Technical Information

Grid Support Utility Interactive Inverters for SMA Central Inverters

Sunny Central-US and Sunny Central Storage-US

Sunny Central UP-US and Sunny Central Storage UP-US

ENGLISH

SC_SCS-US-GridServices-TI-en-11 | Version 1.1

Table of Contents

1 Grid Support Utility Interactive Inverters

1.1 Content and Structure of this Document

In this document, the advanced inverter functions (see Section 1.2, page 3) as well as the SMA inverters equipped with these functions (see Section 1.3, page 3) are presented in accordance with the current UL 1741 SA "Grid Support Utility Interactive Inverters and Converters".

In addition, the advanced inverter functions are presented in detail (see Section 2, page 5). The following structure is being used:

- Function description in accordance with UL 1741 SA "Grid Support Utility Interactive Inverters and Converters" with the most important key values
- Implementation of the individual functions with SMA invertes via Speedwire/Webconnect parameters or Modbus registers (SMA Modbus or SunSpec Modbus)
- Maximum value tested
- Minimum value tested
- Value tested according to CPUC Rule 21 or tested average

Depending on the product, the functions can be configured via the user interface of the inverter or a communication product (e.g. SMA Cluster Controller). Depending on the availability, the configuration can also be performed using SMA Modbus or SunSpec Modbus. Information on how to change operating parameter can be found in the respective documentation at www.SMA-Solar.com.

1.2 Advanced Functionality of SMA Inverters

Inverters convert direct current into grid-compliant alternating current. If the grid voltage or grid frequency exceeds the thresholds specified by the grid operator, the grid-tied inverters must stop to feed in alternating current and disconnect from the utility grid in accordance with local standards and directives.

Inverters are also able to modulate their output power to support the utility grid interactively. Inverters react to changes in the utility grid by varying their power factor for example or by achieving an improved grid stability using other grid management services.

With the growth of the PV industry and a rising proportion of PV power in allover power generation, it becomes increasingly important that PV inverters make a significant contribution to improved grid stability and grid services. The prerequisite for this is the smart grid interconnection of PV inverters with an advanced inverter function to the grid in accordance with the current UL 1741 SA "Grid Support Utility Interactive Inverters and Converters".

1.3 Interactive SMA Inverters

The following SMA inverters feature from firmware version 04.00.10.R advanced inverter functions in accordance with the current UL 1741 SA "Grid Support Utility Interactive Inverters and Converters":

- Sunny Central 1850-US (SC-1850-US-10)
- Sunny Central 2000-EV-US (SC-2000-EV-US-10)
- Sunny Central 2200-US (SC-2200-US-10)
- Sunny Central 2500-EV-US (SC-2500-EV-US-10)
- Sunny Central 2750-EV-US (SC-2750-EV-US-10)
- Sunny Central 4000 UP-US (SC-4000 UP-US)
- Sunny Central 4200 UP-US (SC-4200 UP-US)
- Sunny Central 4400 UP-US (SC-4400 UP-US)
- Sunny Central 4600 UP-US (SC-4600 UP-US)
- Sunny Central Storage 2200-US (SCS2200-US-10)
- Sunny Central Storage 2475-US (SCS2475-US-10)

- Sunny Central Storage 2500-EV-US (SCS2500-EV-US-10)
- Sunny Central Storage 2750-EV-US (SCS2750-EV-US-10)
- Sunny Central Storage 2900-US (SCS2900-US-10)
- Sunny Central Storage 2750 UP-US (SCS-2750UP-US)
- Sunny Central Storage 3450 UP-US (SCS-3450UP-US)
- Sunny Central Storage 3600 UP-US (SCS-3600UP-US)
- Sunny Central Storage 3800 UP-US (SCS-3800UP-US)
- Sunny Central Storage 3950 UP-US (SCS-3950UP-US)

The parameters of inverters with the target country "2U" are set according to the current UL 1741 SA upon delivery.

2 Function Description

2.1 Islanding Detection "Anti Islanding"

The islanding detection function detects the formation of unwanted electrical islands and disconnects the inverter from the utility grid. Unwanted islanding can occur when at the time of utility grid failure, the load in the shut-down sub-grid is roughly equivalent to the current feed-in power of the PV system or battery storage system. With active islanding detection, the inverter continuously checks the stability of the utility grid. If the utility grid is intact, this has no impact on the utility grid and the inverter continues to feed in. Only if an unwanted electrical island has formed will the inverter disconnect from the utility grid.

The islanding detection function is activated by default according to US Rule 21 in parameter **Aid.Mod**.

2.2 Grid Support Depending on Grid Voltage "Low/High Voltage Ride-Through"

Three thresholds for minimum grid voltage and two thresholds for maximum grid voltage are defined in accordance with UL 1741 SA during grid support depending on the grid voltage "Low/High Voltage Ride-Through (L/H VRT)". Each maximum threshold may be exceeded and each minimum threshold may be undershot for a certain time. The permitted overvoltage and undervoltage ranges are derived from these thresholds and time frames.

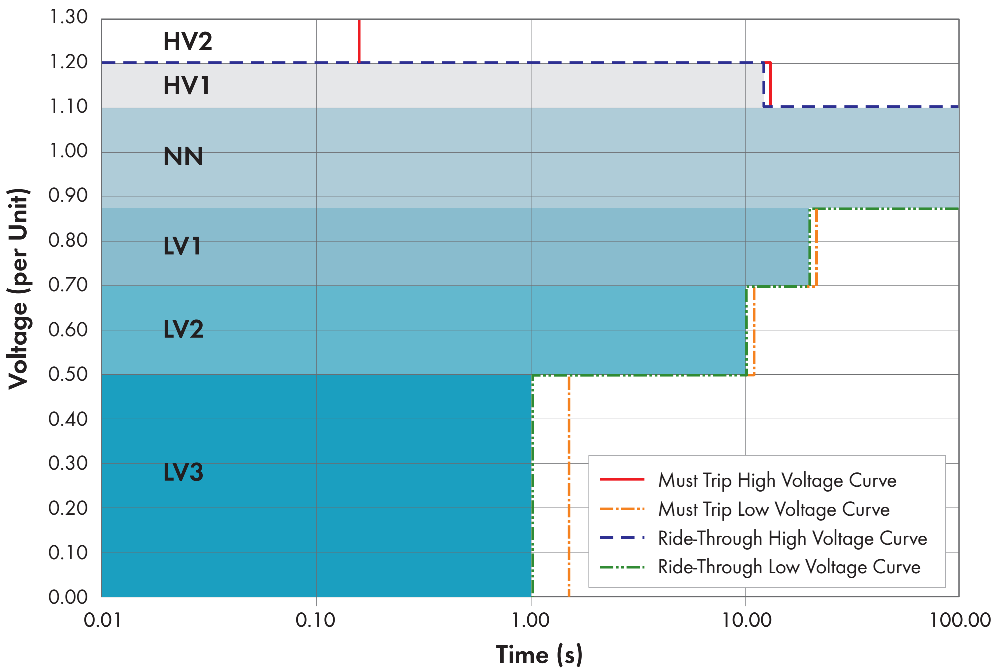

Figure 1: Overvoltage and undervoltage ranges for grid support in accordance with the "Low/High Voltage Ride-Through"

Designation	Description
Voltage (per unit)	Nominal voltage of the connected inverter
Must Trip High Voltage	This curve specifies the thresholds within which the shutdown process of the inverter must be completed when permitted voltage values are exceeded.
Must Trip Low Voltage	This curve specifies the thresholds within which the shutdown process of the inverter must be completed when permitted voltage values are undershot.

Designation	Description
Ride-Through High Voltage	In the "Mandatory Operation" mode, this curve specifies how long the inverter must continue feeding in when permitted voltage values are exceeded. In the "Momentary Cessation" mode, the inverter must have regulated its output current to <10% of the nominal current within 160 ms, and must remain in this regulated state for the Ride-Through period. Once the voltage is within the nominal voltage range again after expiry of this period, the inverter switches back to normal feed-in operation. If the voltage overshoot lasts, the inverter disconnects from the utility grid within the Must-Trip period.
Ride-Through Low Voltage	In the "Mandatory Operation" mode this curve specifies how long the inverter must continue feeding in when permitted voltage values are undershot. In the "Momentary Cessation" mode, the inverter must have regulated its output current to <10% of the nominal current within 160 ms in case of insufficient voltage, and must remain in this regulated state for the Ride-Through period. Once the voltage is within the nominal voltage range again after expiry of this period, the inverter switches back to normal feed-in operation. If the voltage undershoot lasts, the inverter disconnects from the the utility grid within the Must-Trip period.
HV	Overvoltage range
NN	Range around nominal grid voltage
LV	Undervoltage range

The inverter continuously checks the grid voltage. The inverter reacts to non-permitted overvoltages and undervoltages in accordance with the set operating mode:

- "Mandatory Operation" mode

  In the "Mandatory Operation" mode, the inverter continues to feed in up to a set point in time (Ride Through) and then starts the shutdown process. The "Mandatory Operation" mode is always active. You can configure the thresholds of the overvoltage or undervoltage ranges via the parameters listed in the corresponding table.

  The inverter switches to the "Mandatory Operation" mode for the voltage ranges LV1 and LV2.

- "Momentary Cessation" mode

  In the "Momentary Cessation" mode, the inverter reduces its output power to <10% of the nominal current within 160 ms and remains in this state up to a set point in time (Ride Through). If the voltage overshoot or undershoot continues after the Ride-Through period has expired, the inverter starts the shutdown process. The inverter switches to the "Momentary Cessation" mode when the set thresholds exceed or fall below the voltage range. When the grid voltage is outside the specified voltage range, the inverter operates in "Mandatory Operation" mode.

  The inverter switches to the "Momentary Cessation" mode for the voltage ranges HV1, HV2 and LV3.

The time within which the shutdown process must be completed is saved in the inverter via an adjustable parameter defining the time interval before the latest possible shutdown time (Must Trip).

Settings Overview for the Disconnection from the Utility Grid in Case of a Voltage Variation

Required parameters in accordance with UL 1741 SA	Parameter name	Minimum	Maximum	Default value
Overvoltage range HV1	VCtl.Hi1Lim	100% V_{nom}	120% V_{nom}	110% V_{nom}
	VCtl.Hi1LimTm	100 ms	60000 ms	12500 ms
Overvoltage range HV2	VCtl.Hi2Lim	100% V_{nom}	120% V_{nom}	120% V_{nom}
	VCtl.Hi2LimTm	100 ms	59000 ms	160 ms
Additional overvoltage range*	VCtl.Hi3Lim	100% V_{nom}	120% V_{nom}	–
	VCtl.Hi3LimTm	100 ms	59000 ms	–
Undervoltage range LV1	VCtl.Lo1Lim	45.00% V_{nom}	100% V_{nom}	86% V_{nom}
	VCtl.Lo1LimTm	100 ms	60000 ms	20500 ms
Undervoltage range LV2	VCtl.Lo2Lim	45.00% V_{nom}	100% V_{nom}	69% V_{nom}
	VCtl.Lo2LimTm	100 ms	60000 ms	10500 ms
Undervoltage range LV3	VCtl.Lo3Lim	45.00% V_{nom}	100% V_{nom}	49% V_{nom}
	VCtl.Lo3LimTm	100 ms	60000 ms	1250 ms

* The additional overvoltage range is not required in accordance with UL 1741 SA and Rule 21. However, it can be optionally set.

In order to receive the certification as per UL 1741 SA on the basis of the requirements from Rule 21, the set thresholds must not be changed.

2.3 Grid Support Depending on Power Frequency "Low/High Frequency Ride-Through"

Two frequency thresholds both for minimum grid frequency and maximum grid frequency are defined in accordance with UL 1741 SA / Rule 21 during grid support in dependence of the grid frequency "Low/High Frequency Ride-Through (L/H FRT)". Each maximum frequency threshold may be exceeded and each minimum frequency threshold may be undershot for a certain time. The permitted ranges for exceeding or falling below the set frequency are derived from these frequency thresholds and time frames.

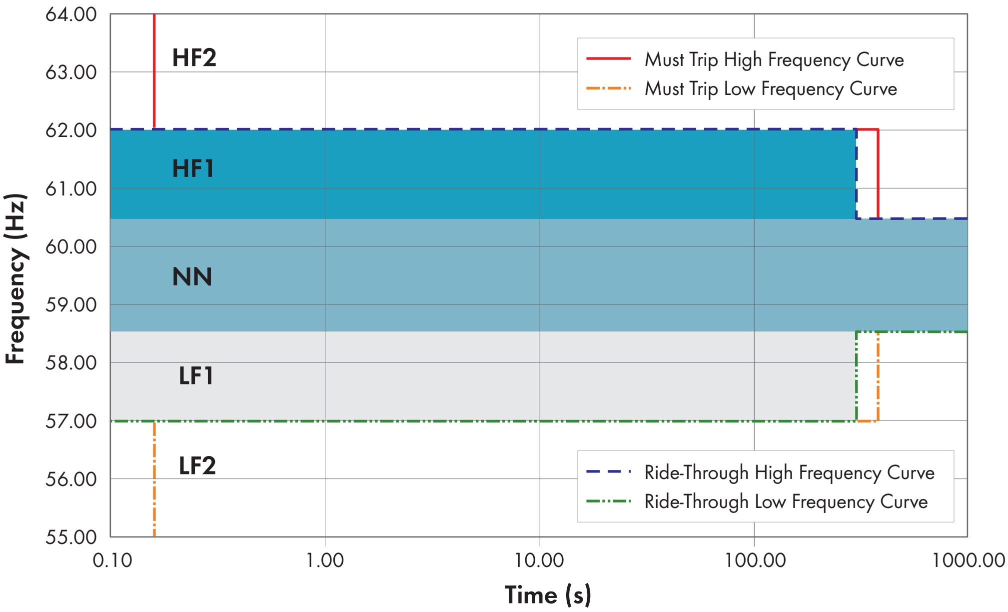

Figure 2: Ranges for exceeding or falling below the set frequency during "Low/High Frequency Ride-Through"

Designation	Description
Must Trip High Frequency	This curve specifies the thresholds within which the shutdown process of the inverter must be completed when permitted frequency is exceeded.
Must Trip Low Frequency	This curve specifies the thresholds within which the shutdown process of the inverter must be completed when permitted frequency is undershot.
Ride-Through High Frequency	This curve specifies how long the inverter must continue feeding in when permitted frequency is exceeded.
Ride-Through Low Frequency	This curve specifies how long the inverter must continue feeding in when permitted frequency is undershot.

The inverter continuously checks the power frequency. The inverter continues to feed in up to a set point in time (Ride Through) when the frequency is exceeded or undershot and then starts the shutdown process. The time within which the shutdown process must be completed is saved in the inverter via an adjustable parameter defining the time interval before the latest possible shutdown time (Must Trip).

The grid support in dependence of the grid frequency is activated by default. You can configure the thresholds via the parameters listed in the following table. The inverter always operates in "Mandatory Operation" mode during grid support in dependence of the grid frequency.

Settings overview for the disconnection from the utility grid in case of a frequency change

Required parameters in accordance with UL 1741 SA	Parameter name	Minimum	Maximum	Default value
Exceeding range of frequency HF1	HzCtl.Hi1Lim	60.1 Hz	62.1 Hz	60.5 Hz
	HzCtl.Hi1LimTm	100 ms	300000 ms	299600 ms
Exceeding range of frequency HF2	HzCtl.Hi2Lim	60.6 Hz	62.1 Hz	62 Hz
	HzCtl.Hi2LimTm	100 ms	10000 ms	160 ms
Permitted range if frequency LF1 falls below a specific value	HzCtl.Lo1Lim	57 Hz	60 Hz	58.5 Hz
	HzCtl.Lo1LimTm	100 ms	300000 ms	299600 ms
Permitted range if frequency LF2 falls below a specific value	HzCtl.Lo2Lim	57 Hz	60 Hz	57 Hz
	HzCtl.Lo2LimTm	100 ms	10000 ms	160 ms

In order to receive the certification as per UL 1741 SA on the basis of the requirements from Rule 21, the set thresholds must not be changed.

2.4 Ramp Rate During Normal Operation "Normal Ramp Rate"

Parameter **AmpGra** can be used to define how the inverter increases its output power when the PV power is increased (fluctuation of the irradiation). This means that the inverter, with constant voltage, gradually increases the power per second by the rate of increase set in this parameter. The rate of increase is set to 100%/s by default. You can configure the rate of increase via the parameters listed in the table.

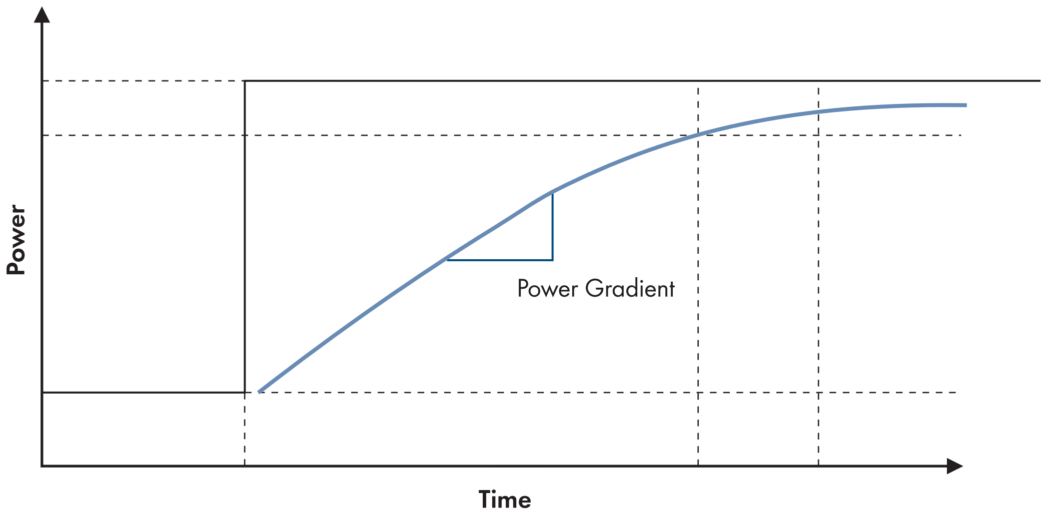

Figure 3: Characteristic curve for inverter ramp-up in "Normal Ramp Rate" mode

Overview of the Required Settings

Required settings in accordance with UL 1741 SA	Parameter name with Speedwire/ Webconnect	Minimum	Maximum	Rule 21
Rate of increase "Power Gradient" for ramp-up of defined power	AmpGra	0.17% I_{nom}/s	100% $I_{nom/s}$	100% $I_{nom/s}$

2.5 Ramp-Up After Grid Fault "Soft Start Ramp Rate"

Via the function "Soft Start Ramp Rate", you can define how the inverter is to begin with power feed-in after a grid fault. The rate of increase for power feed-in has the same specifications as the function "Normal Ramp Rate". The function "Soft Start Ramp Rate" is activated by default in the parameter **WGraReconMod**. The inverter connects with a rate of increase of 100% of the nominal current per second. You can change the rate of increase via the parameters listed in the table.

In addition, a preset time delay of 300 s is activated. After a grid failure, the inverter will wait for the set delay before feeding into the grid again so that the utility grid can stabilize first. You can change the time of delay via the parameters listed in the table.

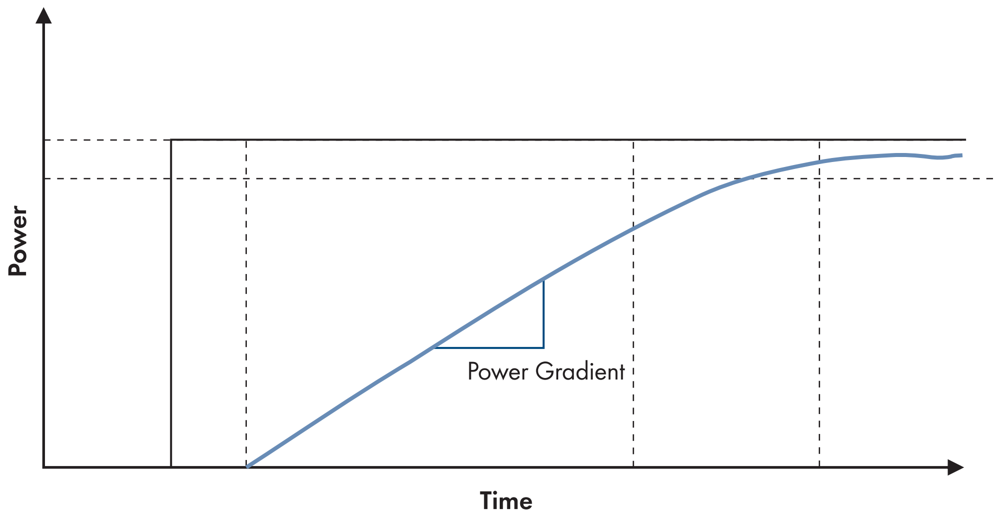

Figure 4: Characteristic curve for inverter ramp-up according to the "Soft Start Ramp Rate" function

Overview of the Required Settings

Required settings in accordance with UL 1741 SA	Parameter name with Speedwire/ Webconnect	Minimum	Maximum	Default value
Rate of increase "Power Gradient" for ramp-up of defined power	WGraRecon	0.17% $I_{nom/s}$	100% $I_{nom/s}$	100% $I_{nom/s}$
Time delay during re-connection after a grid failure	GriErrTm	-	-	-

2.6 Fixed specification of a power factor cos φ "Specified Power Factor"

The reactive power is controlled as a function of a fixed power factor cos φ.

The function is deactivated by default. You can activate the function. Depending on the specification source, set the parameter **GriMng.VArMod** to **PFCtlAnIN**, **PFCtlCom**, **AutoCom** or **PFCtlMan**. The power factor is set to 1 by default after activation. You can configure the power factor and the excitation type of the power factor via the parameters listed in the table.

$$P = S \cdot \cos\varphi$$

$$\cos\varphi = \frac{P}{S} = \frac{2200\ \text{kW}}{2750\ \text{kVA}} = 0.8$$

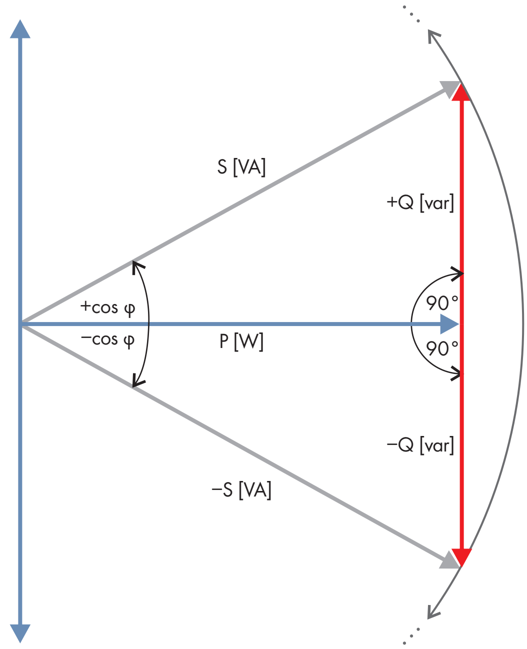

Figure 5: Diagram "Specified Power Factor (cos φ)" with calculation example

Overview of the Required Settings

Required settings in accordance with UL 1741 SA	Parameter name	Minimum	Maximum	Default value
Selecting the setpoint for the reactive power	GriMng.VArMod	-	-	Off
Power factor cos φ	PFCtlCom (for specifications via Modbus protocol) PFCtlMan (for specifications via parameters) PFCtlAnIn (for specifications via ripple control signal via analog inverter inputs)	-0.8	0.8	1

2.7 Reactive Power Control as a Function of Grid Voltage "Volt-Var Mode"

The reactive power is controlled as a function of the grid voltage. By supplying reactive power, the inverter performs voltage-stabilizing measures in the event of overvoltage or undervoltage. The parameterization is carried out by means of a reactive power/voltage characteristic curve.

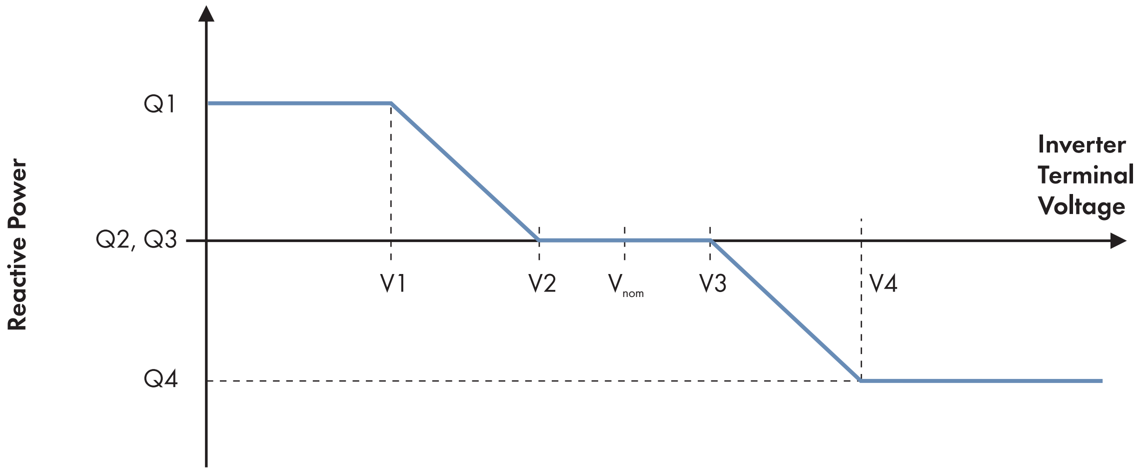

Figure 6: Characteristic curve "Volt-Var" (in this example Q2 and Q3 are the same.)

A quotient is derived from the ratio of the current grid voltage to nominal grid voltage. When the grid voltage is equal to the defined nominal voltage, the reactive power feed-in is zero. If the grid voltage changes and exceeds or falls short of a defined threshold, the inverter reacts according to the voltage/reactive power characteristic curve by adjusting its reactive power feed-in. Four values can be set for each voltage quotient and the applicable reactive power setpoints separately defined. Four interpolation points can be defined through this parameterization. Thus, the reactive power/voltage characteristic curve can be flexibly configured.

The reactive power control as a function of grid voltage is deactivated by default. Parameter **GriMng.InvVArMod** must be set to **VArCtlVol** to activate this function. You must activate the characteristic curve before activating the function. The configuration should take place based on mutual agreement between the PV system operator and the grid operator. You can change the configuration of this characteristic curve via the parameters listed in the table.

Overview of the Required Settings

	Characteristic curve		**in % of V_{nom}**		**in % of S_{rtg}**
1	Most Aggressive	V1	98	Q1	60
		V2	100	Q2	0
		V3	100	Q3	0
		V4	102	Q4	-60
2	Average	V1	91.9	Q1	30
		V2	93.5	Q2	0
		V3	106.5	Q3	0
		V4	108.1	Q4	-30

	Characteristic curve		in % of V_{nom}		in % of S_{rtg}
3	Least Aggressive	V1	85	Q1	15
		V2	87	Q2	0
		V3	113	Q3	0
		V4	115	Q4	-15
4	Least Aggressive +	V1	85	Q1	15
		V2	100	Q2	0
		V3	100	Q3	0
		V4	115	Q4	-15

Least Aggressive+ is an additionally certified configuration with minimal deadband and minimal gradients.

Relevant Parameters for the Characteristic Curve Configuration

Parameter	Most Aggressive	Average	Least Aggressive	Least Aggressive +	Unit*
VArCtlVol.HiGra1	30	0	0	1	p.u.
VArCtlVol.HiGra2	0	18.75	7.5	0	p.u.
VArCtlVol.HiGra3	0	0	0	0	p.u.
VArCtlVol.HiVolRef2	2	1.065	1.13	2	p.u.
VArCtlVol.HiVolRef3	2	1.081	1.15	2	p.u.
VArCtlVol.LoGra1	30	0	0	1	p.u.
VArCtlVol.LoGra2	0	18.75	7.5	0	p.u.
VArCtlVol.LoGra3	0	0	0	0	p.u.
VArCtlVol.LoVolRef1HiVolRef1	1	1	1	1	p.u.
VArCtlVol.LoVolRef2	0	0.935	0.87	0	p.u.
VArCtlVol.LoVolRef3	0	0.919	0.85	0	p.u.

* 1 p.u. corresponds to 100%

Permitted Adjustment Range According to UL 1741 SA

Parameter	Minimum	Maximum	Unit*
VArCtlVol.HiGra1	0	30	p.u.
VArCtlVol.HiGra2	0	30	p.u.
VArCtlVol.HiGra3	0	30	p.u.
VArCtlVol.HiVolRef2	1	2	p.u.

Parameter	Minimum	Maximum	Unit*
VArCtlVol.HiVolRef3	1	2	p.u.
VArCtlVol.LoGra1	1	30	p.u.
VArCtlVol.LoGra2	0	30	p.u.
VArCtlVol.LoGra3	0	30	p.u.
VArCtlVol.LoVolRef1HiVolRef1	1	1	p.u.
VArCtlVol.LoVolRef2	0	1	p.u.
VArCtlVol.LoVolRef3	0	1	p.u.

* 1 p.u. corresponds to 100%

2.8 Active Power Limitation Depending on Power Frequency "Frequency-Watt Mode"

In the case of active power limitation depending on power frequency, the inverter constantly checks the connected power frequency and if necessary regulates the active power feed-in.

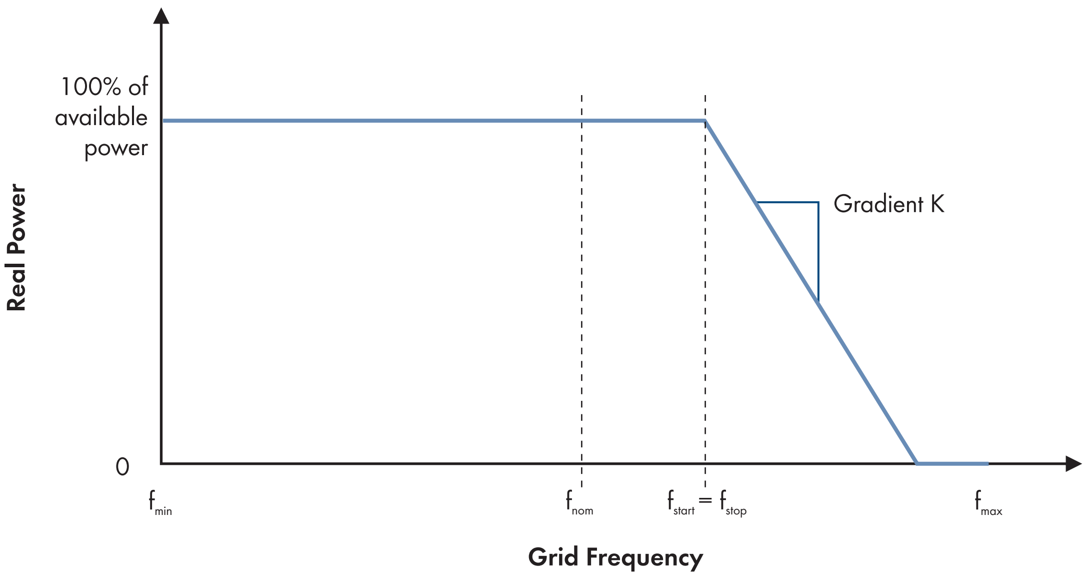

Figure 7: Characteristic curve "Frequency-Watt"

If the grid frequency exceeds a defined starting frequency, the inverter reduces the active power feed-in with a defined gradient. When the grid frequency is dropping, the inverter increases the active power again according to this defined gradient. In order to map the required characteristic curve in accordance with UL 1741 SA, the starting frequency and the stopping frequency must be set to the same value in the inverter.

The active power limitation depending on grid frequency is deactivated by default. For activating this function, the parameter **WCtlHzMod** has to be set to **Enable**. Before activating the function, you should configure the characteristic curve via the parameters listed in the table.

Overview of the Required Settings

Characteristic curve	WCtlHz.Hz1 & WCtlHz.HzStopMax [Hz]	WCtlHz.HzGra1 [pu/Hz]
Characteristic 1 (maximum slope, minimum dead band)	60	2

Characteristic curve	WCtlHz.Hz1 & WCtlHz.HzStopMax [Hz]	WCtlHz.HzGra1 [pu/Hz]
Characteristic 2 (minimum slope, maximum dead band)	62	1
Additional Characteristic 3 (minimum slope, minimum dead band)	60	0.167

Characteristic 3 is an additionally certified configuration with minimal deadband and minimal gradients.

Relevant parameters for the characteristic curve configuration

Parameters	Characteristic 1	Characteristic 2	Characteristic 3*	Unit
WCtlHz.Hz1	60	62	60	Hz
WCtlHz.Hz2	65	65	65	Hz
WCtlHz.Hz3	65	65	65	Hz
WCtlHz.Hz4	65	65	65	Hz
WCtlHz.HzGra1	2	1	0.167	p.u./Hz
WCtlHz.HzGra2	0	0	0	p.u./Hz
WCtlHz.HzGra3	0	0	0	p.u./Hz
WCtlHz.HzGra4	0	0	0	p.u./Hz

* Characteristic 3 is an additionally certified configuration with minimal deadband and minimal gradients.

Permitted adjustment range according to UL 1741 SA

Parameters	Minimum	Maximum	Unit
WCtlHz.Hz1	60	62	Hz
WCtlHz.Hz2	60	65	Hz
WCtlHz.Hz3	60	65	Hz
WCtlHz.Hz4	60	65	Hz
WCtlHz.HzGra1	0.167	2	p.u./Hz
WCtlHz.HzGra2	0.167	2	p.u./Hz
WCtlHz.HzGra3	0.167	2	p.u./Hz
WCtlHz.HzGra4	0.167	2	p.u./Hz

ENERGY
THAT
CHANGES

SMA