MULTI-LINE 2
DESCRIPTION OF OPTIONS



Option D1
Voltage/var/cos phi control

- Description of option
- Functional description

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

Document no.: 4189340694F
SW version:

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
GPC/GPU Hydro	SW version 3.0x.x or later
GPU/PPU	SW version 3.0x.x or later
PPM	SW version 3.0x.x or later

2. General information

2.1 Warnings, legal information and safety

2.1.1 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

Warnings indicate a potentially dangerous situation, which could result in death, personal injury or damaged equipment, if certain guidelines are not followed.

Notes

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

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.

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.

2.1.3 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.

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

2.1.4 Electrostatic discharge awareness

Sufficient care must be taken to protect the terminals against static discharges during the installation. Once the unit is installed and connected, these precautions are no longer necessary.

2.1.5 Factory settings

The Multi-line 2 unit is delivered from factory with certain factory settings. These are based on average values and are not necessarily the correct settings for matching the engine/generator set in question. Precautions must be taken to check the settings before running the engine/generator set.

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. Functional description

4.1 Running mode selection, AGC/PPM

The unit selects the actual set point in one of two ways:
1. Automatic selection based on GB and MB feedback (MB for AGC only).
2. Manual selection based on digital inputs selection.

4.1.1 Automatic selection

When the automatic running mode selection is used, the actual running mode is as indicated in the table:

AGC:

	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	

PPM:

	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	

var sharing mode is a mix of fixed voltage and var sharing. This means that the reactive load will be shared equally between the gensets, AND the voltage will be maintained at the nominal value.

4.1.2 Manual selection

If the manual running mode selection is used, the actual mode depends on the activated input. How to select the manual running mode is described in the Designer's Reference Handbook.

The purpose of manual selection is to be able to use external set points, for example from an external potentiometer or a PLC.

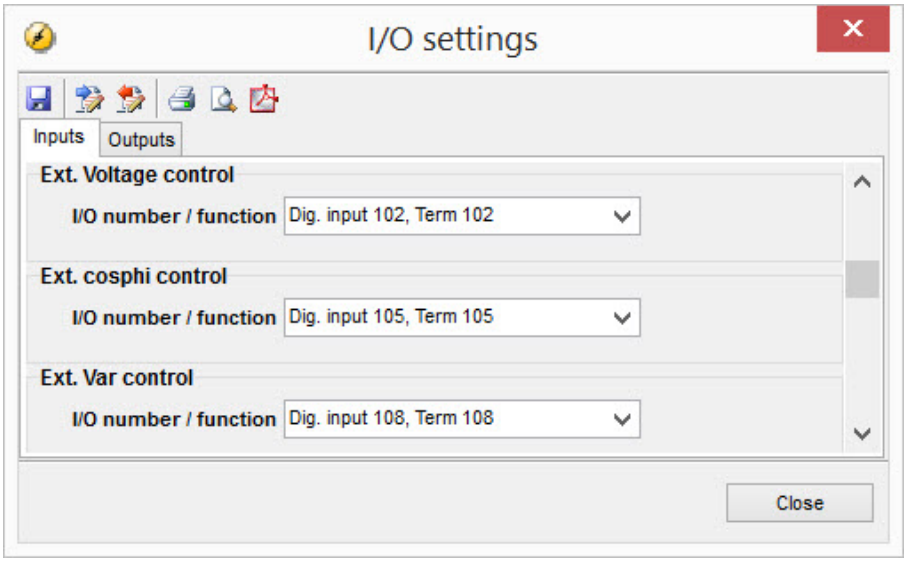
The available running modes and their respective adjustment ranges:

Mode	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

0 to 100 % relates to the nominal power of the generator.

4.1.3 Input selection

In order to activate the input for the external set point, the digital input functions "Ext. U control", "Ext. cos phi control" or "Ext. Q control" must be programmed in the PC utility software (USW) as illustrated below.



Only one of the functions needs to be programmed.

4.2 Regulation mode selection, GPC/PPU

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

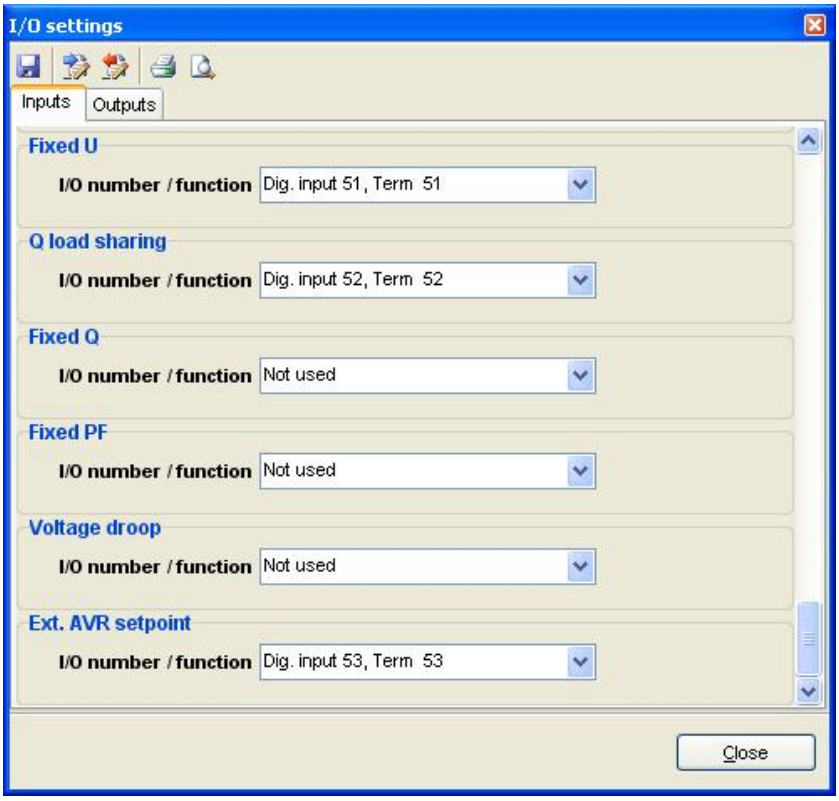
The modes are used to change the control method of the AVR when the GB is closed. With the GB open, the running mode is fixed voltage and frequency unless manual or SWBD mode is activated.

Available regulator modes with option D1:

Mode	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 mode inputs must be programmed in the PC utility software (USW) as illustrated below (default settings).



Only one of the functions needs to be programmed.

4.2.2 Regulators

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. In order to activate the external set point, the mode input called "Ext. AVR set point" is used. When the input is high, the external set point is used and 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 running modes and their respective adjustment ranges are described in the table below:

Mode	"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 %	

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

4.2.4 AVR mode undefined (menu 2750)

After the breaker has been closed, it is required that one AVR regulation mode is selected. In case no mode is selected or more than one mode is selected, the following action will be performed regardless of the fail class selected for "AVR mode undef." in menu 2750:

1. No mode input active: the unit is changed to manual mode (regulator OFF) and an "AVR mode undef." alarm is raised after the delay has expired.
2. More than one mode input active: the unit is maintained in the first selected running mode and an "AVR mode undef." alarm is raised.

4.3 Regulation mode selection, GPU

There is no regulation mode selection available for the GPU. It will always operate in fixed voltage control when the GB is open, make voltage matching during synchronisation and after closing of the GB, the regulation is turned OFF.

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.

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)

4.6.1 Voltage support

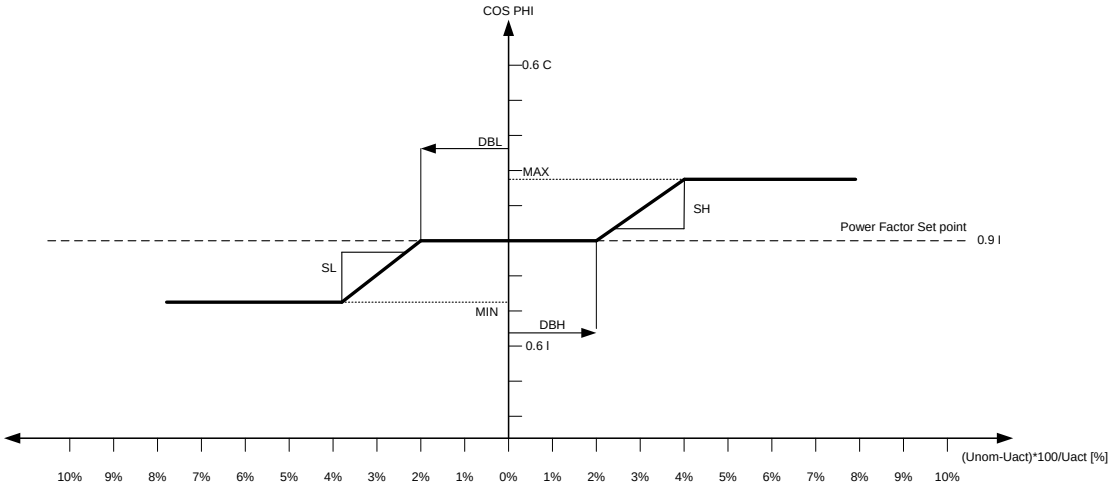
The voltage support function is also referred to as "Voltage-dependent cos phi/Q control (y2(x2) droop)". The function changes the cos phi or the kvar set point of the generators if the mains voltage changes beyond certain values in order to support the mains voltage. The idea is that if the mains voltage 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 modes: "fixed power", "mains power export" or "peak shaving". It cannot be used in island mode applications.

Functional 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.

AGC-4 from SW version 4.54.x and 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**	**Menu**
Minimum cos phi Limit	90 to 96 %	Min. limit	7171
Decreasing slope Low	96 to 98 %	Sloping	7175
Deadband	98 to 102 %	0.90	7151-7152
Increasing slope High	102 to 104 %	Sloping	7176
Maximum cos phi Limit	104 to 110 %	Max. limit	7173

Parameters
The above diagram is configured with the following parameter settings:

Menu	Settings	Name	Description
7052	0.9	cos phi	cos phi set point 0.6 to 1.
7053	Inductive	cos phi	Inductive/capacitive.
7151	2.00	DBL [%]	Deadband low in percentage of nominal X2.
7152	2.00	DBH [%]	Deadband high in percentage of nominal X2.
7153	1.00	HYSL [%]	Hysteresis low in percentage of nominal X2. If HYSL is set above DBL, the hysteresis low is disabled. (Not shown in the diagram).
7154	1.00	HYSH [%]	Hysteresis high in percentage of nominal X2. If HYSH is set above DBH, the hysteresis high is disabled. (Not shown in the diagram).
7171	0.8	MI	Minimum output of droop handling. This setting is related to the setting in 7172.
7172	Inductive	I/C	Minimum output of droop handling.
7173	1.00	MA	Maximum output of droop handling. This setting is related to the setting in 7174.
7174	Inductive	I/C	Maximum output of droop handling.
7175	-0.05	SL [cos phi/%]	Slope low. The setting determines the increase/decrease of cos phi reference per percent the actual X2 drops below nominal X2.
7176	0.05	SH [cos phi/%]	Slope high. The setting determines the increase/decrease of cos phi reference per percent the actual X2 rises above nominal X2.
7181	cos phi(X2)	Y2(X2)	Output type for curve 2. Selections currently available “Reactive Power” and “cos phi”.
7182	U	X2	Input type for curve 2. Selections currently available “Power” and “Voltage”.
7183	ON	ENA	Enable/disable of curve 2.

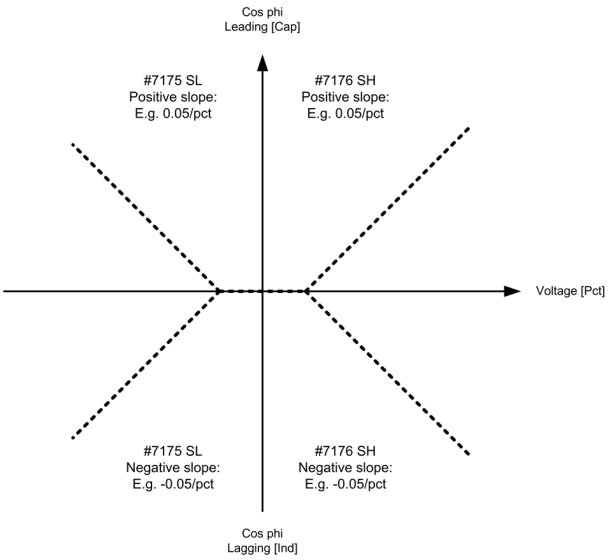
Hysteresis
In addition to the mentioned settings, a hysteresis can also be used. The function of the hysteresis is that the cos phi set point stays at the drooped value if the voltage returns towards nominal until the adjusted hysteresis is reached.

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.

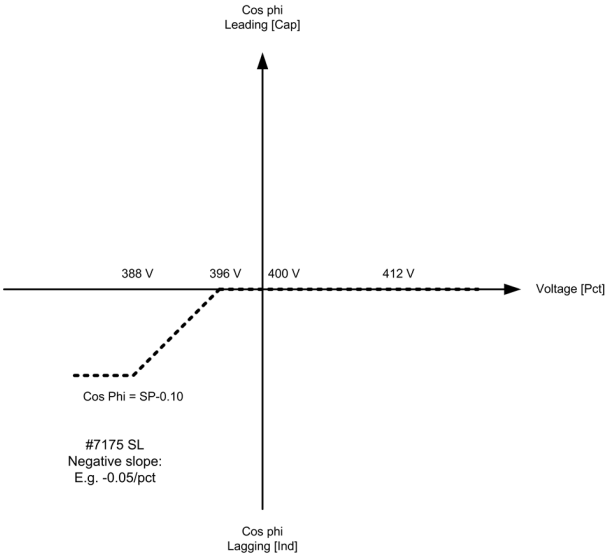
In order to explain when to adjust positive or negative sign, the following coordinate system is used.



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).

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

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.

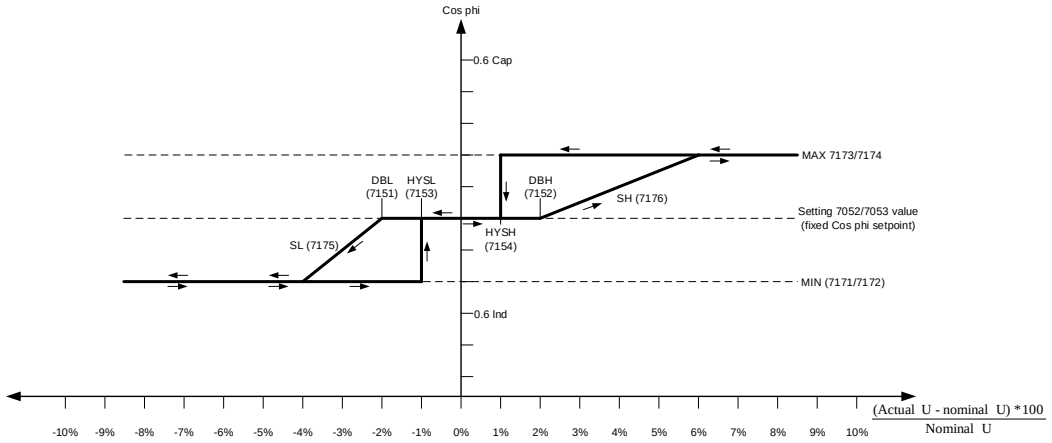
These settings are only relevant if: menu 7182 is set to "U", and menu 7183 is set to "ON".

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

If selecting reactive power control in setting 7181, the programming is similar to that of frequency droop (y1(x1)). Please refer to 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.

Voltage-dependent cos phi droop curve



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.

AGC-4 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.

AGC: this function is only active when generator is parallel to grid.

GPC/PPU: this function is only active when "fixed cos phi" or "fixed Q" mode is activated, dependent on the setting in menu 7143.

PPM: this function is not supported.

4.6.3 Example of power-dependent cos phi control

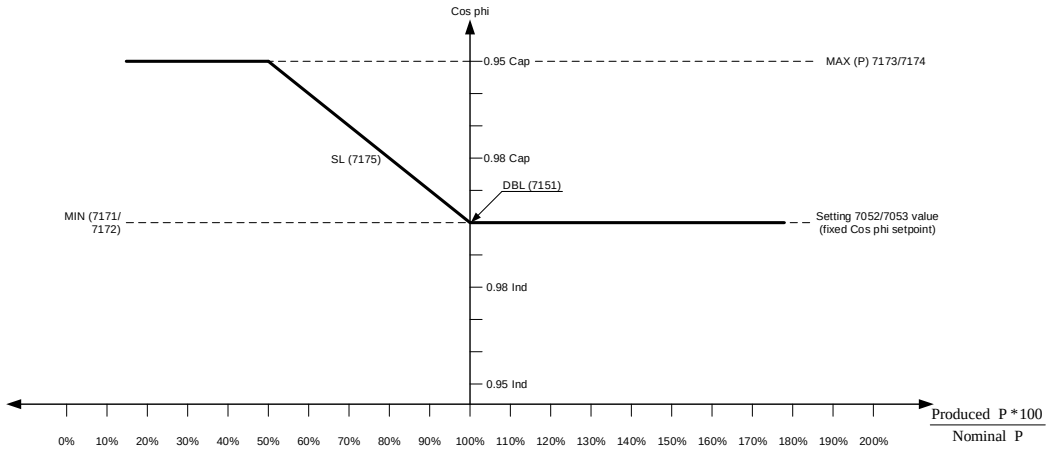
Power-dependent cos phi control is a function that gives a dynamic cos phi control in a parallel to mains system based on the generator-produced power. The purpose is to support the mains voltage locally behind a transformer by minimising the reactive current flow in the grid.

These settings are only relevant if: menu 7182 is set to "P", and menu 7183 is set to "ON".

Menu	Settings	Name	Description
7052	1.0	cos phi	Fixed cos phi set point 0.6 to 1.
7053	Inductive	cos phi	Fixed cos phi inductive/capacitive selection.
7151	0.00	DBL[%]	Deadband low in percentages of nominal power. In this example set to 0 to disable the deadband.
7152	50.00	DBH[%]	Deadband high in percentages of nominal power. In this example, the deadband is set high as the droop is not expected to be used.
7153	1.00 %	HYSL[%]	Hysteresis high in percentages of nominal power. If HYSL is set above the value of 7152(DBH), the hysteresis high is disabled.
7154	51.00	HYSH[%]	Hysteresis high in percentages of nominal power. If HYSL is set above the value of 7152(DBH), the hysteresis high is disabled. In this example the hysteresis is disabled.
7171	1.0	MI	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.
7172	Inductive	I/C	Minimum output of droop handling (inductive/capacitive selection).
7173	0.95	MA	Maximum output of droop handling (voltage increasing). This setting is related to the setting in 7174.
7174	Capacitive	I/C	Maximum output of droop handling (inductive/capacitive selection).
7175	0.001	SL[cos phi/%]	Slope low. The setting determines the increase/decrease of cos phi reference per percentage the actual voltage drops below nominal.
7176	0.000	SH[cos phi/%]	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 %.
7181	cos phi(X2)	Y2(X2)	Output type for curve 2. Selections currently available "Reactive Power" and "cos phi".

If selecting reactive power control in setting 7181, the programming is similar to that of frequency droop (y1(x1)). Please refer to the Designer's Reference Handbook explanation of frequency droop.

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.

AGC-4 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.

AGC: this function is only active when generator is parallel to grid.

GPC/PPU: this function is only active when "fixed cos phi" or "fixed Q" mode is activated, dependent on the setting in menu 7143.

PPM: this function is not supported.

5. Parameters

5.1 Further information

The option D1 relates to the parameters 2640-2690, 2730, 2750 and 2783; for voltage-dependent cos phi/Q control parameter 7150/7180.

For further information, please see the separate parameter list for the Multi-line unit in question:

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