Conext™ Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB Grid Tie Photovoltaic Inverter

Grid Support Guide

AP-XC-003 Revision J

March 2017

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Overview

DANGER

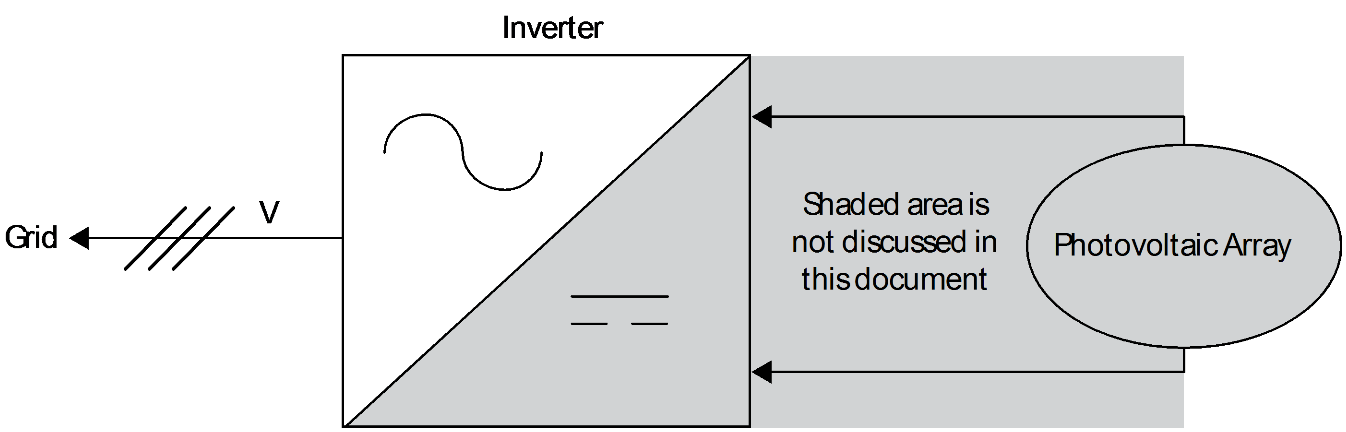
HAZARD OF ELECTRIC SHOCK, EXPLOSION, ARC FLASH, AND FIRE

This document is in addition to, and incorporates by reference, the relevant product manuals for Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB grid tie photovoltaic inverters. Before reviewing this document, you must read the relevant product manuals. Unless specified, information on safety, specifications, installation and operation is as shown in the primary documentation received with the product. Ensure you are familiar with that information before proceeding.

Failure to follow these instructions will result in death or serious injury.

The Schneider Electric Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverters are designed to draw power from photovoltaic (PV) arrays, convert it to alternating current, and transfer it to the utility grid on demand. The relationship between the inverter, PV array and grid is shown below.

Figure 1 Relationship between inverter, PV array, and grid



The inverter firmware uses a series of algorithms with preset default values to match the power frequencies and voltage levels of the grid. The firmware also contains parameters that determine how the inverter interacts with the grid. *Grid qualification* parameters determine when the inverter disconnects and reconnects to the grid. *Grid support* parameters determine how voltage and frequency are supported.

The values of most grid parameters are pre-determined by the utility region that is assigned to the inverter. When an adjustment is required to any of these pre-determined values, you should carefully consider the impact on inverter and grid operations before making the change. Discuss the proposed change with the local Authority Having Jurisdiction (AHJ).

⚠ WARNING

UNEXPECTED EQUIPMENT OPERATION

Do not change any parameter setting unless you fully understand the implications on Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB operation.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

This document explains how a Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverter maintains continuous operation and continuous output current during normal operating conditions and during grid-related events.

Abbreviations and Acronyms

AHJ	Authority Having Jurisdiction
FRT	Frequency ride through
HF	High frequency
HFRT	High frequency ride through
HV	High voltage
HVRT	High voltage ride through
I_{Lmax}	Maximum AC output current
LF	Low frequency
LFRT	Low frequency ride through
LV	Low voltage
LVRT	Low voltage ride through
MPPT	Maximum power point tracking
OVSPD	Overvoltage soft power down
P	Active power
P(f)	Power as a function of frequency
$P_{out-max}$	Maximum obtainable active power
P_{user}	User setting for active power limit
pf	Power factor
φ_{user}	User setting for phase angle reference
p.u.	per unit
PV	Photovoltaic
PVCQ	PV with constant reactive power (operating mode)
Q	Reactive power

Q_{AVR}	Reactive power for voltage regulation
Q_{max}	Maximum reactive power
Q_{out}	Reactive power output
Q_{user}	User setting for reactive power limit
S	Apparent power
S_{max}	Maximum apparent power
Vac	Line-to-line voltage (measured)
vHF	Very high frequency
vHV	Very high voltage
vLF	Very low frequency
vLV	Very low voltage
VRT	Voltage ride through

Related Information

You can find more information about Schneider Electric Solar Business as well as its products and services at http://solar.schneider-electric.com/.

2 Support Under Abnormal Grid Conditions

What's in This Chapter?

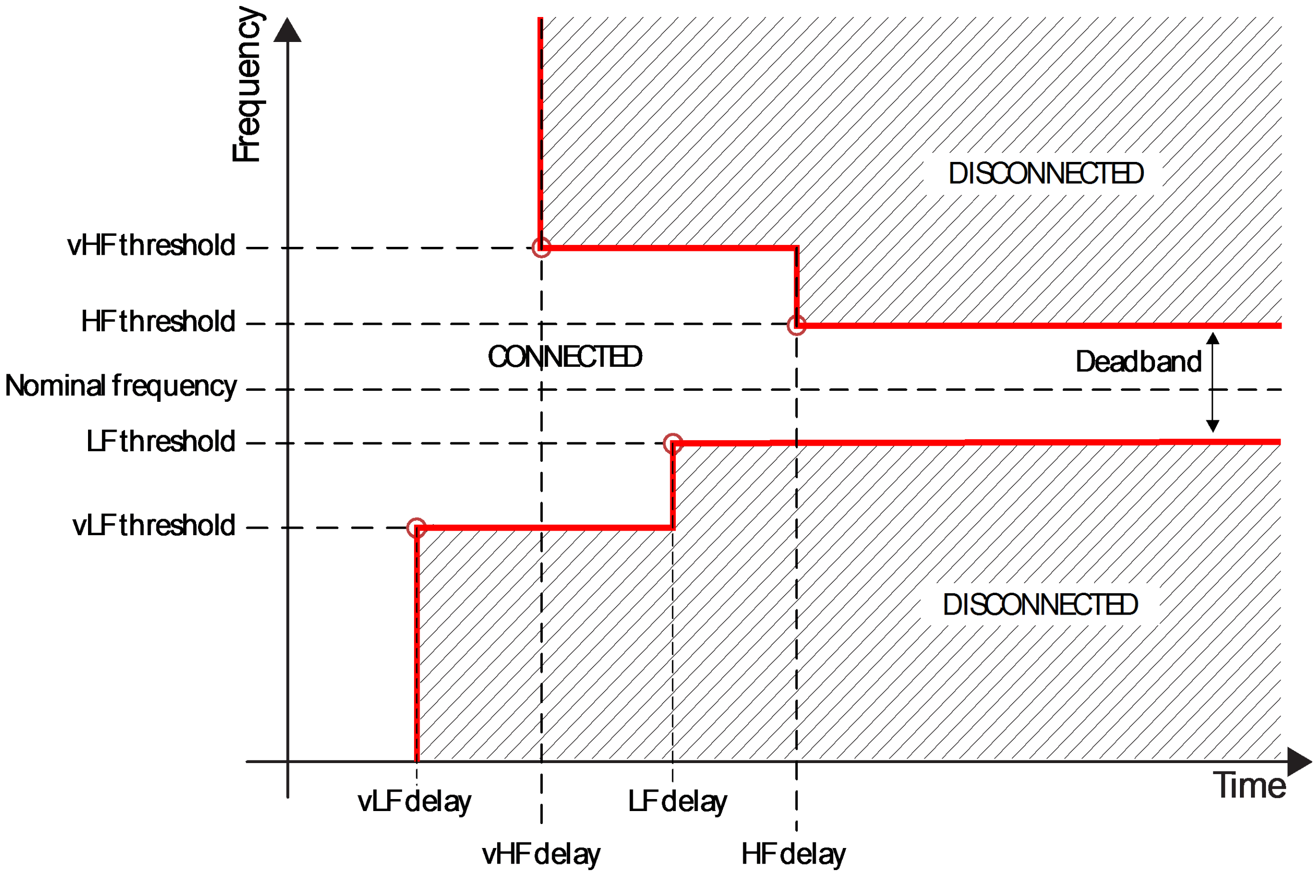
Overview

This chapter describes and illustrates how an inverter reacts to *abnormal* grid-related events. Abnormal events occur when the grid voltage or frequency is outside of the operating deadband (that is, outside of normal conditions).

Frequency Ride Through

Frequency ride through (FRT) is the capability of the inverter to maintain output current and remain online when the grid frequency is outside the nominal deadband. If grid frequency remains outside the deadband beyond a preset time, the inverter goes offline. The inverter reconnects to the grid when the frequency returns within the preset grid reconnect limit. *Figure 2* illustrates the FRT profile.

Figure 2 Frequency ride through profile



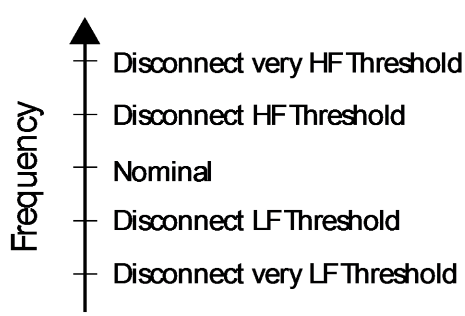
The parameters in *Table 1 on page 13* define when the inverter disconnects from the grid during abnormal frequency conditions.

Table 1 Over/under frequency grid disconnection parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA40	52.00	65.00	50.00	**Disconn very HF Threshold**	Value (Hz) at which, once crossed, disconnection occurs due to AC very high frequency.	Hz
0xFA42	3000	65535	0	**Disconn very HF Delay**	Length of time that the inverter must be above “Disconn very HF Threshold” before it disconnects.	ms
0xFA0F	51.50	65.00	50.00	**Disconn HF Threshold**	Value (Hz) at which, once crossed, disconnection occurs due to AC high frequency.	Hz
0xFA07	100	65535	0	**Disconn HF Delay**	Length of time that the inverter must be above “Disconn HF Threshold” before it disconnects.	ms
0xFA10	47.50	60.00	40.00	**Disconn LF Threshold**	Value (Hz) at which, once crossed, disconnection occurs due to AC low frequency.	Hz
0xFA08	10.00	655.35	0.00	**Disconn LF Delay**	Length of time that the inverter must be below “Disconn LF Threshold” before it disconnects.	sec
0xFA3D	40.00	60.00	40.00	**Disconn very LF Threshold**	Value (Hz) at which, once crossed, disconnection occurs due to AC very low frequency.	Hz
0xFA3F	3000	65535	0	**Disconn very LF Delay**	Length of time that the inverter must be below “Disconn very LF Threshold” before it disconnects.	ms

Figure 3 illustrates the dependencies that affect the frequency disconnection parameters.

Figure 3 FRT dependencies



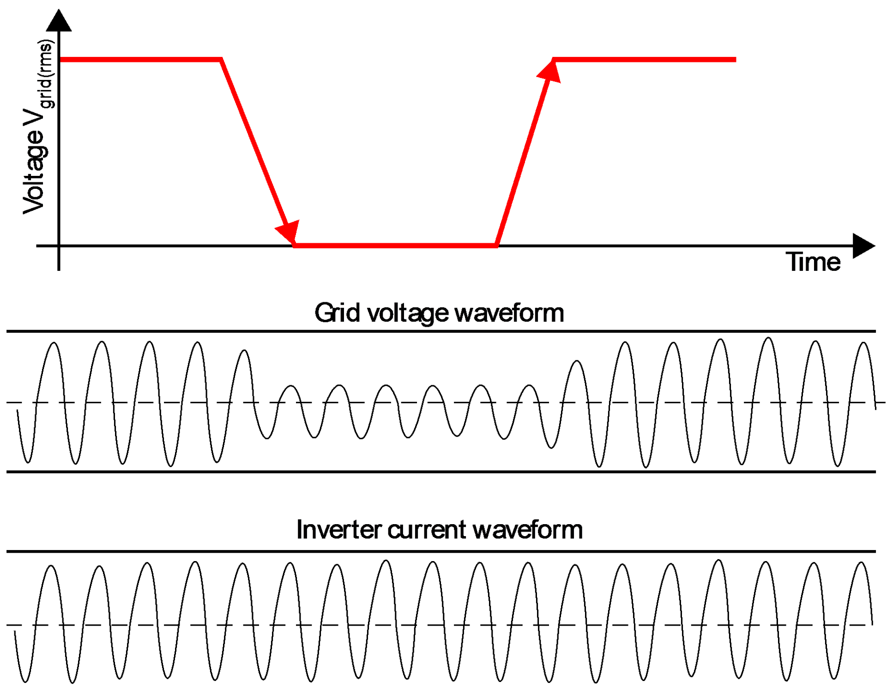
Voltage Ride Through

Voltage ride through (VRT) is the capability of the inverter to maintain output current and remain online when the voltage in the grid is temporarily outside the nominal deadband. When grid voltage drops below the preset low voltage (LV) threshold, the event is called *low voltage ride through* (LVRT). When grid voltage rises above the preset high voltage (HV) threshold, the event is called *high voltage ride through* (HVRT).

If voltage ride through extends beyond a preset delay time (the disconnect delay), the inverter goes offline. The inverter reconnects to the grid when the voltage returns within the preset grid reconnect limit.

During LVRT and HVRT, the inverter remains online and its output current is continuous, as illustrated in *Figure 4*.

Figure 4 Inverter output current during LVRT



The standard two-level VRT profile is illustrated in *Figure 5 on page 15*. Some utility regions require that the LVRT profile matches the critical fault clearing time, as illustrated in *Figure 6 on page 15*. You can choose the appropriate VRT profile by setting the “Disconn Profile” parameter (see *Table 2 on page 16*).

Figure 5 Two-level VRT profile

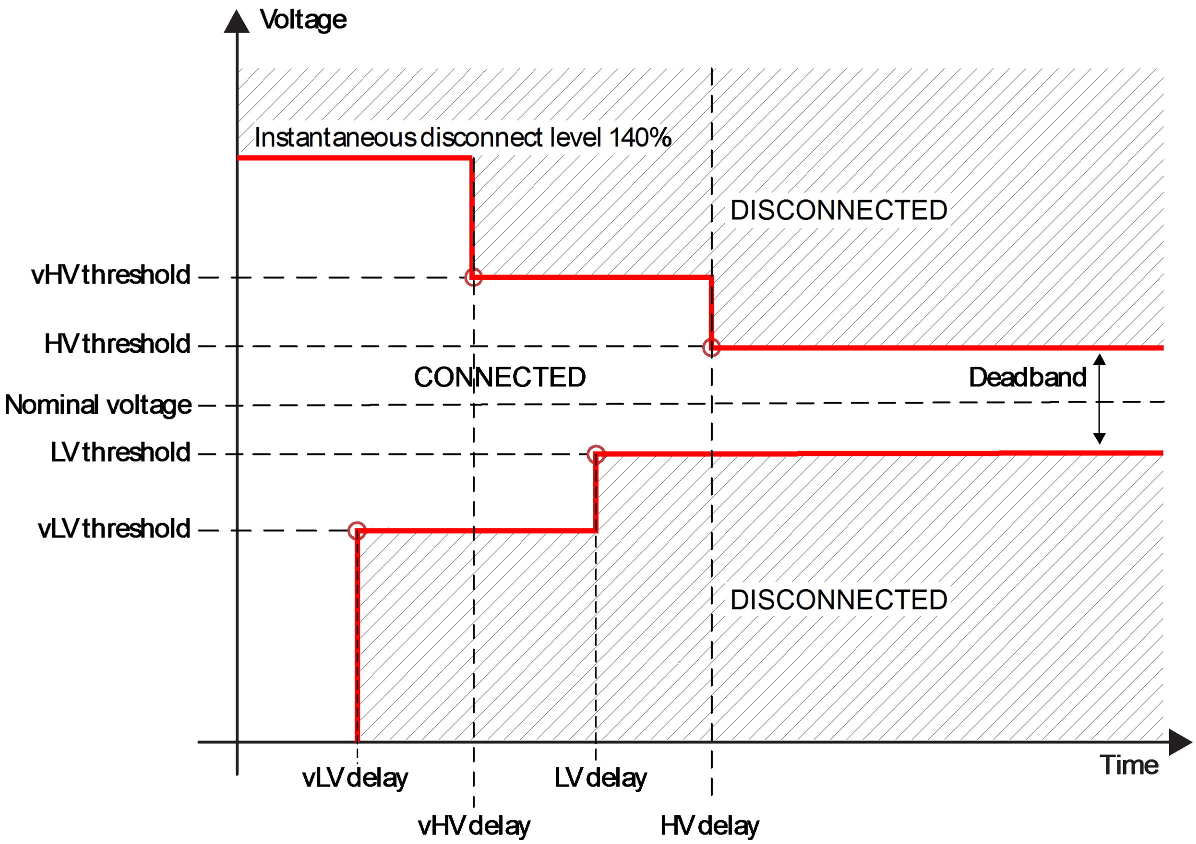
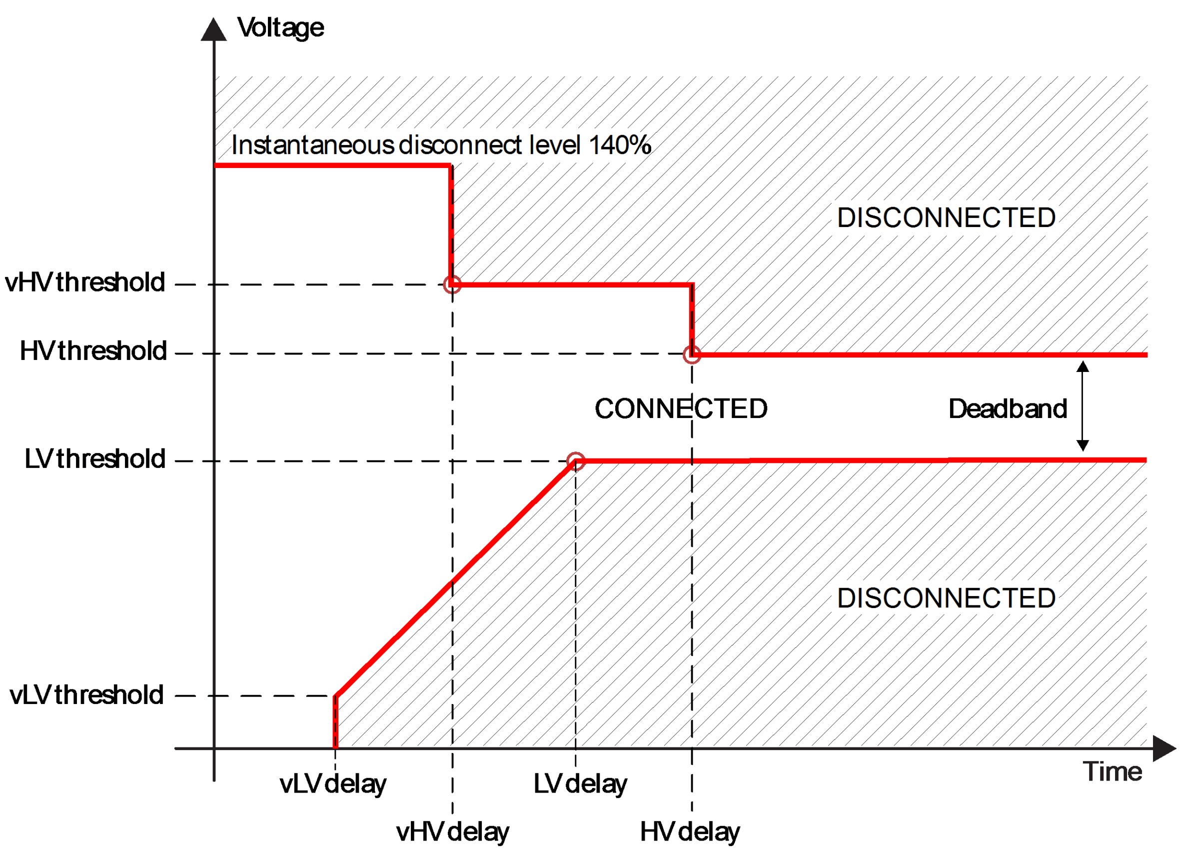


Figure 6 Critical fault clearing VRT profile



The parameters in *Table 2* define when the inverter disconnects from the grid during VRT.

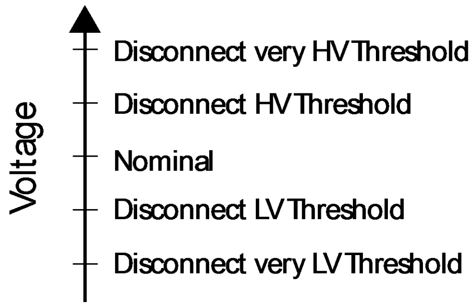
Table 2 Over/under voltage grid disconnection parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA36	300/350/ 380	450	280	**System L-to-L Voltage**	Nominal AC line to line voltage used as a reference to: 1. Decide if there is an AC voltage low or high condition. 2. Decide if it is ok to reconnect after a grid event disconnection. 3. Calculate voltage ride through (VRT) thresholds.	Vrms
0xFA37	120	140	100	**Disconn very HV Threshold**	Once this level, as a percentage of “System L-to-L voltage”, is crossed, disconnection occurs due to AC very high voltage.	%
0xFA39	3000	65535	0	**Disconn very HV Delay**	Length of time that the inverter must be above “Disconn very HV Threshold” before it disconnects.	ms
0xFA0B	120	120	100	**Disconn HV Threshold**	Once this level, as a percentage of “System L-to-L voltage”, is crossed, disconnection occurs due to AC high voltage.	%
0xFA05	100	65535	0	**Disconn HV Delay**	Length of time that the inverter must be above “Disconn HV Threshold” before it disconnects.	ms
0xFA0C	80	100	60	**Disconn LV Threshold**	Once this level, as a percentage of “System L-to-L voltage”, is crossed, disconnection occurs due to AC low voltage.	%
0xFA06	2000	65535	0	**Disconn LV Delay**	Length of time that the inverter must be below “Disconn LV Threshold” before it disconnects.	ms
0xFA3A	25	100	0	**Disconn very LV Threshold**	Once this level, as a percentage of “System L-to-L voltage”, is crossed, disconnection occurs due to AC very low voltage.	%
0xFA3C	1000	65535	0	**Disconn very LV Delay**	Length of time that the inverter must be below “Disconn very LV Threshold” before it disconnects.	ms

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB10	135	200	130	**Voltage Envelope Threshold**	Once this level, as a percentage of “System L-to-L voltage”, is crossed, disconnection occurs due to an instantaneous high AC voltage. For example: If “System L-to-L voltage” is set to 380 and “Voltage Envelope Threshold” is set to 135, the actual threshold value is 725.5 V instantaneous (380 x 1.35 x √2 = 725.5).	%
0xFB11	3	65535	1	**Voltage Envelope Delay**	Length of time (in samples) that the inverter must continuously be above “Voltage Envelope Threshold” before it disconnects. Each sample is 158 μs.	integer
0x408E	TWO LEVEL DISCONNECT	CRITICAL FAULT CLEARING	TWO LEVEL DISCONNECT	**Disconnect Profile**	Configurable LV disconnect profiles: TWO LEVEL DISCONNECT Profile with step change between “Disconn LV Threshold” and “Disconn very LV Threshold”. CRITICAL FAULT CLEARING Profile with ramp change between “Disconn LV Threshold” and “Disconn very LV Threshold”.	N/A
0xFB98	2.00	2.00	0.00	**Asymmetry Voltage Factor**	Level (as a multiplier of “System L-to-L voltage”) at which the voltage difference between grid phases triggers an asymmetric low voltage ride-through event. This value is represented by an integer in RenFile as a multiplier, 2.00 = 200%.	integer
0xFB99	0.40	1.00	0.00	**Asymmetry Current Limit Factor**	Maximum additive reactive current support during an asymmetric Voltage Ride-Through event as a multiplier of Nominal Line Current.	integer
0x40A8	ACTIVE AND REACTIVE IN LVRT	REACTIVE ONLY IN LVRT	ACTIVE AND REACTIVE IN LVRT	**LVRT Control Type**	Controls whether active power is suppressed during LVRT event. ACTIVE AND REACTIVE IN LVRT Active power NOT suppressed during LVRT. REACTIVE ONLY IN LVRT Active power suppressed during LVRT.	N/A

Figure 7 on page 18 illustrates the dependencies that affect the VRT disconnection parameters.

Figure 7 VRT dependencies



Reactive Current Injection During VRT

The Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB can provide reactive current in support of grid voltage during abnormal events. When the “Voltage Support Function” parameter is set to 1 (ON), the inverter injects either capacitive reactive current or inductive reactive current, depending on the grid voltage as follows:

Capacitive reactive current	is injected when...	grid voltage < “V-Support Low Threshold”
Inductive reactive current	is injected when...	grid voltage > “V-Support High Threshold”
No reactive current	is injected when...	“V-Support Low Threshold” ≤ grid voltage ≤ “V-Support High Threshold”

The parameters listed in *Table 3* define voltage support during voltage ride through events.

Table 3 Voltage support parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA24	ON	ON	OFF	**Voltage Support Function**	Determines whether the inverter provides reactive current in support of grid voltage during abnormal events. ON The inverter injects either capacitive reactive current or inductive reactive current, depending on the grid voltage. OFF Function disabled.	N/A
0xFA49	0.0	100.0	0.0	**Voltage Support Factor**	Constant that determines the amount of reactive current provided during VRT events, as a function of the depth of the voltage dip. Related to “Voltage Support Function” parameter above.	N/A

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA59	90	120	0	**V-Support Low Threshold**	Level (as a percentage of "System L-to-L voltage") below which the inverter will produce reactive current (overexcited, capacitive mode). Related to "Voltage Support Function" parameter above.	%
0xFA5A	110	150	30	**V-Support High Threshold**	Level (as a percentage of "System L-to-L voltage") above which the inverter will absorb reactive current (underexcited, inductive mode). Related to "Voltage Support Function" parameter above.	%
0x408D	0	2000	0	**V-Support Reset Time**	Length of time before the reactive current injection drops to zero after AC voltage reaches "V-Support Low Threshold" or "V-Support High Threshold".	ms
0xFBE0	100	100	0	Q(V) Q_{maxAVR}	Maximum reactive power reference used by "Voltage Support Function" to calculate the reactive power to be injected during VRT (Voltage Ride Through).	%

Reactive Current Injection During Symmetric VRT

If the "V-Support Reset Time" parameter is 0 (default) during symmetric VRT, the amount of reactive current provided by the inverter is calculated using equation (1).

$$\Delta I_{reactive\,(pu)} = \begin{cases} k \cdot \frac{I_n}{V_n}\left(V_{VRThigh} - V_{ac-psq}\right) & if \quad V_{VRThigh} < V_{ac-psq} \\ 0 \quad if \quad V_{VRTlow} \leq V_{ac-psq} \leq V_{VRThigh} & \\ k \cdot \frac{I_n}{V_n}\left(V_{VRTlow} - V_{ac-psq}\right) & if \quad V_{ac-psq} \leq V_{VRTlow} \end{cases} \quad (1)$$

where

$\Delta I_{reactive}$ = reactive current contribution during ride through

k = "Voltage Support Factor" parameter

I_n = "Nominal Line Current" parameter

V_n = "Nominal L-to-L Voltage" parameter

$V_{VRThigh}$ = "V-Support High Threshold" parameter

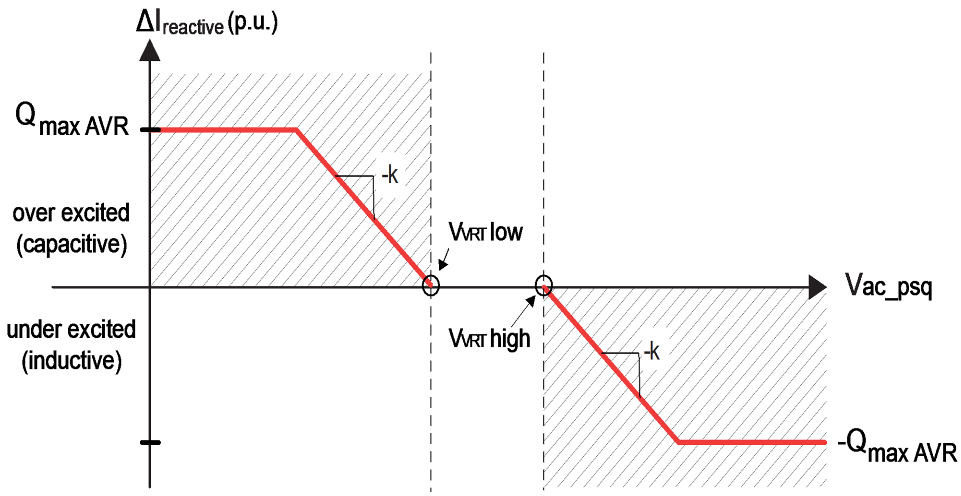
V_{VRTlow} = "V-Support Low Threshold" parameter

V_{ac-psq} = Measured positive sequence voltage

The amount of reactive current support ($\Delta I_{reactive}$) is added to the existing reactive current reference.

Reactive current injection where “V-Support Reset Time” is equal to 0 is illustrated in *Figure 8 on page 20*.

Figure 8 Reactive current injection, “V-Support Reset Time” = 0



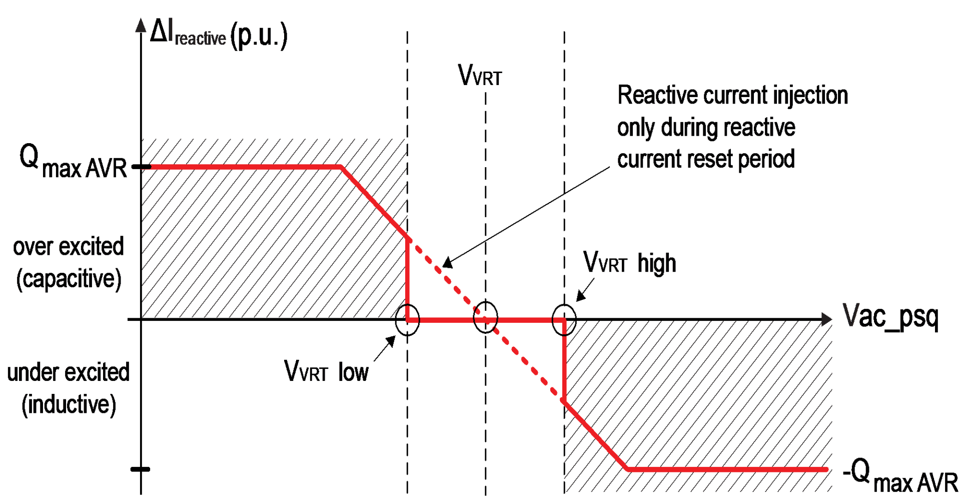
If the “V-Support Reset Time” parameter is higher than 0, the $\Delta I_{reactive}$ that the inverter injects is calculated using equation (2).

$$\Delta I_{reactive\,(pu)} = \begin{cases} k \cdot \frac{I_n}{V_n}\left(V_{VRT} - V_{ac-psq}\right) & if \quad V_{VRThigh} < V_{ac-psq} \\ 0 \quad if \quad V_{VRTlow} \leq V_{ac-psq} \leq V_{VRThigh} & \\ k \cdot \frac{I_n}{V_n}\left(V_{VRT} - V_{ac-psq}\right) & if \quad V_{ac-psq} \leq V_{VRTlow} \end{cases} \qquad (2)$$

and $V_{VRT} = \frac{V_{VRTlow} + V_{VRThigh}}{2}$

Reactive current injection where “V-Support Reset Time” is higher than 0 is illustrated in *Figure 9*.

Figure 9 Reactive current injection, “V-Support Reset Time” > 0



Reactive Current Injection During Asymmetric VRT

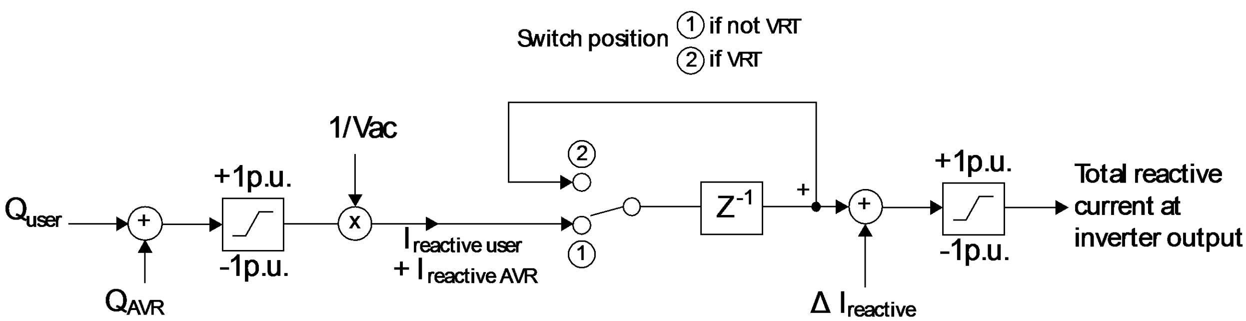
During asymmetric LVRT, too much positive reactive current may trigger an AC overvoltage event. In order to prevent triggering an AC overvoltage event during an asymmetric LVRT, the parameters “Asymmetry Voltage Factor” and “Asymmetry Current Limit Factor" should be adjusted according to the application.

Reactive Current at VRT Onset and Recovery

Reactive current support is an additive output current component. At the onset of a VRT event, if the inverter was delivering reactive power according to the user reference Q_{user} (whether via Modbus, analog, or angle command input), *Figure 10* shows the resulting level of reactive current. Reactive current which is the result of Q_{user} and Q_{AVR}[1] is frozen during VRT and the switch toggle will transition from position 1 (open loop) to position 2 (closed loop). After the voltage recovers, the toggle transitions from position 2 to position 1.

While the switch is in position 2, the additive contribution $\Delta I_{reactive}$ will influence any adjustments of reactive power.

Figure 10 Reactive current support

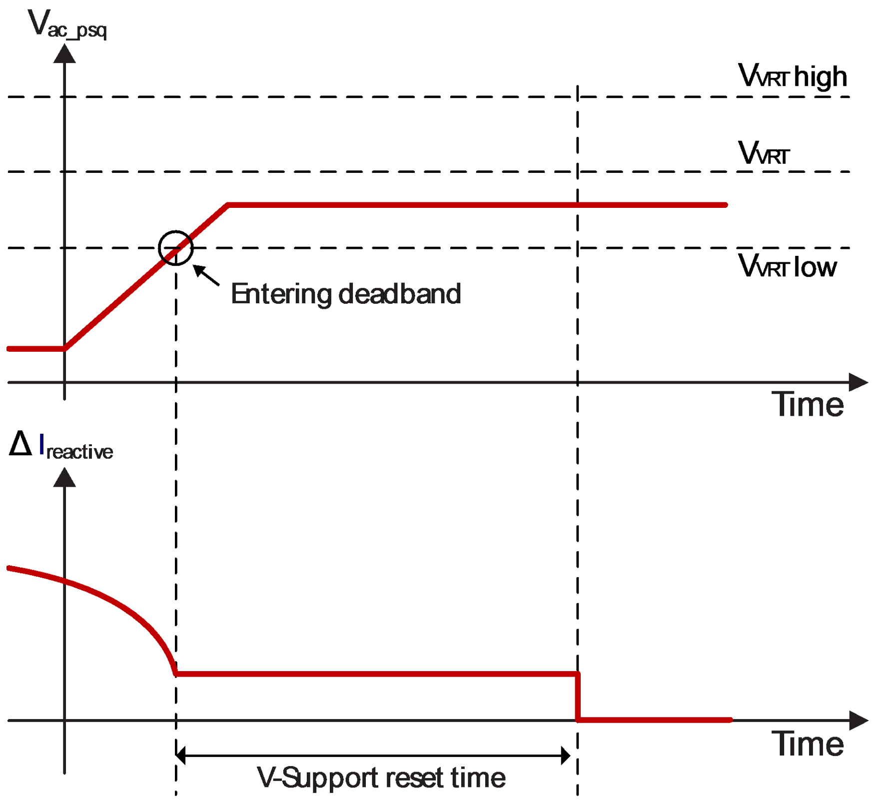


Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverters provide the ability to configure how to recover from a VRT event. When the “V-Support Reset Time” parameter is higher than 0, $\Delta I_{reactive}$ will be determined according to equation (2) *on page 20*.

When grid voltage re-enters the deadband, reactive current will be maintained during the reset period “V-Support Reset Time”. At the end of the reset period, $\Delta I_{reactive}$ will be reset to 0 as shown in *Figure 11 on page 22*.

[1] For more information about Q_{AVR} see *Voltage Regulation on page 42*.

Figure 11 Reactive current reset



Reconnection After Grid-Related Events

The inverter automatically reconnects to the grid and returns to the online state when grid voltage and frequency have recovered. The parameters in *Table 4* define grid reconnection levels.

Table 4 Reconnection parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xF9FA	110	140	100	**Reconn HV Threshold**	Level (as a percentage of “System L-to-L voltage”) at which the AC high voltage condition is cleared and the reconnect delay begins (parameter “Grid Reconnection Delay”).	%
0xFA45	95	100	60	**Reconn LV Threshold**	Level (as a percentage of “System L-to-L voltage”) at which the AC low voltage condition is cleared and the reconnect delay begins (parameter “Grid Reconnection Delay”).	%
0xFA44	50.50	65.00	50.00	**Reconn HF Threshold**	Value (Hz) at which the high frequency condition is cleared and the reconnect delay begins (parameter “Grid Reconnection Delay”).	Hz
0xFA43	49.00	60.00	40.00	**Reconn LF Threshold**	Value (Hz) at which the low frequency condition is cleared and the reconnect delay begins (parameter “Grid Reconnection Delay”).	Hz
0xFA09	20	1800	0	**Grid Reconnection Delay**	Length of time the grid must be within range before the inverter can transition out of shutdown state. This length of time runs in parallel with parameter “Renconnect Start Delay”.	sec
0xFB64	10	3600	0	**Reconnect Start Delay**	Length of time before the inverter transitions to the online state, including after a grid event. This length of time runs in parallel with parameter “Grid Reconnection Delay”.	sec

Active Power Ramping

When the inverter returns to the online state after a grid-related event, active power may be ramped up gradually from 0% to 100% over a specified time period using the “Reconn Power Ramp Time” parameter. For example, if you set the “Reconn Power Ramp Time” to 10 minutes (600 seconds), then the power will increase at 10% per minute.

When you set the “Reconn Power Ramp Time” value, you should take into account the following factors:

- The “Reconn Power Ramp Time” parameter should be changed only while the inverter is disabled.
- If you set “Reconn Power Ramp Time” to 0, power ramping will not occur. Instead, when the inverter reconnects it will supply the available PV power into the grid instantly.

During power ramping, the inverter does not source the entire available power from the PV panels. As a result, PV voltage (V_{PV}) can reach values that are above the DC operating level of the inverter and force the inverter offline due to a PV overvoltage condition. *Figure 12* illustrates power ramping over time.

Figure 12 Power ramping method

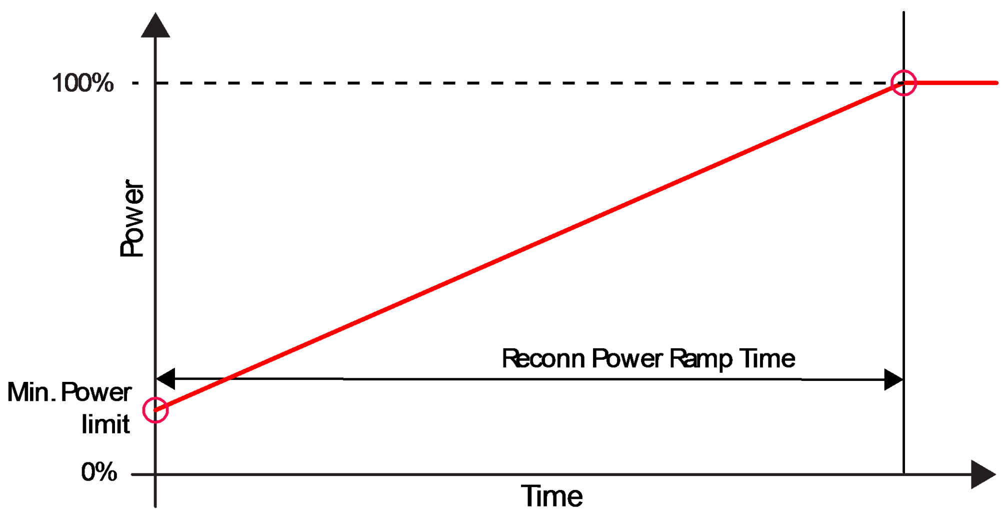


Table 5 lists the parameters that define the active power ramping function.

Table 5 Active power ramping parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA46	0	1800	0	**Reconn Power Ramp Time**	Ramp up time to gradually increase power output when the inverter goes online. For example, a value of 600 (10 minutes) will result in an increase of 10% of power per minute (10% * 10 minutes = 100% in 10 minutes). Related to “Reconnect Power Ramp Type”.	sec
0xFB00	5	20	1	**Min. Power Limit**	Initial output power limit when the inverter goes online. Related to “Reconn Power Ramp Time”.	%

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB65	GRID ERROR	GLOBAL	GRID ERROR	**Reconnect Power Ramp Type**	Determines when “Reconn Power Ramp Time” is active. The options are: GRID ERROR Ramping is only triggered by grid errors. GLOBAL Ramping is triggered at each online transition, including after a grid event.	N/A
0xFB94	850	900	0	**Maximum DC Operating Voltage (Max OC PV for Power Ramp)**	If the open circuit PV voltage is above this level, a special online procedure will be applied to avoid the overvoltage condition.	V
0xFB95	15	1440	0	**PV OC Recovery Delay**	At startup, if the open circuit PV voltage is above “Maximum DC Operating Voltage”, the inverter will wait for the “PV OC Recovery Delay” before going online. To prevent overvoltage tripping, the online transition is without ramping.	min

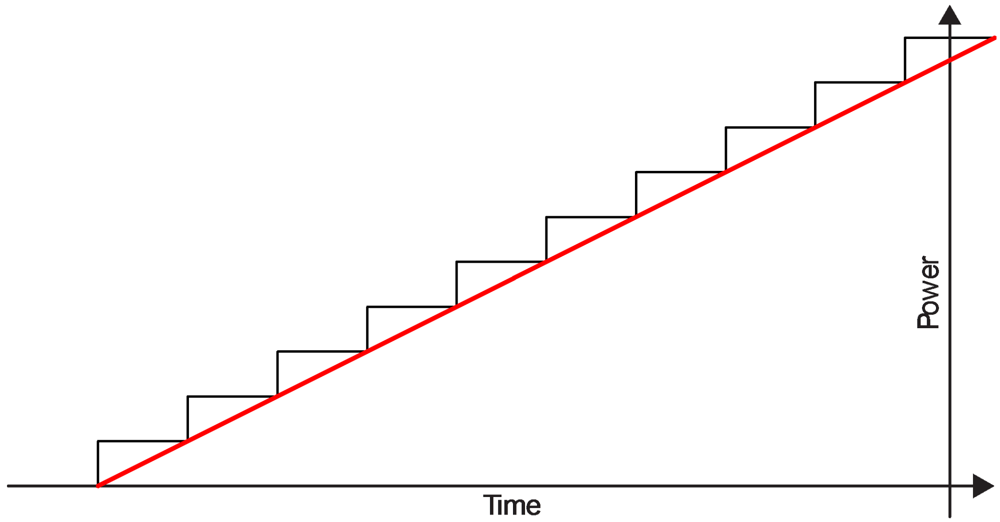
Alternative Power Ramping Method

A method for ramping power up that avoids the risk of a PV overvoltage condition is to stagger the reconnection delays of the individual inverters within a PV power plant. For example, if a plant has 10 inverters you might set the following individual reconnection delay times:

Inverter #	Reconnection Delay (minutes)	Inverter #	Reconnection Delay (minutes)
1	1	6	6
2	2	7	7
3	3	8	8
4	4	9	9
5	5	10	10

These delay times would result in a gradual power ramping as shown in *Figure 13*.

Figure 13 Alternative power ramping method: plant level



Anti-islanding

Islanding occurs when a distributed generation source continues to energize a portion of the utility grid (the *island*) after the electrical utility has stopped providing power. Distributed generation sources such as the Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB can detect an islanding condition and stop energizing the grid.

The Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverter detects grid voltage or frequency instability when the load and generation demand is unbalanced and transitions to the offline state. At times, however, the load and generation demand in the islanded area are balanced, and the self resonance of the grid is at the same frequency as the nominal grid frequency. In this situation, the inverter would continue to supply the islanded area with power if it did not have a special feature known as *grid perturbation* or *active anti-islanding*.

In most medium voltage applications, the Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverter is not required to perform grid perturbation because such plants are remotely controlled (dispatched) by the electrical utility. Without grid perturbation, more stable, continuous and accurate delivery of active and reactive power is possible.

Schneider Electric authorized personnel can turn the active anti-islanding function on or off during configuration of the Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB, with the agreement of the local utility.

The parameters of anti-islanding functions are listed in *Table 6*.

Table 6 Anti-islanding parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA1A	OFF	ON	OFF	**Active Anti-Islanding Function**	Setting determines whether the inverter is performing active anti- islanding detection. OFF ON	N/A
0xFB5D	AI TYPE 0	AI TYPE 1	AI TYPE 0	**Anti-islanding Type**	Type of anti-islanding function used by the inverter. AI TYPE 0 Two levels of perturbation are used depending on frequency changes. AI TYPE 1 Only one level of perturbation is used.	N/A
0xFA54	0.15	2.00	0.00	**Anti-Island Pert Duration**	Duration of the perturbation caused by either AI TYPE 0 or AI TYPE 1 anti-islanding.	sec
0xFA55	0.50	2.00	0.00	**Anti-Island Pert Occurrence**	Interval between the start of two consecutive perturbations caused by either AI TYPE 0 or AI TYPE 1 anti-islanding.	sec
0xFA56	0.060	1.000	0.000	**Anti-island Pert Factor**	Level of the reactive power perturbation as a percentage of the real output power caused by either AI TYPE 0 or AI TYPE 1 anti-islanding.	integer
0xFBA0	0.50	20.00	0.00	**AI Pert. High Threshold**	Frequency threshold that triggers a deeper anti-islanding perturbation and duration. When the difference between two consecutive grid frequency readings crosses this value, “AI Pert. High Factor” and “AI Pert. High Duration” are applied if AI TYPE 1 anti-islanding mode is selected.	Hz
0xFBA1	0.36	2.00	0.00	**AI Pert. High Duration**	Duration of the perturbation triggered when “AI Pert. High Threshold” is crossed. Active when AI TYPE 0 anti-islanding mode is selected.	sec
0xFBA2	0.120	1.000	0.000	**AI Pert. High Factor**	Level of the reactive power perturbation as a percentage of the real output power triggered when “AI Pert. High Threshold” is crossed. It is only active when anti-islanding AI TYPE 0 is selected.	integer

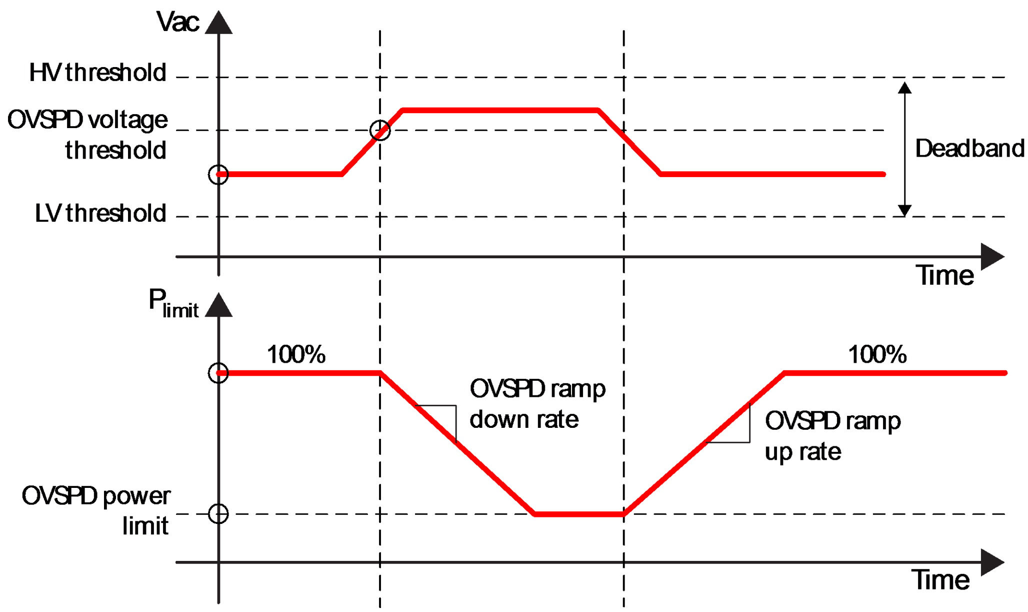
Overvoltage Soft Power Down

The overvoltage soft power down (OVSPD) feature is an additional active power limiting function that runs independently of other power ramping and power limiting features. This function is used in large systems to avoid stress on the plant's voltage frequency protection relays.

When grid voltage is reached the "OVSPD Voltage Threshold", active power is ramped down at the "OVSPD Ramp Down Rate". During ramp down, the inverter responds to the following conditions:

- If the grid voltage drops below the "OVSPD Voltage Threshold", the power is then ramped up at the "OVSPD Ramp Up Rate".
- If the voltage does not drop below the "OVSPD Voltage Threshold" during ramp down, the inverter remains online but the maximum power will be limited to the "OVSPD Power Limit".

Figure 14 Overvoltage soft power down feature



The parameters listed in *Table 7* define OVSPD.

Table 7 Overvoltage soft power down (OVSPD) parameters

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB6A	140	140	80	**OVSPD, Voltage Threshold**	Overvoltage Soft Power Down activation threshold as a percentage of "System L-to-L voltage". When grid voltage reaches this threshold, an output power power down is initiated according to "OVSPD, Ramp down rate".	%
0xFB6B	100	100	5	**OVSPD, Power Limit**	Power level (as a percentage of nominal output power) at which output power down ramp initiated by Overvoltage Soft Power Down function stops. Setting the value of this parameter to 100 disables OVSPD function.	%

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB6C	10.0	6553.5	0.10	**OVSPD, Ramp Down Rate**	Output power ramp down rate (as a percentage of nominal output power per minute) at which the power is ramped down when “OVSPD, Voltage Threshold” is reached.	%
0xFB6D	10.0	6553.5	0.10	**OVSPD, Ramp Up Rate**	Output power ramp up rate (as a percentage of nominal output power per minute) at which the power is ramped up when grid voltage is below “OVSPD, Voltage Threshold” after a OVSPD has started.	%

3 Support Under Normal Grid Conditions

What's in This Chapter?

Overview

This chapter describes and illustrates how the Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverters participate in grid stabilization during normal grid conditions.

Operating Modes

The Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB provides reactive power compensation (VArs) in support of grid voltage. The level of voltage support depends on the inverter's operating mode: PV mode (default) or PVCQ mode. Operating mode defines the set of state machine procedures, protections and controls that ensure effective operation of the product.

PV Mode

In the PV mode of operation, the inverter will transition to the online state if PV power is available (daylight hours). If PV power is not available (night time), the inverter will be offline. While the inverter is online it has the full functionality of sourcing the maximum power from the PV generator (MPPT tracking). Concurrently, the inverter will support the grid during abnormal or normal grid conditions by producing or absorbing reactive power (Q).

PVCQ Mode

In the PVCQ mode of operation, even if PV power is not available (night time), the inverter maintains its online status[1] . This allows for continuous control of reactive power during daytime hours and at night. Implicitly, reactive current support during VRT events will occur at night too. In PVCQ mode, MPPT functionality is the same as in PV mode.

Enabling PVCQ Mode

You can set the inverter to operate in PVCQ mode by setting the "CQ Mode" parameter. If you disable "CQ Mode" by setting the value to 0, the inverter will operate in PV mode. The register can be changed in either of two ways: through remote Modbus communication or using the front panel user interface. You must shut down the inverter before changing the operating mode.

To enable/disable CQ Mode using remote Modbus communication:

Note: You can only enable the inverter remotely when it is in remote shutdown state and no error condition exists.

1. Change parameter control from the front panel user interface to Modbus by writing 2 (MODBUS) to register 0xE0E0.
2. Disable the inverter by writing 1 (REMOTE SHUTDOWN) to register 0xEFFE.
3. View register 0xFB9D (CQ MODE).

[1] System energy consumption is impacted when the inverter remains online at night.

4. Write 1 (ON) to register 0xFB9D to set the inverter to CQ Mode. Write 0 (OFF) to set the inverter operating mode back to the default PV mode.
5. Return parameter control back to the front panel user interface by writing 1 (PANEL CONTROL) to register 0xE0E0.
6. Enable the inverter by writing 0 (REMOTE START) to register 0xEFFE.

To enable/disable CQ Mode using the front panel user interface:

1. Turn the ENABLE STATE /DISABLE STATE switch S11 to disable and the inverter ON/OFF switch to OFF.
2. Wait for capacitors to discharge (15 minutes for Conext Core XC Series, 10 minutes for Conext Core XC Series, 0G-XC-BB and 5 minutes for Conext Core XC-NA Series).
3. Open the metal cover and plastic shield over the front panel user interface.
4. On the front panel user interface, press the center of the scroll wheel. A menu appears.
5. Select **5 Inverter Operating Mode.** The current operating mode appears: `PV` or `PVCQ`.

   To move up and down in the menu, turn the scroll wheel. To select a menu option or apply an entered value, press the center of the scroll wheel.
6. Select **5.3 CQ Mode**.
7. Select ON to set the inverter to operate in PVCQ mode. Select OFF to set the inverter to operate in PV mode.
8. Press F4 to return to the home page.

Table 8 lists the settings for changing the inverter operating mode.

Table 8 User settings to change inverter operating mode

Register Address	Default Value	Register Name	Description	Units
0xE0E0	PANEL CONTROL	**Parameter Control Station**	Enables write access via Modbus (when set to Modbus). PANEL CONTROL MODBUS	N/A
0xEFFC	CP MODE	**Change Inverter Operating Mode**	Sets the inverter operating mode and is persistent across a unit reset. PV MODE CP MODE[2] PVCQ MODE	N/A

[2] CP mode is only used for testing. The inverter ships in PV mode.

Register Address	Default Value	Register Name	Description	Units
0xFB9D	OFF	**CQ Mode**	Enables/disables CQ mode. OFF ON	N/A
0xEFFE	N/A	**Remote Disable/Enable**	Enables/disables the inverter. REMOTE START REMOTE SHUTDOWN	N/A

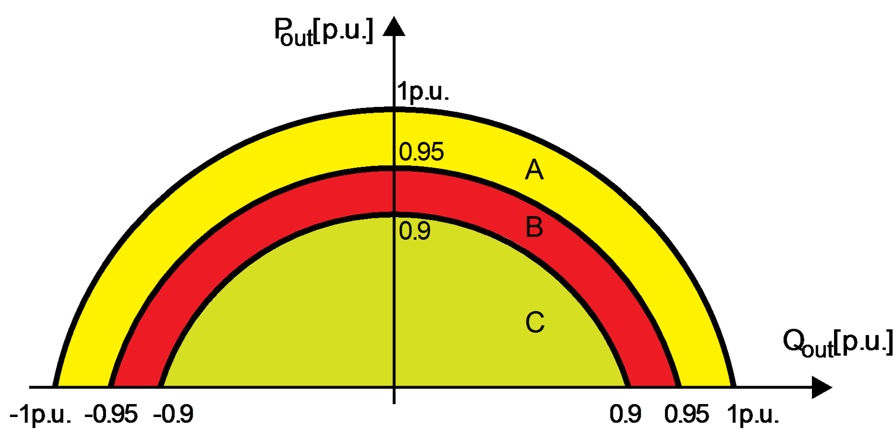
Active Power and Reactive Power Capability

When the Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverter receives a request from the grid for reactive power (Q), the available active power (P) may be reduced to meet the reactive power demand. This section explains the relationship between P and Q availability in PQ dispatch mode and Ppf dispatch mode (see *Dispatch Modes on page 37*).

PQ Capability

The PQ availability area at the inverter terminals is shown in *Figure 15 on page 34*, as a function of the grid voltage Vac.

Figure 15 Reactive power availability in PQ dispatch mode



A + B + C

Vac ≥ 1 p.u., | P_{Amax} | = 1 p.u. | Q_{Amax} | = 1 p.u., radius | S_{Amax} | = 1 p.u.

B + C

Vac = 0.95 p.u., | P_{Bmax} | = 0.95 p.u. | Q_{Bmax} | = 0.95 p.u., radius | S_{Bmax} | = 0.95 p.u

C

Vac = 0.9 p.u., | P_{Cmax} | = 0.9 p.u. | Q_{Cmax} | = 0.9 p.u., radius | S_{Cmax} | = 0.9 p.u

Reactive power always has priority over active power. Therefore, the full amount of required reactive power will be delivered ($Q_{out} = Q_{user}$) regardless of the amount of demanded active power.

Since reactive power has priority, the maximum obtainable active power ($P_{out\text{-}max}$) can be calculated as shown in equations (3) and (4).

$$P_{out-max} = \sqrt{S_{max}^2 - Q_{out}^2} \quad (3)$$

where

$$S_{max}\left(pu\right) = \begin{cases} 1pu & ifVac(pu) \geq 1pu \\ Vac(pu) & ifVac(pu) < 1pu \end{cases} \quad (4)$$

All variables are normalized according to *Table 9 on page 35*.

Table 9 Normalized variables

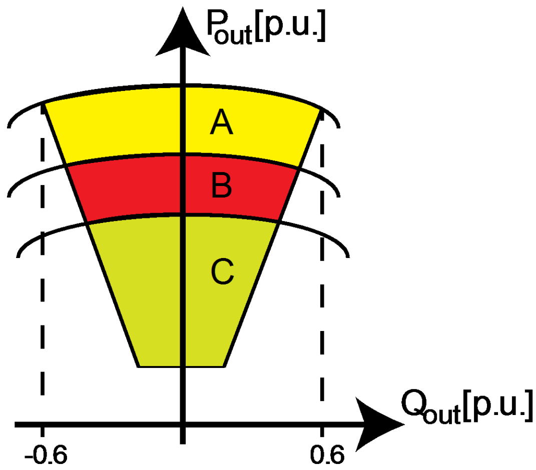
1 p.u.	S [kVA]	Vac [V]	I_L [kA]
XC733-NA	733	407	1.04
XC680 / XC680-NA	680	380	1.04
XC630 / XC630-NA	630	350	1.04
XC540 / XC540-NA	540	300	1.04

PQ Capability in Ppf Dispatch Mode

The PQ availability area at the inverter terminals when in Pφ dispatch mode is shown in *Figure 16 on page 36* as a function of the grid voltage Vac.

- Pφ > 0 = overexcited
- Pφ < 0 = underexcited

Figure 16 Reactive power availability in Ppf dispatch mode



A + B + C

Vac ≥ 1 p.u., | P_{Amax} | = 1 p.u. | Q_{Amax} | = 0.6 p.u., radius | S_{Amax} | = 1 p.u.

B + C

Vac = 0.95 p.u., | P_{Bmax} | = 0.95 p.u. | Q_{Bmax} | = 0.6 p.u., radius | S_{Bmax} | = 0.95 p.u

C

Vac = 0.9 p.u., | P_{Cmax} | = 0.9 p.u. | Q_{Cmax} | = 0.6 p.u., radius | S_{Cmax} | = 0.9 p.u

PQ Availability Example

In this example, the inverter reduces active power to meet the reactive power demand from the grid.

Scenario

Vac = 0.9 p.u. The voltage at the inverter terminals is 90% of nominal.
P_{user} = 1 p.u. The active power reference from dispatch is 1.
Q_{user} = 0.3 p.u. The reactive power reference from dispatch is 0.3.

Calculation

The maximum obtainable active power is calculated as follows:

Although P_{user} = 1 p.u., the actual available active power capacity will always be below 1 p.u since Vac =0.9 p.u.

Based on equation *(3) on page 35*, where *Vac* = 0.9 p.u. and the maximum AC output current (I_{Lmax}) = 1 p.u., we find that the maximum apparent power (S_{max}) = 0.9 p.u.

Since $|Q_{user}| \leq S_{max}$ and considering that Q has priority over P, we have

$$Q_{out} = Q_{user}.$$

According to equation *(4) on page 35*, we can now calculate the maximum obtainable active power as follows:

$$P_{out-max} = \sqrt{0.9^2 - 0.3^2} = 0.85pu$$

Conclusion

If *Vac* = 0.9 p.u. and Q_{user} = 0.3 p.u., the inverter can only produce up to $P_{out-max}$ = 0.85 p.u active power.

Dispatch Modes

The electric utility can manage the overall generating capacity of the PV array system in response to load demand. The plant control center (also known as the dispatch center) uses the two-point dispatch modes described in this section to control the active and reactive power level delivered by the PV array.

Table 10 summarizes the inverter operating modes and configuration settings that are available for controlling power when in each dispatch mode.

Table 10 Dispatch modes

	Inverter Operating Mode	Available Active Power (P) Control Setting	Available Reactive Power (Q) Control Setting
PQ Dispatch Mode	PV	User Active Power Limit P_{user}	User Reactive Power Reference Q_{user}
	PVCQ	User Active Power Limit P_{user}	User Reactive Power Reference Q_{user}
Ppf Dispatch Mode	PV	User Active Power Limit P_{user}	User Phase Angle Reference φ_{user}

PQ Dispatch Mode

In PQ dispatch mode, the plant control center sends the “User Active Power Limit” (P_{user}) and the “User Reactive Power Reference" (Q_{user}) to the inverter.

User Active Power Limit

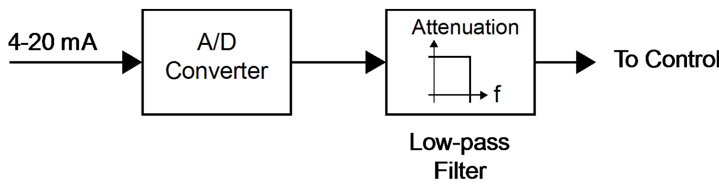
Actual active output power that the inverter delivers is a function of the available power in the PV array, but users can predefine an active power limit using the “User Active Power Limit” setting. This is useful when a set limit is needed to improve system stability.

You can set the “User Active Power Limit” (P_{user}) using either Modbus communication, the front panel user interface on the inverter, or analog reference signals (4 mA-20 mA). The analog reference signals correspond to the following P settings:

- 4 mA = 0% of P_n
- 20 mA = P_n

The signals from 4-20 mA are digitized and then passed through a digital low-pass filter as illustrated in *Figure 17*. The filter is a first order filter with time constants that can be adjusted via parameter "P-analog Filter Timer". The default time constant for the filter is 0.1 s. If filter time is set to 0, the low-pass filter function is disabled. Some level of filtering is recommended as it generally improves the accuracy and noise immunity.

Figure 17 Filtering of analog reference signals



The time that it takes the inverter to respond to the P_{user} reference depends on the method used to set the reference. If you set P_{user} using analog reference signals, the overall response time is approximately 10 ms. If you set P_{user} using Modbus communication, the overall response time will be slightly higher due to the Modbus transportation delay.

The effect of the “Power Ref. Ramp Time” parameter is illustrated in *Figure 18*. The default value for “Power Ref. Ramp Time” is 0.

Figure 18 Power ramping time

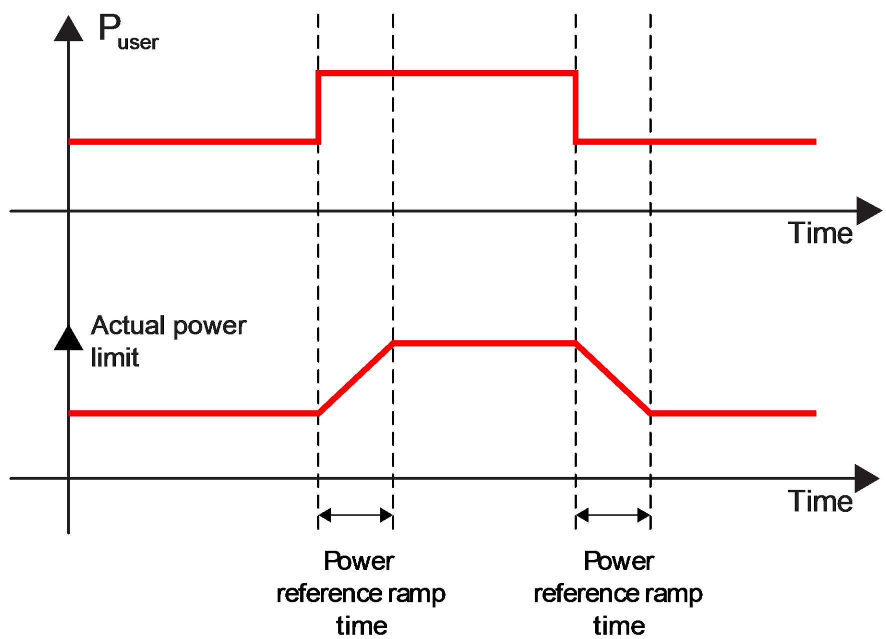


Table 11 lists the user settings for controlling active power in PQ dispatch mode.

Table 11 User settings for active power control in PQ dispatch mode

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA48	MODBUS	MODBUS	ANALOG	**Power Reference Selection**	Selects the input for active and reactive power level command. MODBUS Commands are received via serial communication port using Modbus protocol (PQ dispatch mode and Ppf dispatch mode). ANALOG Input Commands are received via analog input (inverter's connector XT14. PQ dispatch mode only).	N/A
0xFA19	540.0/630.0/ 680.0/733.0	733.0*	0.0	**User Active Power Limit**	Requested active power output (P_{user}) from the inverter.This value can be dynamically changed via "Power Reference Selection" parameter.	kW
0xFA1D	540.0/630.0/ 680.0/733.0	720.0/733.0	0	**User Apparent Power Limit**	Maximum apparent power output from the inverter. If the reactive power command (Q_{user}) combined with the active power command (P_{user}) exceeds the "User Apparent Power Limit", delivering reactive power has priority over delivering active power.	kVA
0xFA1E	100	100	5	**User Phase Current Limit**	Maximum AC current limit as a percentage of nominal line current. The inverter will limit the AC output current to this value.	%
0x408F	0.10	30	0	**P Analog Filter Timer**	Time constant for active power command analog input signal first order low-pass filter. To disable the filter, set the parameter to 0. Related to "User Active Power Limit" parameter above.	sec
0xFA35	50	20000	20	**Power Ref. Ramp Time**	Power change response rate for active power user reference changes (parameter "User Active Power Limit") as the ratio between the inverter nominal power and "Power Ref. Ramp Time". For example, setting this parameter to 50 will make a 680 Kw inverter to respond with 13.5 Kw/msec power output changes (680 / 50 = 13.5).	ms

*Model-dependent (the value shown is for XC733-NA models only).

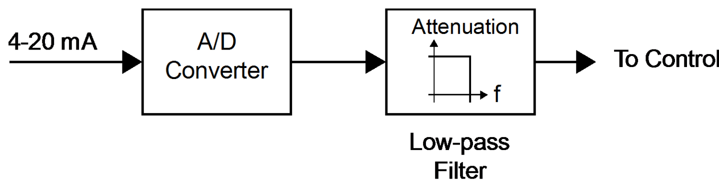
User Reactive Power Reference

Users can command a reactive power level in PQ dispatch mode using the "User Reactive Power Reference" setting. You can set the "User Reactive Power Reference" (Q_{user}) using either Modbus communication, the front panel user interface, or analog reference signals (4 mA-20 mA). The analog reference signals correspond to the following Q settings:

- 4 mA = $-Q_{max}$
- 12 mA = 0 kVAr
- 20mA = Q_{max}

The signals from 4-20 mA are digitized and then passed through a digital low-pass filter as illustrated in *Figure 19*. The filter is a first order filter with time constants that can be adjusted via parameter "Q-analog Filter Timer". The default time constant for the filter is 0.1 s. If filter time is set to 0, the low-pass filter function is disabled. Some level of filtering is recommended as it generally improves the accuracy and noise immunity.

Figure 19 Filtering of analog reference signals



The time that it takes the inverter to respond to the Q_{user} reference depends on the method used to set the reference. If you set Q_{user} using analog reference signals, the overall response time is approximately 10 ms. If you set Q_{user} using Modbus communication, the overall response time will be slightly higher due to the Modbus transportation delay.

The maximum reactive power (Q_{max}) and the minimum reactive power (Q_{min}) settings are the same in both PV mode and PVCQ mode, at:

XC540 or XC540-NA	XC630 or XC630-NA	XC680 or XC680-NA	XC733-NA
± 540 kVAr	± 630 kVAr	± 680 kVAr	± 733 kVAr

If the reactive power command Q_{user} combined with the active power output exceeds the maximum apparent power of the inverter, then reactive power will have priority over active power.

Table 12 lists the user settings for controlling reactive power in PQ dispatch mode.

Table 12 User settings for reactive power control in PQ dispatch mode

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA48	MODBUS	MODBUS	ANALOG	**Power Reference Selection**	Selects the input for active and reactive power level command. MODBUS Commands are received via serial communication port using Modbus protocol (PQ dispatch mode and Ppf dispatch mode). ANALOG Input Commands are received via analog input (inverter's connector XT14. PQ dispatch mode only).	N/A
0xFA1B	0.0	+733.0*	-733.0*	**User Reactive Power Reference**	Requested reactive power output (Q_{user}) from the inverter. This value can be dynamically changed via "Power Reference Selection" parameter.	kVAr
0x4090	0.10	30	0	**Q Analog Filter Timer**	Time constant for reactive power command analog input signal first order low-pass filter. To disable the filter, set the parameter to 0. Related to "User Reactive Power Reference" parameter above.	sec

*Model-dependent (the value shown is for XC733-NA models only).

Ppf Dispatch Mode

In Ppf dispatch mode, the plant control center sends the "User Active Power Limit" (P_{user}) and the "User Phase Angle Reference" (φ_{user}) to the inverter.

The power factor (pf) at the inverter output terminal will be:

pf = $\cos \varphi_{user}$

If $\varphi < 0$, the inverter will be underexcited (inductive). If $\varphi > 0$, the inverter will be overexcited (capacitive).

The inverter accepts the "User Phase Angle Reference" (φ_{user}) if the operating mode is PV and at the same time $Q_{user} = 0$. Otherwise, the inverter ignores the φ_{user} reference and accepts the "User Reactive Power Reference" (Q_{user}).

In contrast to PQ dispatch mode, Ppf dispatch mode accepts user references only via Modbus. If analog input is selected, the only available dispatch mode is PQ. Also if Q_{user} is not 0, the only available dispatch mode is PQ. *Table 13* lists the user settings for controlling active and reactive power in Ppf dispatch mode.

Table 13 User settings for active and reactive power control in Ppf dispatch mode

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFA19	540.0/630.0/ 680.0/733.0	733.0*	0.0	**User Active Power Limit**	Requested active power output (P_{user}) from the inverter. This value can be dynamically changed via "Power Reference Selection" parameter	kW
0xF9FB	0	+45	-45	**User Phase Angle Reference**	Phase angle for Var Command (positive for capacitive reactive power, negative for inductive reactive power).	deg

*Model-dependent (the value shown is for XC733-NA models only).

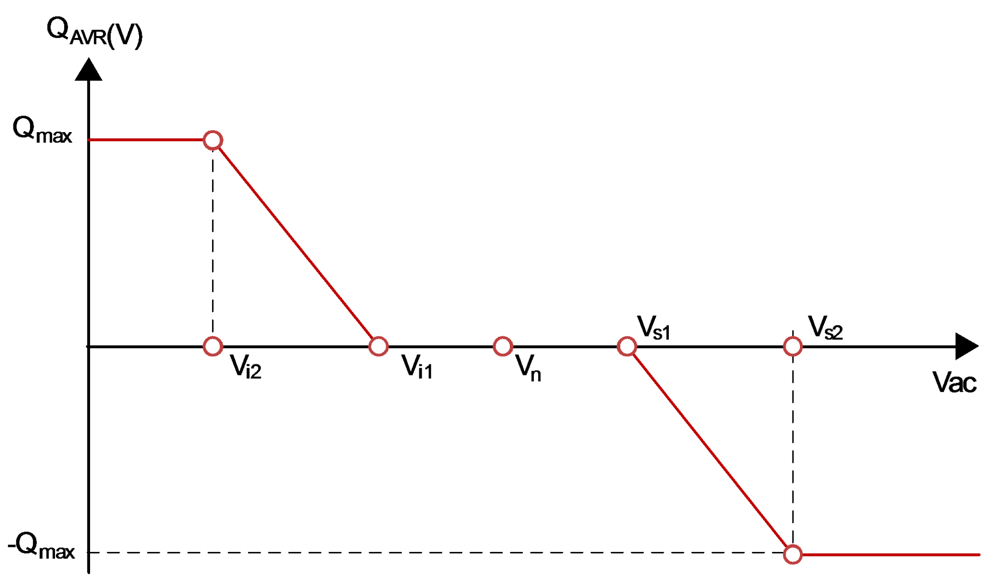
Voltage Regulation

Grid voltage is regulated at the inverter terminal by producing or absorbing reactive power (Q_{AVR}). This section describes the two methods of voltage regulation: reactive power droop function and power factor schedule function.

Reactive Power Droop Function

In voltage regulation, the adjustable parameters V_{i1}, V_{i2}, V_{s1}, and V_{s2} define the voltage control gain and the target or reference level. The Q(V) function is enabled if the "Vac-Regulation" parameter (see *Table 14 on page 44*) is equal to 1. *Figure 20* illustrates the standard voltage regulation curve.

Figure 20 Standard voltage regulation curve



The change of reactive power for voltage regulation is a function of voltage as follows:

$$Q_{AVR} = f(V_{ac})$$

Reactive power (Q_{AVR}) is calculated using the following equations:

$Q_{AVR} = -Q_{max}$	if	$Vac > V_{s2}$

$Q_{AVR} = -(Q_{max}/(V_{s2} - V_{s1})) \cdot (V_{ac} - V_{s1})$	if	$V_{s1} < Vac \leq V_{s2}$
$Q_{AVR} = 0$	if	$V_{i1} \leq Vac \leq V_{s1}$
$Q_{AVR} = (Q_{max}/(V_{i2} - V_{i1})) \cdot (Vac - V_{i1})$	if	$V_{i2} \leq Vac < V_{i1}$
$Q_{AVR} = Q_{max}$	if	$Vac < V_{i2}$

The compensation level (Q_{AVR}) is an additive reactive power component as illustrated in *Figure 21*. *Table 14* lists the settings for regulating voltage levels.

The reactive power droop function can be disabled automatically (lock out) or enabled (lock in) based on the current level of active power P. In order to droop reactive power permanently, regardless of active power, set the “Q(V), P Lock_in” and “Q(V), P Lock_out” parameters to 0. When selecting the lock in and lock out delay times (“P Lock_in Delay” and “P Lock_out Delay”), it is recommended to set them longer than the LV and HV disconnect delay times as this will prevent reactive power discontinuities during LVRT and HVRT.

Figure 21 Reactive power compensation

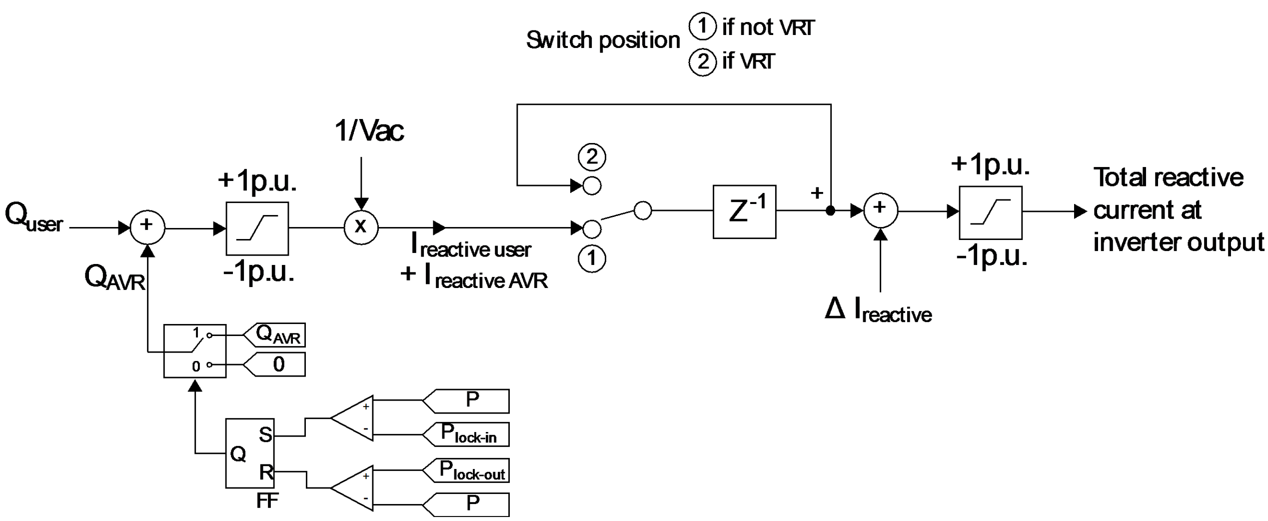


Table 14 Voltage regulation settings

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB58	OFF	PHI(P) REGULATION	OFF	**Vac-Regulation**	Voltage regulation function options: OFF Function deactivated. Q(V) REGULATION Automatic absorption according to Q=f(V). The change of reactive power for voltage regulation is a function of grid voltage. PHI(P) REGULATION Automatic adjustment according to cos φ f(P)[3]. Uses power factor based on active power output to adjust reactive power automatically. The purpose of this option is to avoid voltage swells when the generator is delivering a significant amount of active power.	N/A
0xFB59	110	140	60	**Q(V), $V2_s$**	Voltage superior high threshold as a percentage of “System L-to-L voltage”. Used when “Q(V) Regulation: automatic absorption according to Q = f(V)” option is selected for “Vac-Regulation”. It determines the change of reactive power for voltage regulation together with “Q(V), V1s”, “Q (V), V1i”, and “Q(V), V2i”. Used when option “Q(V) Regulation: automatic absorption according to Q = f(V)” is selected for “Vac-Regulation”.	%
0xFB5A	108	140	60	**Q(V), $V1_s$**	Voltage superior low threshold as a percentage of “System L-to-L voltage”. Used when “Q(V) Regulation: automatic absorption according to Q = f(V)” option is selected for “Vac-Regulation”. It determines the change of reactive power for voltage regulation together with “Q(V), V2s”, “Q (V), V1i”, and “Q(V), V2i”. Used when option “Q(V) Regulation: automatic absorption according to Q = f(V)” is selected for “Vac-Regulation”.	%

[3] For details, see *Power Factor Schedule Function on page 46*.

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB5B	92	140	60	**Q(V), V1$_i$**	Voltage inferior high threshold as a percentage of “System L-to-L voltage”. Used when “Q(V) Regulation: automatic absorption according to Q = f(V)” option is selected for "Vac-Regulation”. It determines the change of reactive power for voltage regulation together with “Q(V), V2s”, “Q (V), V1s”, and “Q(V), V2i”. Used when option “Q(V) Regulation: automatic absorption according to Q = f(V)” is selected for “Vac-Regulation”.	%
0xFB5C	90	140	60	**Q(V), V2$_i$**	Voltage inferior low threshold as a percentage of “System L-to-L voltage”. Used when “Q(V) Regulation: automatic absorption according to Q = f(V)” option is selected for “Vac-Regulation”. It determines the change of reactive power for voltage regulation together with “Q(V), V2s”, “Q (V), V1s”, and “Q(V), V1i”. Used when option “Q(V) Regulation: automatic absorption according to Q = f(V)” is selected for “Vac-Regulation”.	%
0xFB66	20	100	0	**Q(V), P Lock_in**	Threshold to enable voltage regulation function. If active output power is above this threshold level for longer than “P Lock_in delay”, the voltage regulation function will be enabled. If “Q(V), P Lock_in” and “Q(V), P Lock_out” are set to zero, voltage regulation function ignores active power level. Used when option “Q(V) Regulation: automatic absorption according to Q = f(V)” is selected for “Vac-Regulation”.	%
0xFB67	5	100	0	**Q(V), P Lock_out**	Threshold to disable voltage regulation function. If active output power is below this threshold level for longer than “P Lock_out delay”, the voltage regulation function will be disabled. If “Q(V), P Lock_out” and “Q(V), P Lock in” are set to zero, voltage regulation function ignores active power level. Used when option “Q(V) Regulation: automatic absorption according to Q = f(V)” is selected for “Vac-Regulation”.	%

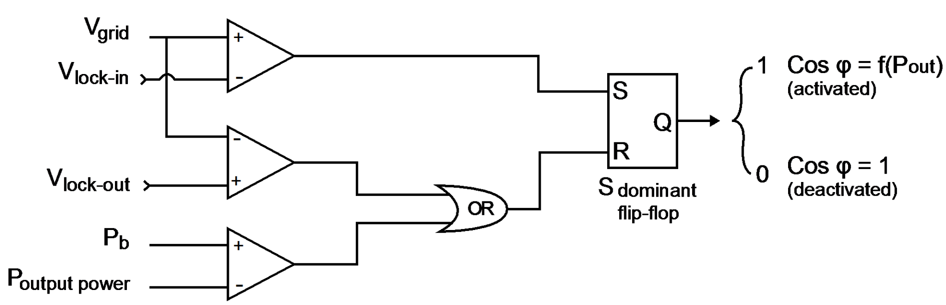
Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB68	0.20	600.00	0.00	**P Lock_in Delay**	Period of time the active output power must be above “Q(V), P Lock_in” before voltage regulation function is activated. Used in all “Vac-Regulation” options. Set this parameter longer than the LV and HV disconnect delay times to prevent reactive power discontinuities during LVRT and HVRT.	sec
0xFB69	0.20	600.00	0.00	**P Lock_out Delay**	Period of time the active output power must be below “Q(V), P Lock_out” before voltage regulation function is disabled. Used in all “Vac-Regulation” options. Set this parameter longer than the LV and HV disconnect delay times to prevent reactive power discontinuities during LVRT and HVRT.	sec

Power Factor Schedule Function

An alternative type of voltage regulation uses power factor based on active power output to adjust reactive power automatically. The power factor is scheduled based on the amount of active power. The purpose of this function is to avoid voltage swells when the generator is delivering a significant amount of active power. According to this function, the generator will absorb reactive power (inductive compensation) each time that the grid voltage and the amount of active power are high. The net effect is a flatter voltage profile along transmission lines which contain a mix of distributed generators and loads.

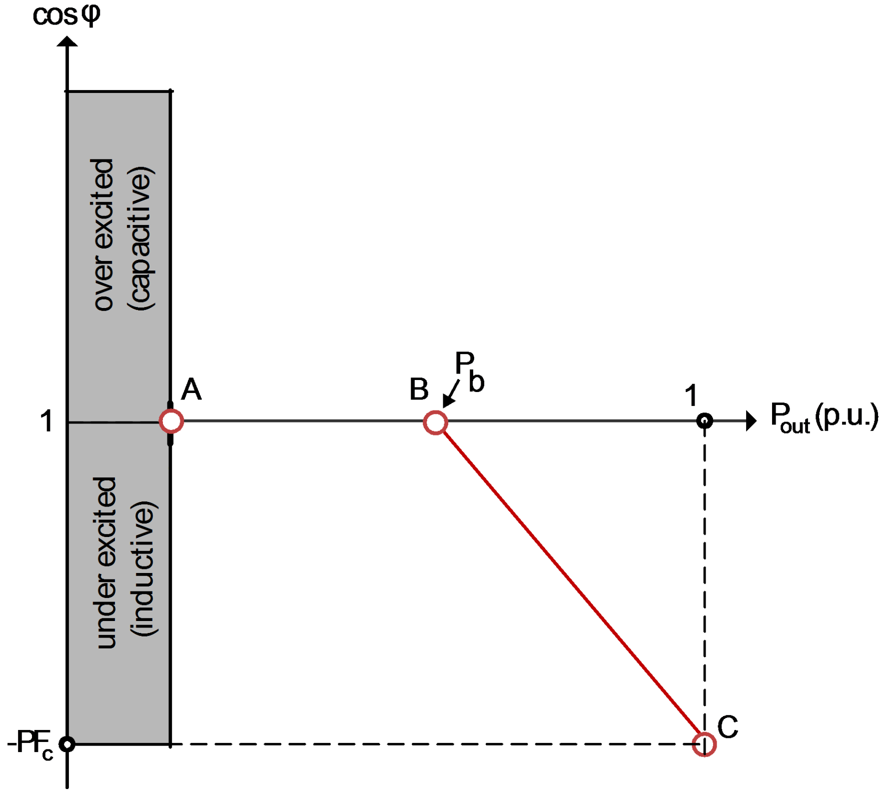
The software circuit diagram of the activation logic is shown in *Figure 22 on page 46*.

Figure 22 Activation logic for power factor schedule function



The cosφ = f(P_{out}) function is a piece-wise linear function as shown in *Figure 23*, where by convention a negative non-unity power factor indicates an underexcited or inductive mode. Compensation is activated if grid voltage exceeds the $V_{lock\text{-}in}$ level. The adjustable parameters of this function are P_b and PF_c.

Figure 23 Voltage regulation according to active power output curve



If the function cosφ = f(P) is activated and the active output power is above P_b, then the power factor will be a linear function of output active power, as shown in the following equation:

$$\cos\varphi = \begin{cases} 1(unity) & if \quad P_{out} \leq P_b \\ -\left|1 - \frac{1-PF_c}{1-P_b}(P_{out} - P_b)\right| & if \quad P_b < P_{out} \leq 1p.u. \end{cases}$$

The function cosφ = f(P) will deactivate if V_{grid} drops below $V_{lock\text{-}out}$ or if output power is below P_b (also called *initial activation power*).

As with the reactive power droop function[4] , the function cosφ = f(P_{out}) is an additive reactive compensation function, illustrated in *on page 42*.

In the power factor schedule function, Q_{avr} is calculated iteratively as:

$$Q_{AVR_n} = -S_{AVR_{n-1}} \cdot \sin\varphi_{n-1}$$

where

$$S_{AVR_{n-1}} = \sqrt{{P_{out_{n-1}}}^2 + {Q_{AVR_{n-1}}}^2}$$

$$\cos\varphi_{n-1} = f\left(P_{out_{n-1}}\right)$$

and

$$\sin\varphi_{n-1} = \sqrt{1 - \cos{\varphi_{n-1}}^2}$$

[4] See *Reactive Power Droop Function on page 42*.

Table 15 lists the settings for controlling voltage using this method.

Table 15 Voltage regulation settings according to active power output

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB5E	50	100	20	**Phi(P), Pb**	Voltage regulation activation threshold as a percentage of active output power. Active output power equal or greater than this value activates the function. Levels below this value deactivate the function. Used when option “Phi (P) Regulation“ is selected for “Vac-Regulation”.	%
0xFB5F	0.90	0.99	0.01	**Phi(P), PFc**	Target power factor at 100% output power. This value is used to calculate the reactive power to be commanded as a function of active output power. Used when option “Phi (P) Regulation” is selected for “Vac-Regulation”.	1
0xFB60	105	140	60	**Phi(P), Vlock_in**	Threshold as a percentage of “System L-to-L voltage” to enable voltage regulation function. If grid voltage is above this threshold level for longer than “P Lock_in delay”, the voltage regulation function will be enabled. Used when option “Phi (P) Regulation” is selected for “Vac-Regulation”.	%
0xFB61	100	140	60	**Phi(P), Vlock_out**	Threshold as a percentage of “System L-to-L voltage” to disable voltage regulation function. If grid voltage is below this threshold level for longer than “P Lock_out delay”, the voltage regulation function will be disabled. Used when option “Phi (P) Regulation” is selected for “Vac-Regulation”.	%

Power-Frequency Droop Function

The PV generator can adjust active power as a response to the grid frequency level, using the power-frequency droop function. This function improves grid stability in cases where there is a mismatch between produced and consumed energy.The two types of power-frequency droop function implemented in the Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB are hysteretic power-frequency droop and non-hysteretic power-frequency droop.

Hysteretic Power-Frequency Droop Function

In the hysteretic function, if frequency exceeds the “P(f) Control, Corner Frequency” parameter, the active power level will be locked and derated based on the locked level and the actual grid frequency as shown in *Figure 24 on page 49*.

Parameter “P(f) Control, Slope” is used if “P(f) Type 1” is selected. “P(f) Control, Slope” = % of change / nominal grid frequency.

The equation is: ΔP = “P(f) Control, Slope” * Pm * (“P(f) Control, Corner Freq” – Fgrid)
Where: PM = actual output power before grid frequency reaches “P(f) Control, Corner Freq”. Fgrid = actual grid frequency.

Figure 24 Hysteretic power-frequency droop function profile

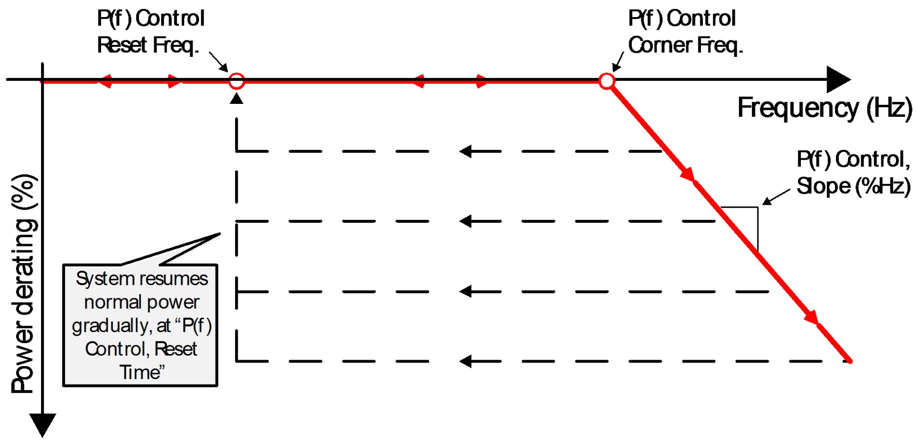


Table 16 lists the hysteretic power-frequency droop function settings.

Table 16 Hysteretic power-frequency droop function settings

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xF9F6	OFF	P(F) TYPE2	OFF	**P(f) Control Function**	Power-Frequency Droop Function: OFF Function deactivated. P(F) TYPE1 = HYSTERETIC MODE If frequency exceeds the “P(f) Control, Corner Freq” parameter, the active power level will be locked and derated based on "P(f) Control, Slope" parameter. P(F) TYPE2 = NON-HYSTERETIC MODE The amount of Plimit (f) is programmable as a piece-wise linear function defined by the coordinates (PA, fA); (PB, fB); (PC, fC) and (PD, fD). Where: PA = “P(f)2, A Frequency” parameter PB = “P(f)2, B Frequency” parameter PC = “P(f)2, C Frequency” parameter PD = “P(f)2, D Frequency” parameter fA = “P(f)2, A Power” parameter fB = “P(f)2, B Power” parameter fC = “P(f)2, C Power” parameter fD = “P(f)2, D Power” parameter	N/A

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0x40BB	RESET BASED ON NOMINAL	RESET BASED ON SNAPSHOT	RESET BASED ON NOMINAL	**P(f), Slew Rate Type**	Power-Frequency Droop Function Reset Slew Rate Type: RESET BASED ON NOMINAL Power recovery slope is based on nominal power. RESET BASED ON SNAPSHOT Power recovery slope is based on snapshot of power taken when frequency variation starts.	N/A
0xFA58	120	1800	0	**P(f) Control, Reset Time**	Time to recover from active power control as a function of frequency. This parameter determines the slope for “P(f), Slew Rate Type” (which determines the target power). The actual time may be less than the value set in this parameter because the ramp step assumes that the device starts at 0% power.	sec
0xFA29	50.2	70.0	50.0	**P(f) Control, Corner Frequency**	Frequency at which “P(f) Control Function” starts reducing power. Parameter used if “P(f) Type 1” is selected.	Hz
0xFA34	40	100	1	**P(f) Control, Slope**	Active power slope used by “P(f) Control Function Type 1” to reduce power (as a percentage of the active power present when “P(f) Control, Corner Freq” was reached).	%/Hz
0xFA28	50.05	64.00	47.00	**P(f) Control, Reset Freq. High**	Frequency reset high threshold. This parameters and “P(f) Control, Reset Freq. Low” are the reset thresholds for the inverter to recover from power derating. They are lower than “P(f) Control, Corner Frequency” and are set equal to each other by default. If they are not equal they form a power recovery range within which the inverter will recover.	Hz
0xFB96	50.05	64.00	47.00	**P(f) Control, Reset Freq. Low**	Frequency reset low threshold. This parameter and “P(f) Control, Reset Freq. High” are the reset thresholds for the inverter to recover from power derating. They are lower than “P(f) Control, Corner Frequency” and are set equal to each other by default. If they are not equal they form a power recovery range within which the inverter will recover.	Hz
0xFB97	0	900	0	**P(f) Control, Reset Delay**	Delay to start ramp up power when “P(f) Control, Reset Freq. High” is reached. Parameter used if “P (f) Type 1” is selected.	sec

Non-Hysteretic Power-Frequency Droop Function

The non-hysteretic P(f) function produces an active power limit effect as illustrated in the following figures:

Figure 25 P(f) function imposing limits on inverter output active power

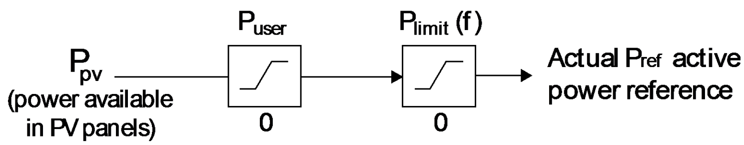
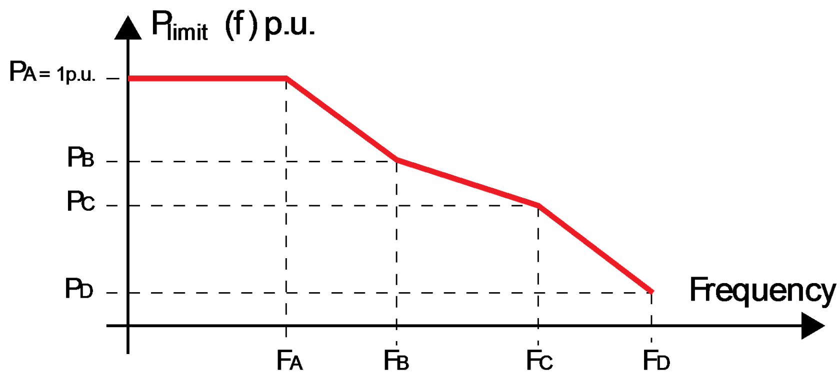


Figure 26 Non-hysteretic power frequency droop function profile



It is possible to activate a snapshot function using the “P(f)2, P Snapshot” parameter. The default for this parameter is `OFF`.

If snapshot is enabled and frequency exceeds “P(f)2, F Lock_in” longer than “P(f)2, Lock_in Delay”, an active power snapshot will be taken. The P_{limit} level will be denormalized based on the snapshot level. If frequency drops below “P(f)2, F Lock_out” longer than “P(f)2, Lock_out Delay”, the unit is normalized to $P_{nominal}$. If frequency increases again, a new snapshot will be recorded.

P(f)2, P Snapshot determines whether the reference power used by “P(f) Control Function” is nominal output power or power from snapshot. Off: Nominal output power is used as reference. On: Snapshot power is used as reference. Snapshot power is the output power present in the system when the grid frequency exceeds “P(f)2, F Lock_in” for “P(f)2, Lock_in Delay” amount of time.

Figure 27 on page 52 illustrates the dependencies that affect the non-hysteretic power frequency droop function.

Figure 27 Non-hysteretic power frequency droop dependencies

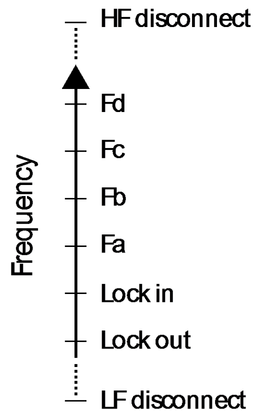


Table 17 lists the non-hysteretic power-frequency droop function settings. In order to enable this function, the “P(f) Control Function” must be set at 2.

Table 17 Non-hysteretic power-frequency droop function settings

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB6E	48.00	70.00	40.00	**P(f)2, A Frequency**	Corner A frequency coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	Hz
0xFB6F	49.80	70.00	40.00	**P(f)2, B Frequency**	Corner B frequency coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	Hz
0xFB70	50.20	70.00	40.00	**P(f)2, C Frequency**	Corner C frequency coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	Hz
0xFB71	52	70.00	40.00	**P(f)2, D Frequency**	Corner D frequency coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	Hz
0xFB72	100.0	100.0	5.0	**P(f)2, A Power**	Corner A power coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	%
0xFB73	95.0	100.0	5.0	**P(f)2, B Power**	Corner B power coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	%
0xFB74	95.0	100.0	5.0	**P(f)2, C Power**	Corner C power coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	%
0xFB75	35.0	100.0	5.0	**P(f)2, D Power**	Corner D power coordinate when “P(f) Type 2” mode is selected for “P(f) Control Function”.	%

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB76	OFF	ON	OFF	**P(f)2, P Snapshot**	It determines whether the reference power used by “P(f) Control Function” is nominal output power or power from snapshot. OFF Nominal output power is used as reference . ON Snapshot power is used as reference. Snapshot power is the output power present in the system when the grid frequency exceeds “P(f)2, F Lock_in” for “P(f)2, Lock_in Delay” amount of time.	N/A
0xFB77	50.10	70.00	40.00	**P(f)2, F Lock_in**	Frequency threshold for power snapshot when “P(f)2, P Snapshot” parameter is set to On. When the grid frequency exceeds “P(f)2, F Lock_in” for “P(f)2, Lock_in Delay” amount of time, “P(f) Control Function” uses the existing output power as reference.	Hz
0xFB78	50.00	70.00	40.00	**P(f)2, F Lock_out**	Frequency threshold to go back to using nominal output power reference when “P(f)2, P Snapshot” parameter is set to On. When the grid frequency is below “P(f)2, F Lock_out” for “P(f)2, Lock_out Delay” amount of time, “P(f) Control Function” goes back to using nominal output power as reference.	Hz
0xFB79	200	10000	0	**P(f)2, Lock_in Delay**	Amount of time the grid frequency must be above “P(f)2, F Lock_in” before “P(f) Control Function” starts using snapshot power as reference.	ms
0xFB7A	200	10000	0	**P(f)2, Lock_out Delay**	Amount of time the grid frequency must be below “P(f)2, F Lock_out” before “P(f) Control Function” goes back to using nominal output power as reference.	ms

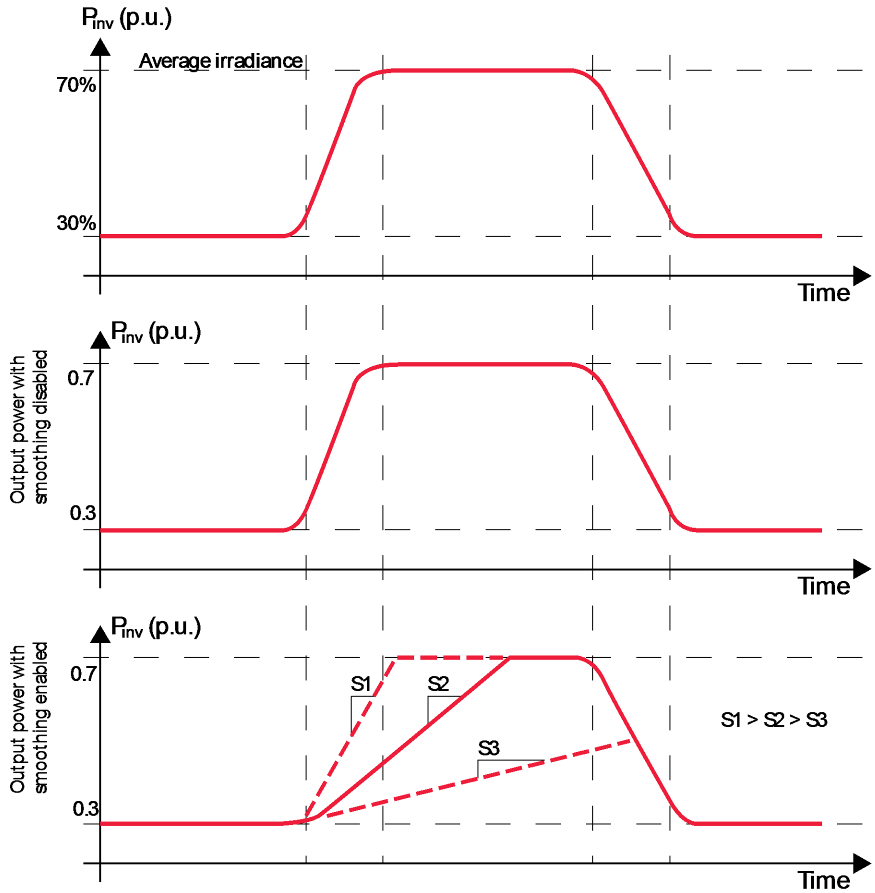
Active Power Smoothing

Abrupt changes in output active power can occur when the light conditions are good but clouds are moving quickly overhead. To prevent frequency or power flow disturbances, utilities may limit the rate of change for active power production.

The Conext Core XC, Conext Core XC-NA and Conext Core XC, 0G-XC-BB inverters can be programmed to limit the positive active power slew rate. By setting the “Power Ramp Rate” parameter
(%/min), the user can limit the active power rate of rise to the set level. The inverter cannot control the negative slew rate, which is a function of average irradiance decline over the solar field.

The effect of power smoothing is illustrated in *Figure 28 on page 54*.

Figure 28 Active power smoothing



By default, active power smoothing is disabled (desensitized) where the “Power Ramp Rate” = 6000%/min. In order to limit the rate of rise, set “Power Ramp Rate” to the desired level.

Table 18 lists the active power smoothing settings.

Table 18 Active power smoothing settings

Register Address	Default Value	Max Value	Min Value	Register Name	Description	Units
0xFB62	6000.0	6000.0	0.5	**Power Ramp Rate**	Limits the output power rise rate per minute as a percentage of nominal power output . This value is used to smooth power changes in fast moving cloud situations. For example, setting this parameter to 0.5 will result in a power ramp rate of 3.4kW/min in a 680kW inverter (680 * 0.005 = 3.4). Set to 6000.0 to deactivate this function.	%/min
0xFB63	2.0	50.0	0.0	**Min. Power Ramp Step**	Minimum power ramp step when “Power Ramp Rate” is activated.	kW

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