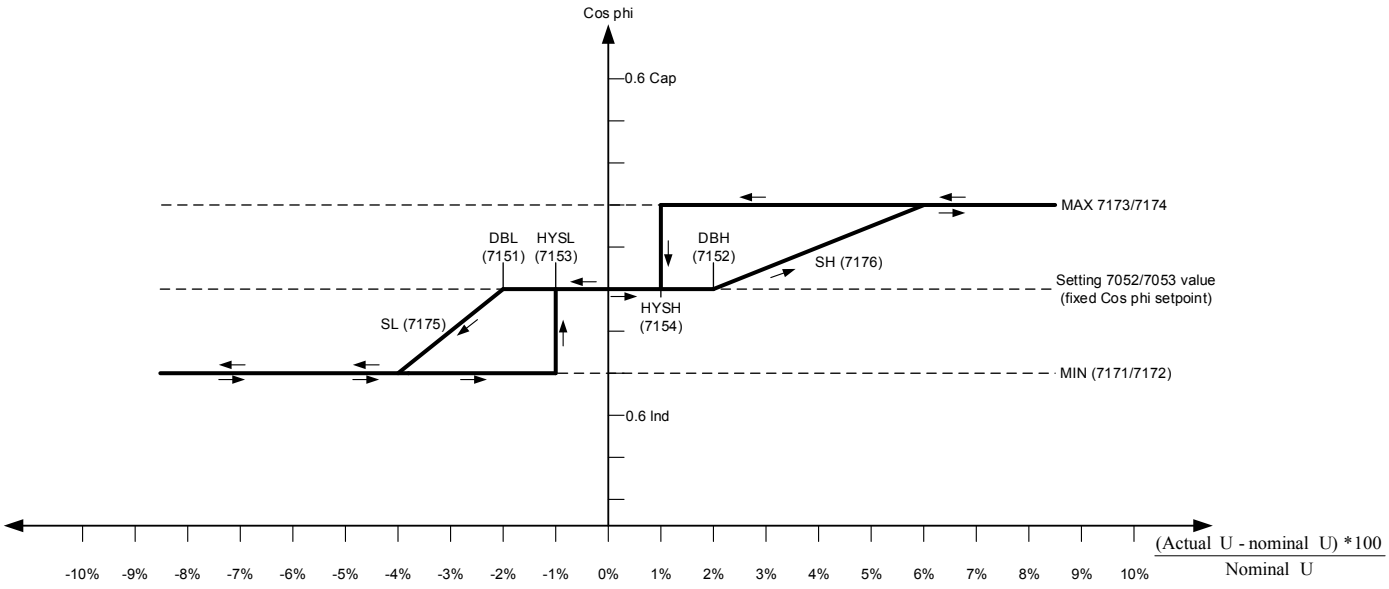
These settings are only relevant if parameter 7182 is **U**, and 7183 is **ON**.

Name	Parameter	Settings	Description
cos phi	7052	0.9	Fixed cos phi set point 0.6 to 1.
cos phi	7053	Inductive	Fixed cos phi inductive/capacitive selection.
DBL[%]	7151	2.00	Deadband low in percentages of nominal voltage.
DBH[%]	7152	2.00	Deadband high in percentages of nominal voltage.
HYSL[%]	7153	1.00	Hysteresis low in percentages nominal voltage. If HYSL is set to 0 or above the value of 7151(DBL), the hysteresis low is disabled.
HYSH[%]	7154	1.00	Hysteresis high in percentages nominal voltage. If HYSH is set to 0 or above the value of 7152(DBH), the hysteresis high is disabled.
MI	7171	0.7	Minimum output of droop handling (voltage decreasing). This setting is related to the setting in 7172.
I/C	7172	Inductive	Minimum output of droop handling (inductive/capacitive selection).
MA	7173	0.9	Maximum output of droop handling (voltage increasing). This setting is related to the setting in 7174.
I/C	7174	Capacitive	Maximum output of droop handling (inductive/capacitive selection).
SL[cos phi/%]	7175	-0.1	Slope low. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage drops below nominal.
SH[cos phi/%]	7176	0.05	Slope high. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage rises above nominal.
Y2(X2)	7181	cos phi(X2)	Output type for curve 2. Other settings are **Reactive Power** and **cos phi**.

INFO
If you select **Reactive Power** control in parameter 7181, the function is similar to frequency droop (y1(x1)). See the **Designer's Reference Handbook** explanation of frequency droop.

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. The genset will then droop to a cos phi of 0.95 inductive according to the above settings.

Figure 4.3 Voltage-dependent cos phi droop curve



INFO
The settings of MA and MI can be reversed, meaning that the reactive power will move in the inductive direction with increasing voltage.

The system measures and reacts based on the mains voltage measurement. The function will make a dynamic voltage-dependent cos phi that is used to support the mains voltage. The ramp has a configurable deadband (DBL/DBH) 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.

The system is able to run the generator with a capacitive and an inductive cos phi lowering or raising the mains voltage.

The system 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 ramp slope is set in % per unit [%/u] where the unit is in V AC, meaning that the nominal setting for slope low, 10 %/u means 10 % increase of cos phi per volt AC deviation.

INFO
This function is only active when "fixed cos phi" or "fixed Q" is activated, dependent on the setting in parameter 7143.

4.7.3 Example of power-dependent cos phi control (GPC-3)

For GPC-3, power-dependent cos phi control is a function that 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 voltage locally behind a transformer by minimising the reactive current flow in the grid.

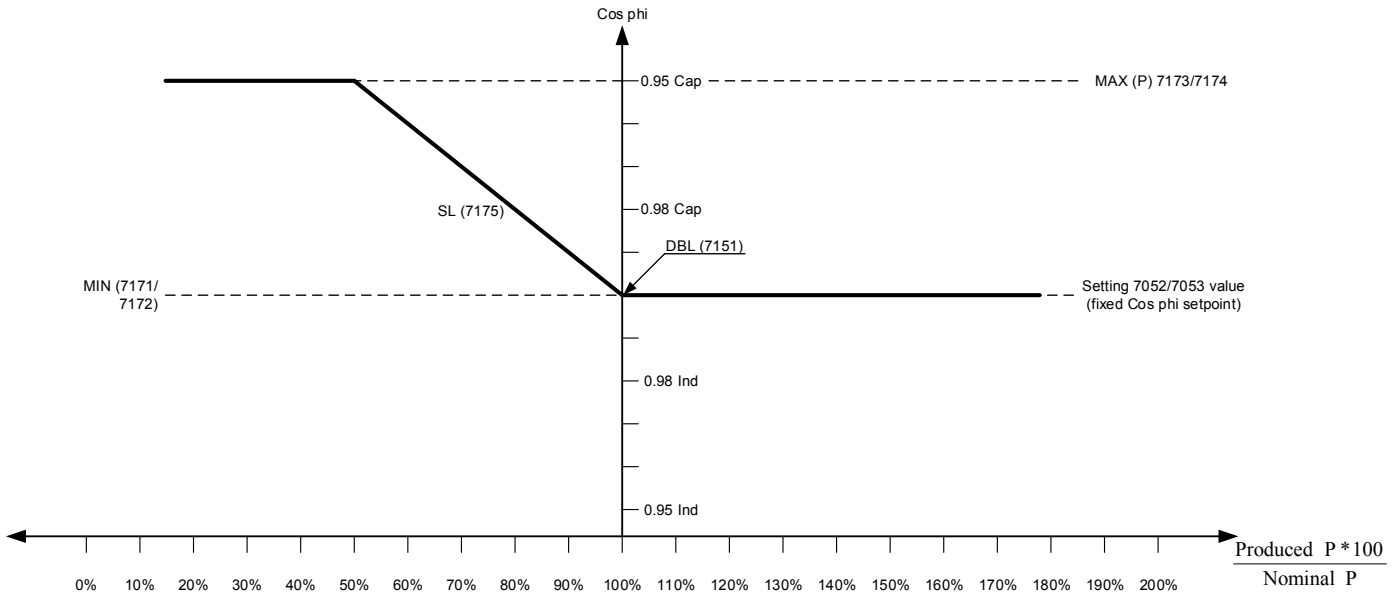
INFO
These settings are only relevant if parameter 7182 is **P**, and 7183 is **ON**.

Name	Parameter	Settings	Description
cos phi	7052	1.0	Fixed cos phi set point 0.6 to 1.
cos phi	7053	Inductive	Fixed cos phi inductive/capacitive selection.
DBL[%]	7151	0.00	Deadband low in percentages of nominal power. In this example set to 0 to disable the deadband.
DBH[%]	7152	50.00	Deadband high in percentages of nominal power. In this example, the deadband is set high as the droop is not expected to be used.
HYSL[%]	7153	1.00 %	Hysteresis high in percentages of nominal power. If HYSL is set above the value of 7151(DBL), the hysteresis low is disabled.
HYSH[%]	7154	51.00	Hysteresis high in percentages of nominal power. If HYSH is set above the value of 7152(DBH), the hysteresis high is disabled. In this example the hysteresis is disabled.
MI	7171	1.0	Minimum output of droop handling (voltage decreasing). This setting is related to the setting in 7172. If the power increases above 100 %, the cos phi is kept at 1.0.
I/C	7172	Inductive	Minimum output of droop handling (inductive/capacitive selection).
MA	7173	0.95	Maximum output of droop handling (voltage increasing). This setting is related to the setting in 7174.
I/C	7174	Capacitive	Maximum output of droop handling (inductive/capacitive selection).
SL[cos phi/%]	7175	0.001	Slope low. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage drops below nominal.

Name	Parameter	Settings	Description
SH[cos phi/%]	7176	0.000	Slope high. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage rises above nominal. In this example, the cos phi is kept at the nominal cos phi when the power is increasing above 100 %.
Y2(X2)	7181	cos phi(X2)	Output type for curve 2. Other settings are **Reactive Power** and **cos phi**.

INFO
If you select **Reactive Power** control in parameter 7181, the function is similar to frequency droop (y1(x1)). See the **Designer's Reference Handbook** explanation of frequency droop.

Figure 4.4 cos phi droop curve



The system measures and reacts based on the generator power measurement. The function will make 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 (DBH) that can be used with reference to the nominal power of the generator to deactivate the ramp functionality.

This is to have a normal operation band where a normal power variation 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 power measurement is outside the deadband, the power production 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.

The system is able to run the generator with a capacitive and an inductive cos phi to compensate for mains voltage.

The system 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.

INFO
This function is only active when "fixed cos phi" or "fixed Q" is activated, dependent on the setting in parameter 7143.

5. Parameters

5.1 Further information

Option D1 relates to the parameters 2640-2690, 2730, 2750 and 2783.

For voltage-dependent cos phi/Q control:

- For GPC-3, the parameters are 7150/7180.
- For AGC-3, the parameters are under **Advanced Protection**.

For further information, please see the parameter list:

AGC-3	Document number 4189340705
AGC-4	Document number 4189340688
PPM-3	Document number 4189340672
GPC-3, GPC-3 Gas, GPC-3 Hydro, GPU-3 Gas, GPU-3 Hydro	Document number 4189340580
PPU-3, GPU-3	Document number 4189340581