ABB solar inverters

Grid Support Function
Application Guideline for PVS-166/175-TL-US inverters

General liability warnings concerning inverter use

Please refer to the Product Manual for complete installation instructions and product use.

ABB accepts no liability for failure to comply with the instructions for correct installation and will not be held responsible for systems upstream or downstream the equipment it has supplied. It is absolutely forbidden to modify the equipment. Any modification, manipulation, or alteration not expressly agreed with the manufacturer, concerning either hardware or software, shall result in the immediate cancellation of the warranty.

The Customer is fully liable for any modifications made to the system.

Given the countless array of system configurations and installation environments possible, it is essential to check the following: sufficient space suitable for housing the equipment; airborne noise produced depending on the environment; potential flammability hazards.

ABB will NOT be held liable for defects or malfunctions arising from: improper use of the equipment; deterioration resulting from transportation or particular environmental conditions; performing maintenance incorrectly or not at all; tampering or unsafe repairs; use or installation by unqualified personnel.

ABB will NOT be held responsible for the disposal of: displays, cables, batteries, accumulators etc. The Customer shall therefore arrange for the disposal of substances potentially harmful for the environment in accordance with the legislation in force within the country of installation.

Field of use, general conditions

ABB shall not be liable for any damages whatsoever that may result from incorrect or careless operations.

You may not use the equipment for a use that does not conform to that provided for in the field of use. The equipment MUST NOT be used by inexperienced staff, or even experienced staff if carrying out operations on the equipment that fail to comply with the indications in this manual and enclosed documentation.

Intended or allowed use

This equipment is a multi-string inverter designed for transforming a continuous electrical current (DC) supplied by a photovoltaic generator (PV) in an alternating electrical current (AC) suitable for feeding into the public distribution network

Effective: July 08, 2019 Rev. 1.0 (See revision control at end of document)

Contents

Introduction

Rule 21 and Rule 14H are the Source Requirement Documents (SRD) released by the States of California and Hawaii. These documents define the settings and configuration required to be used on "SMART INVERTER GENERATING FACILITY" to ensure compliance with the connection rules.

This document is a guideline to adjust the Grid Support Utility Functions introduced by Rule 21 and Rule 14H and is divided in three blocks:

The first block describes the Grid Support Utility Functions as required by the grid codes and the inverter relevant parameters.

The second part of the document describes how to adjust the parameters within the inverters.

The third block (Annex 2) is a table that correlates Rule 21/14H with inverter firmware

HOW TO USE THIS GUIDELINE:

1. **Check the Tables A2 and A3 on Annex 2 to verify if your inverter is updated to the latest Rule 21/14H requirements.**
2. **In case the inverter need to be adjusted it is suggested to check the chapter "*Phase 1: Autonomous Function Description*" for details about the inverter parameters.**
3. **Adjust the required parameters with the help of the chapter "*Parameter Adjustment*".**

This document applies to the following inverter models and derived sub-models:

- Family PVS-166/175-TL-US
  - PVS-166-TL-US
  - PVS-175-TL-US

And all the above inverter models are certified according to UL1741-SA and includes the grid support functions described on this document

The default settings included on this guideline are aligned to the following Utility advice letters:

- RULE 21:
  - PG&E: Advice Letter 5107-E
  - SCE: Advice Letter 3623-E
  - SDGE: Advice Letter 3094-E

- RULE 14H: HECO SRD-UL-1741-SA-V1.1 / HPUC Order 35266

Interaction between SRD, UL 1741-SA and IEEE 1547a

Rule 21 and Rule 14H defines a new approach for **Distributed Energy Resources (DER)** to build up smart grid for the State of California and Hawaii.

Due to the fact that

- the number of interconnected DER systems are rapidly increasing
- DER systems challenge traditional power system management
- DER systems could become very powerful tools in managing the power system for reliability and efficiency
- DER systems are becoming quite "*smart*" and can perform "*autonomously*"

It was decided to start developing the new technical capabilities of DER systems to satisfy the new challenging evolution of smart grid and the integration into the existing power system.

New DER functions were defined by the technical group, reflecting the DER Systems Modeled in **IEC 61850-90-7**, but an amendment to the Standards IEEE 1547 and UL 1741 was required to avoid any conflict:

- **IEEE 1547a** standard includes an extension to the inner limits to permit the new DER function to be applied
- **UL 1741-SA** includes the test criteria to certify the new DER functions

Moreover Rule 21 and Rule 14H are SRDs to be used with the UL 1741 SA, SRDs set the specific parameter settings to be used with the test methods of the UL 1741 SA.

An inverter compliant with the above standards is defined by the Rule 21 as “*Grid Support Utility Interactive Inverter”*.

Rule 21 Roadmap

Tariff Rule 21 splits the process to develop the new DER functions into three consecutive Phases

- Phase 1: defines and includes all the autonomous functions to be embedded within the inverter
- Phase 2: defines and includes the DER communication capabilities
- Phase 3: defines and includes the advanced inverter functionalities

The Figure 1 summarizes the functions and the timeline for each Phase, a brief description of the autonomous functions included on Figure 1 and the Rule 14H additional functions will be described later on this guide.

Phase 1

Autonomous Functions

- SA8 Anti-islanding Protection
- SA9 Low/ High Voltage Ride-Through
- SA10 Low/ High Frequency Ride-Through
- SA11 Normal Ramp Rate and Soft-Start Ramp Rate
- SA12 Fixed Power Factor
- SA13 Volt/ Var Mode
- SA14 Frequency/ Watt (optional)
- SA15 Volt/ Watt (optional)

Required:

Sep. 8, 2017

Optional Functions are mandatory from Phase 3

Phase 2

Communication capabilities

- Communication capability
- Remote FW update
- TCP/ IP transport level protocol

Required:

currently scheduled to be required Jan. 22, 2020

Phase 3

Advanced inverter functionalities

1. Monitor Key DER Data (***)
2. DER Disconnect/ Reconnect Command (**)
3. Limit Maximum Active Power Mode (**)
4. Set Active Power Mode (⌂)
5. Frequency Watt Mode (*)
6. Volt Watt Mode (*)
7. Dynamic Reactive Support (⌂)
8. Scheduling Power Values and Modes (***)

Required:

(*) Feb. 22, 2019

(**) Earlier of Dec. 2019 or 12 moths after approval of IEEE 1547.1 standard revision

(***) Jan. 22, 2020

(⌂) 12 months after approval of a nationally recognized standard that includes this function

Figure 1: Rule 21 Roadmap

Phase 1: Autonomous Function Description

SA8 Anti Islanding Protection

The Function SA8 Anti Islanding defines the capability of the Grid Support Utility Interactive Inverter to detect an unintentional island situation and cease to energize it within 2 seconds from the formation of the island.

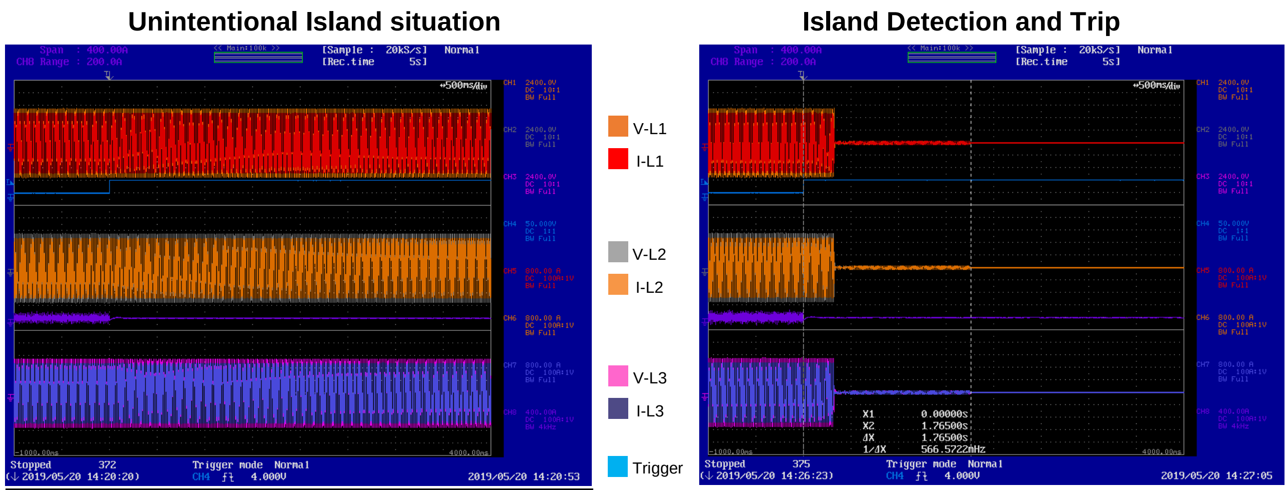


Figure2: Anti-Islanding test example

As shown on the left plot in figure 2, when an inverter is connected to a resonant load with an active (resistive) component that matches the active power output, the inverter could stay connected to the Islanding condition and keep up the voltage with the current injected over the load. A Grid Support Utility Interactive Inverter must be able to detect the islanding condition and disconnect from the grid within a predefined time limit (< 2s) as shown on the right plot in figure 2.

The ABB Grid Support Utility Interactive Inverters listed in this document are equipped with an Anti-Islanding protection that have been certified in accordance to the standard UL 1741-SA.

The Anti-Islanding capability have been certified and is guaranteed only when the grid support functions are enabled in accordance to one of the 6 scenarios listed in the following Interoperability Table (Table 1).

Scenario	SA9 L/HVRT	SA10 L/HFRT	SA12 Spec Pf	SA13 VV	SA11 RR	SA14 FW	SA15 VW
1	✓	✓				**O**	**O**
2	✓	✓			✓	**O**	**O**
3	✓	✓	✓		✓	**O**	**O**
4	✓	✓		✓	✓	**O**	**O**
5	✓	✓	✓			**O**	**O**
6	✓	✓		✓		**O**	**O**

✓ = enabled; **O** = enabled OR disabled

Table 1: Interoperability Table

Any other combination of grid support functions not explicitly specified in Table 1 is not covered by the UL 1741-SA product certification and shall not be used for UL-compliant installations.

When an ABB Grid Support Utility Interactive Inverter is configured to be compliant with Rule 21 or Rule 14H the following settings applies.

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
A.I. operating mode	SA8	Flag	Enabled	Enabled	Fixed

Table 2: Default Settings and range of adjustability for SA8 function

It is not admitted changing the Anti Islanding configuration parameters to users or installers for safety purpose.

SA9 Low and High Voltage Ride Through

Low and High Voltage Ride Through define the capability of a Grid Support Utility Interactive Inverter to support the grid remaining connected when the voltage exceeds the Near Nominal Operating Range.

L/HVRT function can be useful in the following scenarios:

- **High Penetration Circumstances**: the reliable delivery of power to loads becomes dependent on the generation of distributed resources, then fast disconnection during voltage disturbances may not be desirable.
- **Systems with Poor Power Quality**: flexibility in defining the dynamic connect and disconnect behaviors of inverters may be beneficial in small system, island, or long feeder in which voltage disturbances frequently occur.
- **Islanding**: where islanding can occur ride-though requirements may be modified to suit the variability and stability of islanded grids.

L/HVRT range and specific behavior are shown on figure 3 and table 3.

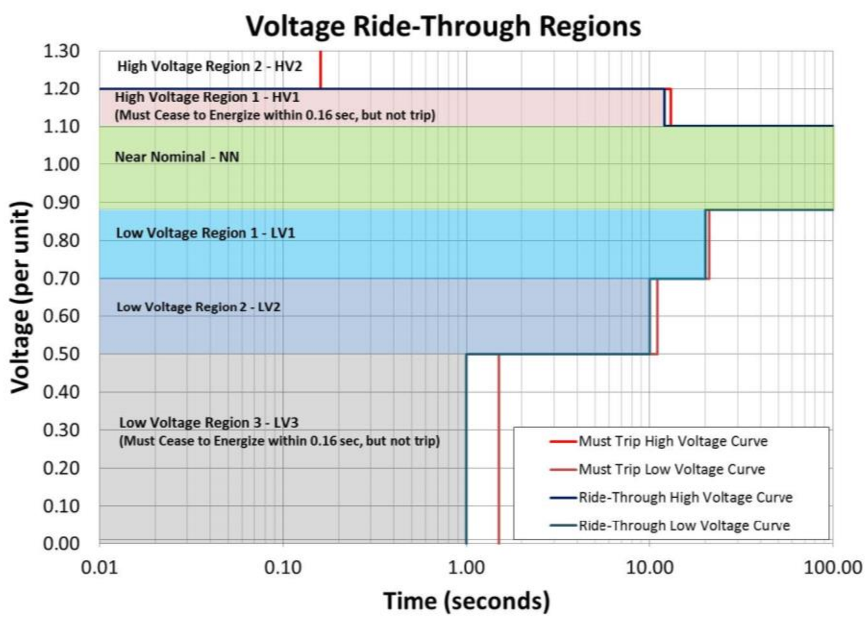


Figure 3: L/HVRT configuration example

Region	Operating mode
High Voltage 2 (HV2)	No Ride Through
High Voltage 1 (HV1)	Momentary Cessation within 0.16 s
Near Nominal (NN)	Continuous Operation
Low Voltage 1 (LV1)	Mandatory Operation
Low Voltage 2 (LV2)	Mandatory Operation
Low Voltage 3 (LV3)	Momentary Cessation within 0.16 s
Mandatory Operation: In response to an abnormal excursion of the area EPS, the DER shall provide maximum available real and reactive current to the area EPS. Any protective functions needed to prevent damage to the DER shall be permitted during mandatory operation.	
Momentary Cessation: In response to an abnormal excursion of the area EPS, the DER shall, with no intentional delay, cease to provide real and reactive current to the area EPS in not more than the maximum specified time	
Continuous Operation: While the area EPS is within normal parameters, the DER unit shall operate normally and provide maximum available real and reactive power to the area EPS.	
Ride-Through: In response to an abnormal excursion of the area EPS, the DER may provide. maximum available real and reactive current to the area EPS or, may cease to energize the area EPS, for not less than the minimum specified duration during ride-through, the DER shall not trip in less than the minimum specified duration.	

Table 3: L/HVRT Regions and behavior

When an ABB Grid Support Utility Interactive Inverter is configured for compliance with Rule 21 or Rule 14H the following settings applies.

Parameter		Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
V>>	OV2 Vgrid Voltage – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	OV2 Vgrid Voltage – Value	U/Un [%]	120	120	Fixed
	OV2 Vgrid Trip Time	s	0.16	0.16	[0.001– 0.16]
V>	OV1 Vgrid Voltage – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	OV1 Vgrid Voltage – Value	U/Un [%]	110	110	[110 – 120]
	OV1 Vgrid Trip Time	S	13	1	[0.16 – 100]
V<	UV1 Vgrid Voltage – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	UV1 Vgrid Voltage – Value	U/Un [%]	88	88	[70 – 88]
	UV1 Vgrid Trip Time	S	21	21	[0.16 – 100]
V<<	UV2 Vgrid Voltage – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	UV2 Vgrid Voltage – Value	U/Un [%]	70	70	[50 – 70]
	UV2 Vgrid Trip Time	S	11	21	[0.16 – 100]
V<<<	UV3 Vgrid Voltage – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	UV3 Vgrid Voltage – Value	U/Un [%]	50	50	Fixed
	UV3 Vgrid Trip Time	S	1.5	0.5	[0.16 – 50]
Momentary Cessation Threshold	HVRT Momentary Cess. Threshold	U/Un [%]	110	120	110 – 120
	LVRT Momentary Cess. Threshold	U/Un [%]	50	50	Fixed

Table 4: L/HVRT Grid Support Utility Inverter settings

The following figure shows the relationship between inverter parameters and SA9 L/HVRT ranges.

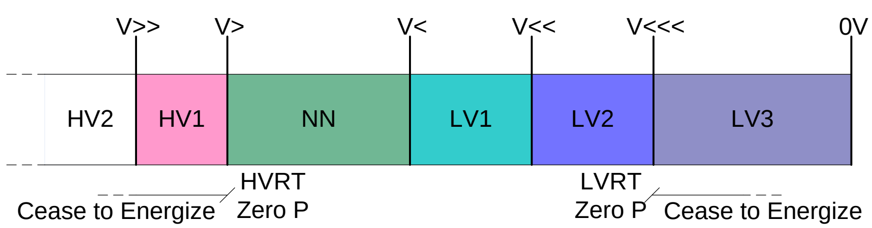


Figure 4: Inverter parameters and SA9 L/HVRT ranges

SA10 Low and High Frequency Ride Through

There is no system benefit for having a distributed generating resource disconnect during under frequency conditions below 57 Hz when most conventional resources will have disconnected, while for over frequency conditions, it is believed that system stability would be enhanced by ramping DER output from maximum near 60 Hz to zero near 61 Hz (and back up again as frequency decreases).

To avoid unnecessary power outage and disconnection due to unbalanced frequency events it is required for Grid Support Utility Interactive Inverter to accomplish to ride through faults accompanied by grid frequency perturbations according to the settings and behavior described on figure 5 and table 5.

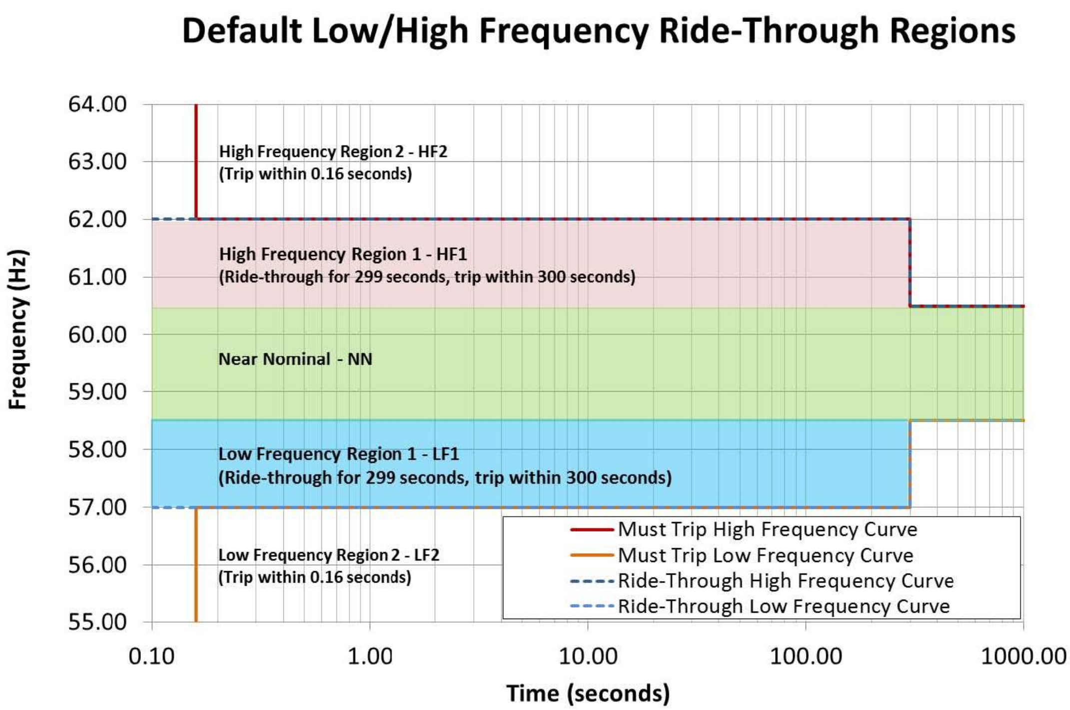


Figure 5: L/HFRT configuration example (Rule 21)

Region	Operating mode
High Frequency 2 (HF2)	No Ride Through
High Frequency 1 (HF1)	Mandatory Operation
Near Nominal (NN)	Continuous Operation
Low Frequency 1 (LF1)	Mandatory Operation
Low Frequency 2 (LF2)	No Ride Through
Mandatory Operation: In response to an abnormal excursion of the area EPS, the DER shall provide maximum available real and reactive current to the area EPS. Any protective functions needed to prevent damage to the DER shall be permitted during mandatory operation.	
Continuous Operation: While the area EPS is within normal parameters, the DER unit shall operate normally and provide maximum available real and reactive power to the area EPS.	
Ride-Through: In response to an abnormal excursion of the area EPS, the DER may provide. maximum available real and reactive current to the area EPS or, may cease to energize the area EPS, for not less than the minimum specified duration During ride-through, the DER shall not trip in less than the minimum specified duration.	

Table 5: L/HFRT Regions and behavior

When an ABB Grid Support Utility Interactive Inverter is configured to be compliance with Rule 21 or Rule 14H the following settings applies.

Parameter		**Unit**	**Default Settings**		**Inverter Range of Adjustment**
			Rule 21	**Rule 14H**	
F>>	OF2 Grid Frequency – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	OF2 Grid Frequency	Hz	62	64	[60.1 – 66]
	OF2 Grid Frequency Trip Time	s	0.16	0.16	[0.16 – 1000]
F>	OF1 Grid Frequency – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	OF1 Grid Frequency	Hz	60.5	63	[60.1 – 66]
	OF1 Grid Frequency Trip Time	s	300	21	[0.16 – 1000]
F<	UF1 Grid Frequency – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	UF1 Grid Frequency	Hz	58.5	57	[50 – 59.9]
	UF1 Grid Frequency Trip Time	s	300	21	[0.16 – 1000]
F<<	UF2 Grid Frequency – En / Dis	-	Enabled	Enabled	Enabled/Disabled
	UF2 Grid Frequency	Hz	57	56	[50 – 59.9]
	UF2 Grid Frequency Trip Time	s	0.16	0.16	[0.16 – 1000]
Momentary Cessation Threshold	HFRT Momentary Cessation	Hz	67	67	[60.1 – 67]
	LFRT Momentary Cessation	Hz	50	50	[50 – 59.9]

Table 6: L/HFRT Grid Support Utility Inverter settings

The following figure shows the relationship between inverter parameters and SA10 L/HFRT ranges

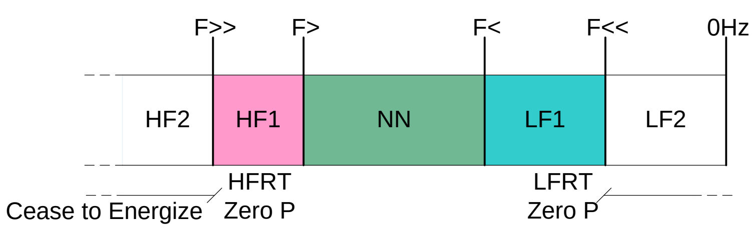


Figure 6: Inverter parameters and SA10 L/HFRT ranges

SA11 Normal Ramp Rate and Soft Start Ramp Rate Control

Ramp rate is the rate of increasing power for transitions between energy output levels, either due to commanded changes or contingent on external situations (Ex. Irradiance dip).

The purpose of establishing ramp-up rates for systems is to help smooth transitions from one output level to another output level.

UL1741-SA defines two types of ramp rates**:**

- SA11 RR: Normal Ramp Up rate when the inverter is adjusting the output power, e.g., when a PV inverter is following the available power from the dc source.
- SA11 SS: Soft Start Ramp Up rate defines the behavior of the inverter to ramp from zero to operating power upon reconnecting after a trip.

Example of Normal Ramp up and Soft Start are shown on figure 7 and figure 8 for a PVS-175-TL-US.

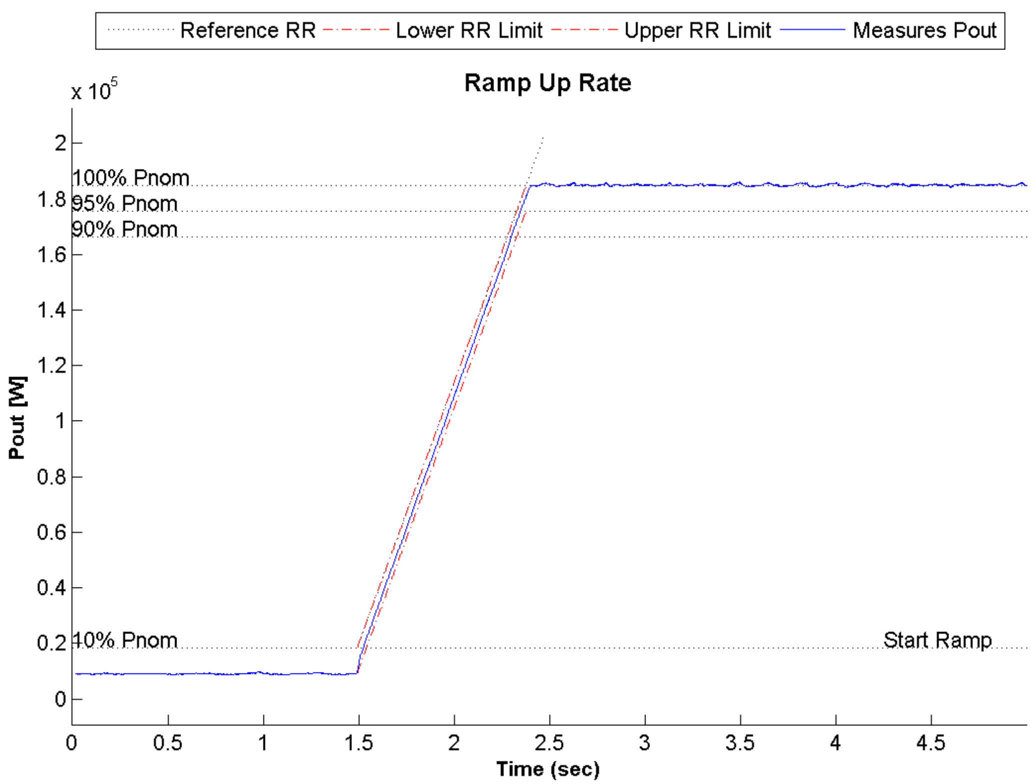


Figure 7: PVS-175-TL-US, Normal Ramp Up @ 100% Prated/s with upper and lower bound

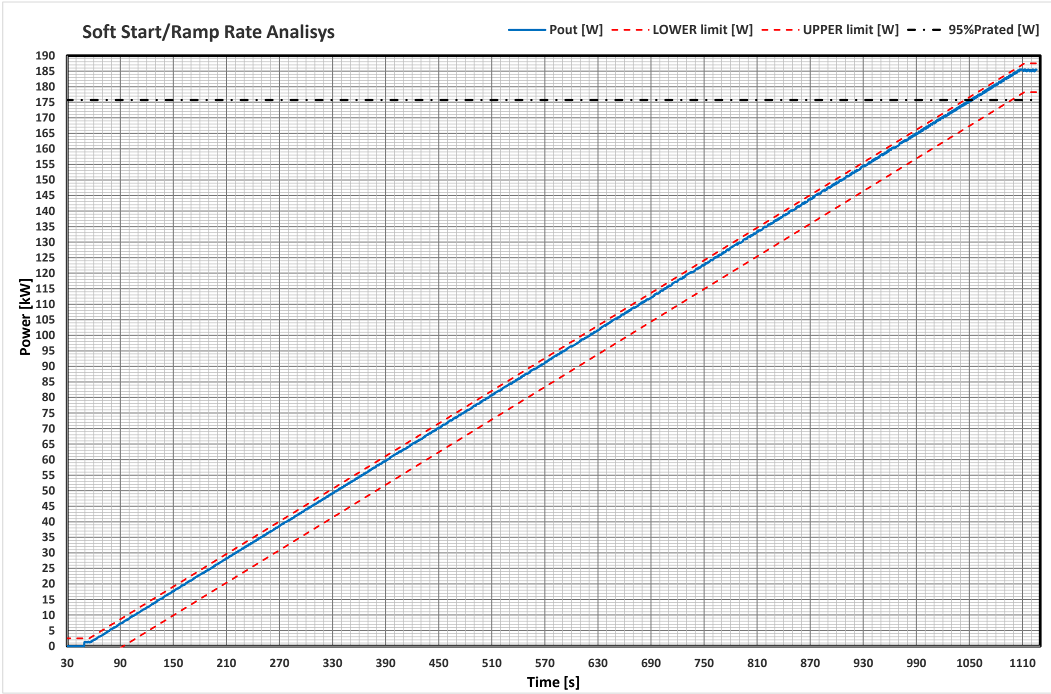


Figure 8: PVS-175-TL-US, Soft Start Ramp Up @ 0.1% Prated/s with upper and lower bound

The manufacturer parameters are declared on annex 1 for ABB Grid Support Utility Interactive Inverter certified for UL1741-SA with Rule 21 and Rule 14H SRDs.

When an ABB Grid Support Utility Interactive Inverter is configured to comply with Rule 21 or Rule 14H the following settings applies.

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Normal Ramp Up Rate (Enabled)	SA11 RR	Flag	Enabled	Enabled	En./Dis.
Normal Ramp Up Rate	SA11 RR	%Imax/s	100	100	[1 – 200]
Soft Start Ramp Rate (Enabled)	SA11 SS	Flag	Enabled	Enabled	En./Dis.
Soft Start Ramp Rate	SA11 SS	%Imax/s	2	0.33	[0.1 – 100]

Table 7: SA11 Normal Ramp Rate and Soft Start Grid Support Utility Inverter settings

SA12 Specified Power Factor

The most efficient operation of a power system is if it has zero reactive power, and thus has the optimal power factor (PF) of 1.0. However different types of loads and power systems can generate reactive power, thus lowering the PF below the optimal value of 1.0.

The purpose of establishing fixed or commanded (dynamic) power factors in power systems is to help compensate for those loads that generate reactive power.

The SRDs Rule 21 and Rule 14H requires to the inverter to adjust the power factor with the following requirements:

- Default Power Factor setting: 1.0 +/- 0.01 (0.99 Lagging to 0.99 Leading)
- If the aggregate generating facility is greater than 15 kW:
    - The power actor shall be adjustable in the range1.0 +/- 0.15 (0.85 Lagging to 0.85 Leading) down to 20% rated power based on available reactive power
- If the aggregate generating facility is less than or equal to 15 kW:
    - The power actor shall be adjustable in the range 1.0 +/- 0.10 (0.90 Lagging to 0.90 Leading) down to 20% rated power based on available reactive power

When an ABB Grid Support Utility Interactive Inverter is configured to comply with Rule 21 or Rule 14H the following settings applies.

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment	
			Rule 21	Rule 14H		
Power Factor (Enabled)	SA12 Spec Pf	Flag	Disabled	Disabled	En./Dis.	En./Dis.
Power Factor (Set Point)	SA12 Spec Pf	-	0.95 UE	0.95 UE	0.8 –1 UE/OE	

Table 8: SA12 Specified Power Factor Grid Support Utility Inverter settings

NOTE: Check Annex 1 for details about the reactive power and power factor sign convention

ABB Grid Support Utility Interactive Inverters are configured and certified according to UL 1741-SA with the capability shown on figure 9.

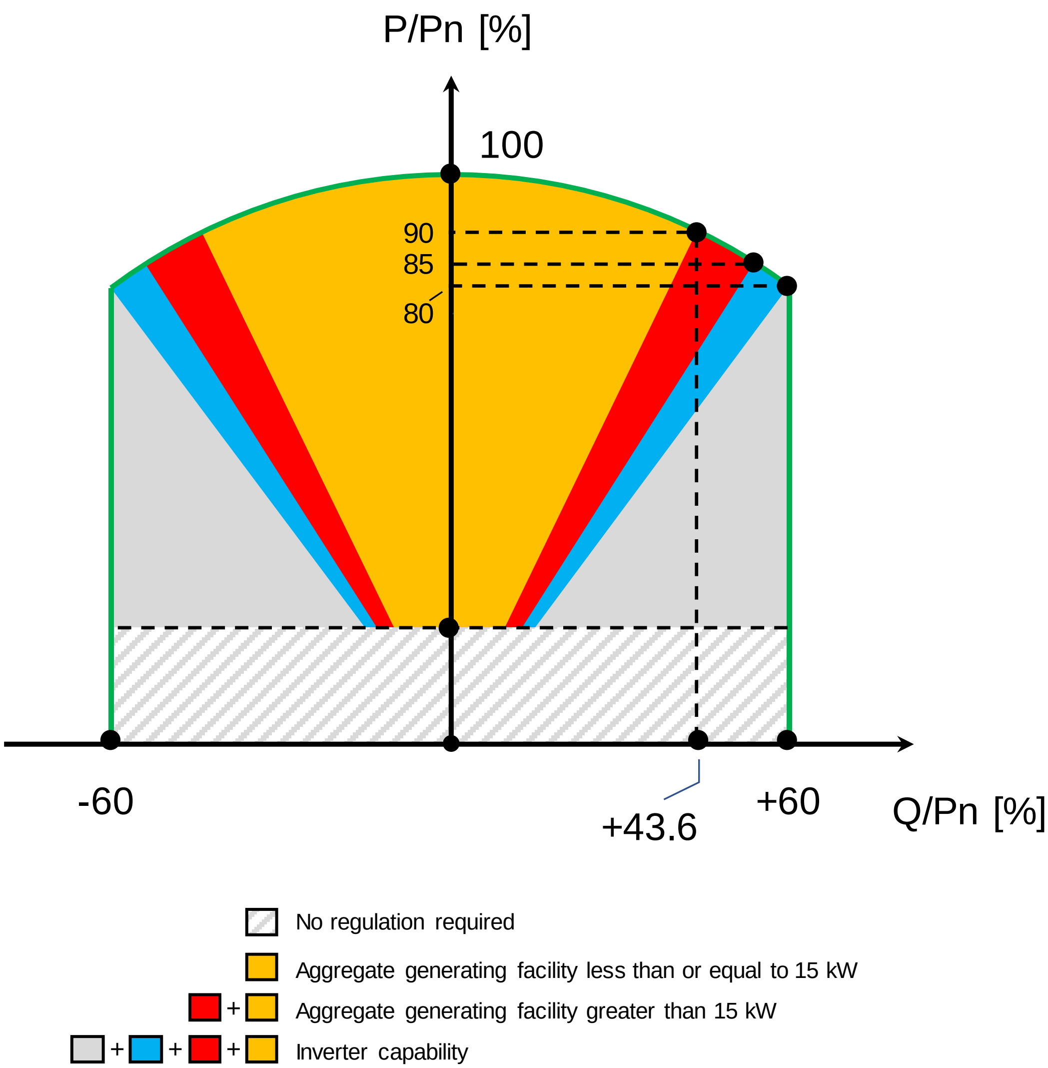


Figure 9: Inverter Capability and power factor required ranges

SA13 Volt/VAr Mode (Q(V))

In order to maintain a stable grid voltage, it is desired that inverters be able to supply or absorb reactive power to/from the grid. One way to achieve this is to have the inverter supply or absorb reactive power in response to fluctuations in grid voltage. The inverter supplies or absorbs reactive power as a function of voltage known as a Q(V) function or Volt-VAr mode.

The purpose of Volt-VAr operations is to use DER systems to help maintain voltage levels within their near-normal ranges. This capability can be particularly important for DER systems (and aggregations of systems) that may impact the normal voltage range on a feeder, such as those at the end of long, electrically “weak” circuits. However, dynamic Volt-VAr operations could be used for other purposes such as helping to maintain conservation voltage reduction levels.

The amount of reactive power can be established by a “curve” defining voltage versus percentage of reactive power, ABB Grid Support Utility Interactive Inverter are certified according to UL1741-SA and Rule 21/14H SRDs to work on any possible scenario between the most aggressive and less aggressive configurations illustrated in fig. 10.

TEST#	Curve	Voltage [V/Vnom]				Q(*) [Q/Srated]			
		V1	V2	V3	V4	Q1	Q2	Q3	Q4
1	Most Aggressive	0.9725	1.0000	1.0000	1.0275	0.60	0.00	0.00	-0.60
2	Average	0.9498	0.9729	1.0271	1.0502	0.30	0.00	0.00	-0.30
3	Least Aggressive	0.9094	0.9459	1.0541	1.0906	0.15	0.00	0.00	-0.15

(*) Positive = Over-excited = producing / Negative = Under-excited = absorbing

Table 9: Volt-VAr Most, Average and Least Aggressive points

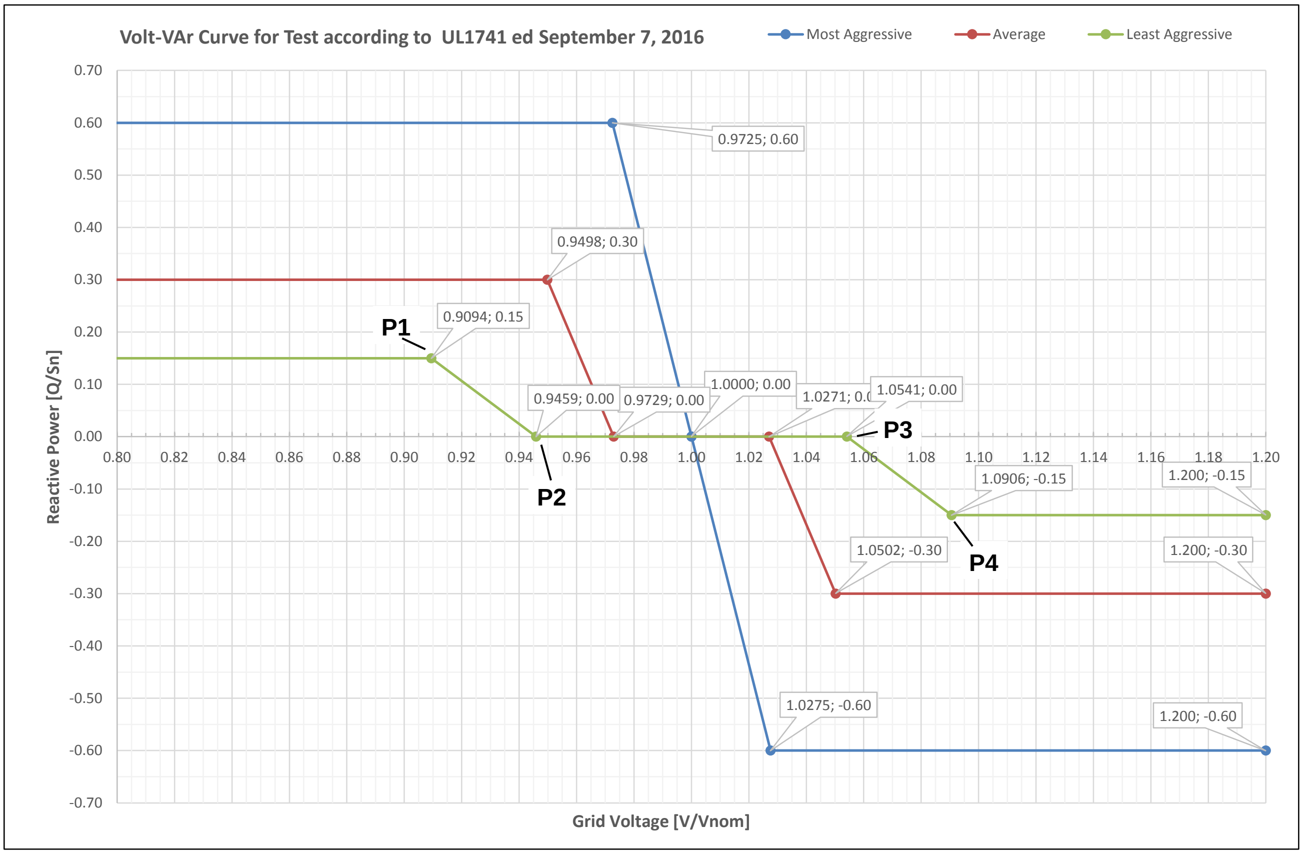


Figure 10: Volt-VAr Most (blue), Average (brown) and Least (green) aggressive curves for PVS-175-TL-US

NOTE: The reference voltage used as input of the Volt-VAr Mode is measured by the inverter directly at the AC output terminals.

NOTE: Check Annex 1 for details about the reactive power and power factor sign convention

Default Settings for ABB Grid Support Utility Interactive Inverters PVS-175-TL-US and PVS-166-TL-US are shown on Table 10.

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Enable/Disable	SA13 VV	Flag	Enabled	Enabled	En./Dis.
Intentional Delay	SA13 VV	ms	0	0	[0 – 3000]
Point 1: V1	SA13 VV	% V/Vn	92	94	[70 – 115]
Point 1: Q1	SA13 VV	% Q/Sn	30	44	[0 - 100]
Point 2: V2	SA13 VV	% V/Vn	96.7	97	[75 – 115]
Point 2: Q2	SA13 VV	% Q/Sn	0	0	[-100 – 100]
Point 3: V3	SA13 VV	% V/Vn	103.3	103	[75 – 115]
Point 3: Q3	SA13 VV	% Q/Sn	0	0	[-100 – 100]
Point 4: V4	SA13 VV	% V/Vn	107	106	[75 – 120]
Point 4: Q4	SA13 VV	% Q/Sn	- 30	- 44	[-100 – 0]
CEI Lock In	SA13 VV	P/Pn	0	0	0/1 (Dis./En)
CEI Lock Out	SA13 VV	P/Pn	0	0	0/1 (Dis./En)
Q(V) Low Pass Input Filter En/Dis	SA13 VV	Flag	Enabled	Enabled	En./Dis.
Q(V) Input Filter Time Constant 3τ	SA13 VV	s	5	10	[0.5 – 120]

Table 10: SA13 VV Grid Support Utility Inverter settings (PVS-166/175-TL-US)

Once the Volt-VAr mode is enabled then Grid Support Utility Interactive Inverter will provide a fixed amount of reactive power proportional to the Voltage level at the inverter output terminals. The above 4 points P1, P2, P3 and P4 defines the Volt-VAr curve and the relationship between reactive power and voltage within the functionality range, when the voltage level at inverter output is greater than the point P4 or lower than the point P1 the inverter will keep the same reactive power reached on that point.

As mentioned earlier, the purpose of Volt-VAr operations is to use DER systems to help maintain voltage levels within their near-normal ranges, responding to slow voltage changes with a proportional amount of reactive power. However, the use of this control function when applied with very fast response times, may be counterproductive, as it will react to voltage glitches and short term voltage transients that are induced during the start-up or disconnection of loads. While it is beneficial to counteract to the long-term (seconds) effects of the voltage changes induced by loads, it is not required an immediate response, because even small delays in the control may generate voltage oscillations and deteriorate the voltage quality.

In order to prevent the side effects induced by the application of Volt-Var control to the feeder voltage profile, the control function integrated in the Grid Support Utility Interactive Inverter is integrating a 1st order low pass filter applied to the AC voltage measured at the output terminals of the unit, that may be adjusted as described below through the "Q(V) Input Filter Time Constant 3τ" parameter.

Q(V) Input Filter Time Constant 3τ: the grid voltage value used for controlling the reactive power in accordance with the Volt-VAr curve may be filtered by a 1st order low pass filter (when **Q(V) Low Pass Input Filter En/Dis = Enabled**). The time constant may be adjusted through this parameter, and its value will represent the time required for the value of the voltage used for the calculation of the P(f) function to reach 95% of its target value in response to a step change of the grid voltage.

NOTE: the points P1…P4 must be kept with incremental voltage settings, the inverter will not accept any configuration if this order is not kept.

ABB Grid Support Utility Interactive Inverter are equipped with additional parameters not directly required by the Rule 21 and Rule 14H but necessary to satisfy other grid codes. In case required by the Utility, it is possible to adjust these parameters:

- **Intentional Delay:** defines the time the voltage need to continuously stay above P3 or below P2 before to feed reactive power into the grid.
- **CEI Lock-In:** the Volt-VAr mode will be active only if the active power exported by the inverter will be greater than the Active Power Lock-In threshold.
- **CEI Lock-Out:** when the inverter is supplying reactive power due to active Volt-VAr mode, the inverter will stop to feed reactive power if the active power exported by the inverter will fall below the Lock Out threshold.
  Note: Lock In threshold must always be greater than Lock Out to create a hysteresis range for Volt-VAr mode.

The inverter capability for Volt-VAr mode is shown on figure 9 and corresponds to:

- Minimum Power Factor (@S_N) $\cos\varphi = 0.8$
- Maximum Reactive Power $Q_{Max} = \sin\varphi * S_N = 0.6 * S_N$

That are equivalent to ($sin^2\varphi + cos^2\varphi = 0.6^2 + 0.8^2 = 1$).

NOTE: Volt-VAr Mode requires reactive power injection, so this autonomous function is mutually exclusive with Fixed Power Factor Mode.

NOTE: Heco SRD 1.1 test plots are available on Annex A3

SA14 Frequency-Watt (FW)

The context for the application of this function includes a variety of needs, for example:

- **Short-Term (Transient) Frequency Deviations**. Under certain circumstances, system frequency may dip suddenly. Autonomous responses to such events are desirable because response must be fast to be of benefit.
- **Long-Term Frequency Deviations or Oscillations**. Particularly in smaller systems or during islanded conditions, frequency deviations may be longer in duration and indicative of system generation shortfalls or excesses relative to load.

In particular the Smart Inverter Working Group (SIWG) analyzed the German Frequency Issue and the adoption of Frequency-Watt mode to avoid the switch off of all the PV generator in case of Over-frequency transients. Such events if not properly managed with the Frequency-Watt mode can create a switch off for a significant amount of generation capacity that could not be replaced by the conventional generation systems and consequently the risk of a national outage of electric power.

To help the power system during over-frequency transient events, the frequency-Watt function requires that the inverter reduces the output power according to a preconfigured droop. When the inverter is capable of increasing real power production the same control may be applied to help stabilize the frequency during under-frequency transients by increasing the generated active power proportionally to the drop of the grid frequency.

The amount of active power can be established by a "curve" defining output power versus frequency. ABB Grid Support Utility Interactive Inverter are certified according to UL1741-SA and Rule 21/14H SRDs with tests illustrated in fig. 11 and fig. 12 and the parameters described on Table 11.

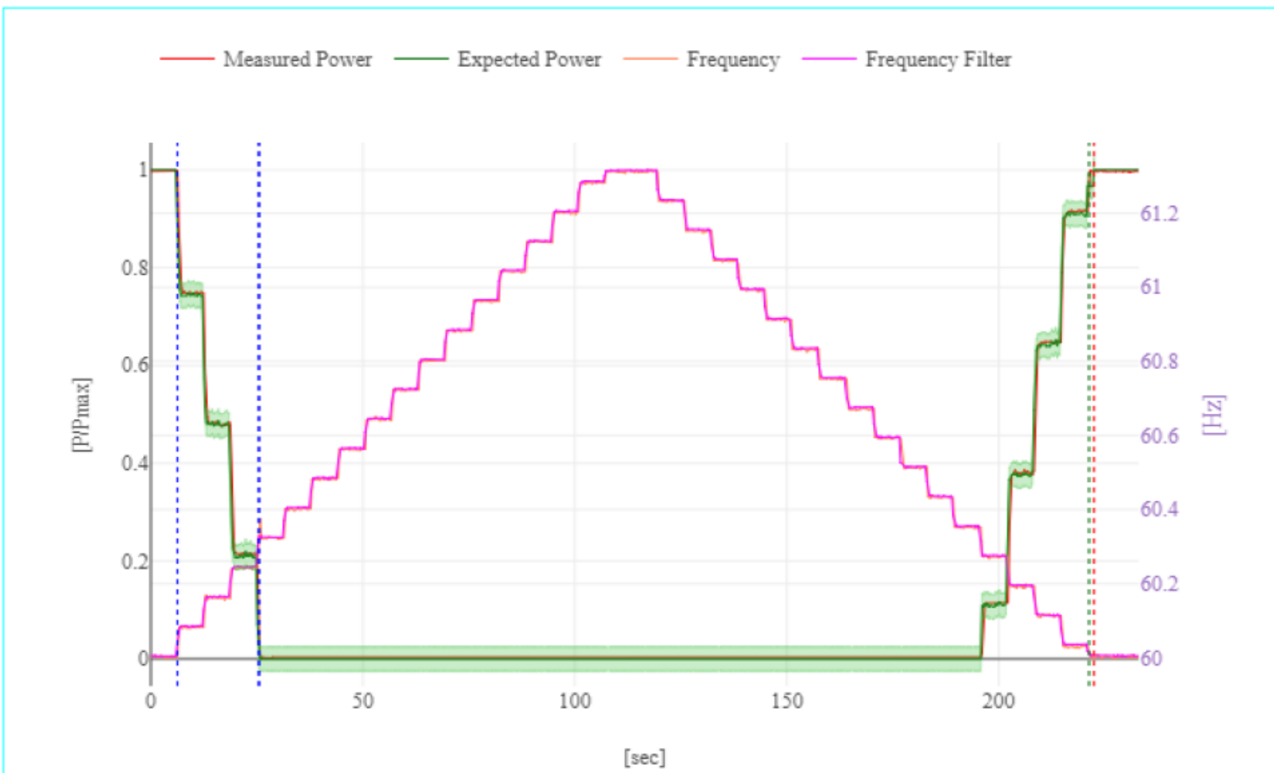


Figure 11: Frequency-Watt Test (PVS-175-TL-US).

Test #2 (max slope). Fstart = 60.01Hz / Fstop = 60.31 Hz, Droop = 333.33%*Pn/Hz

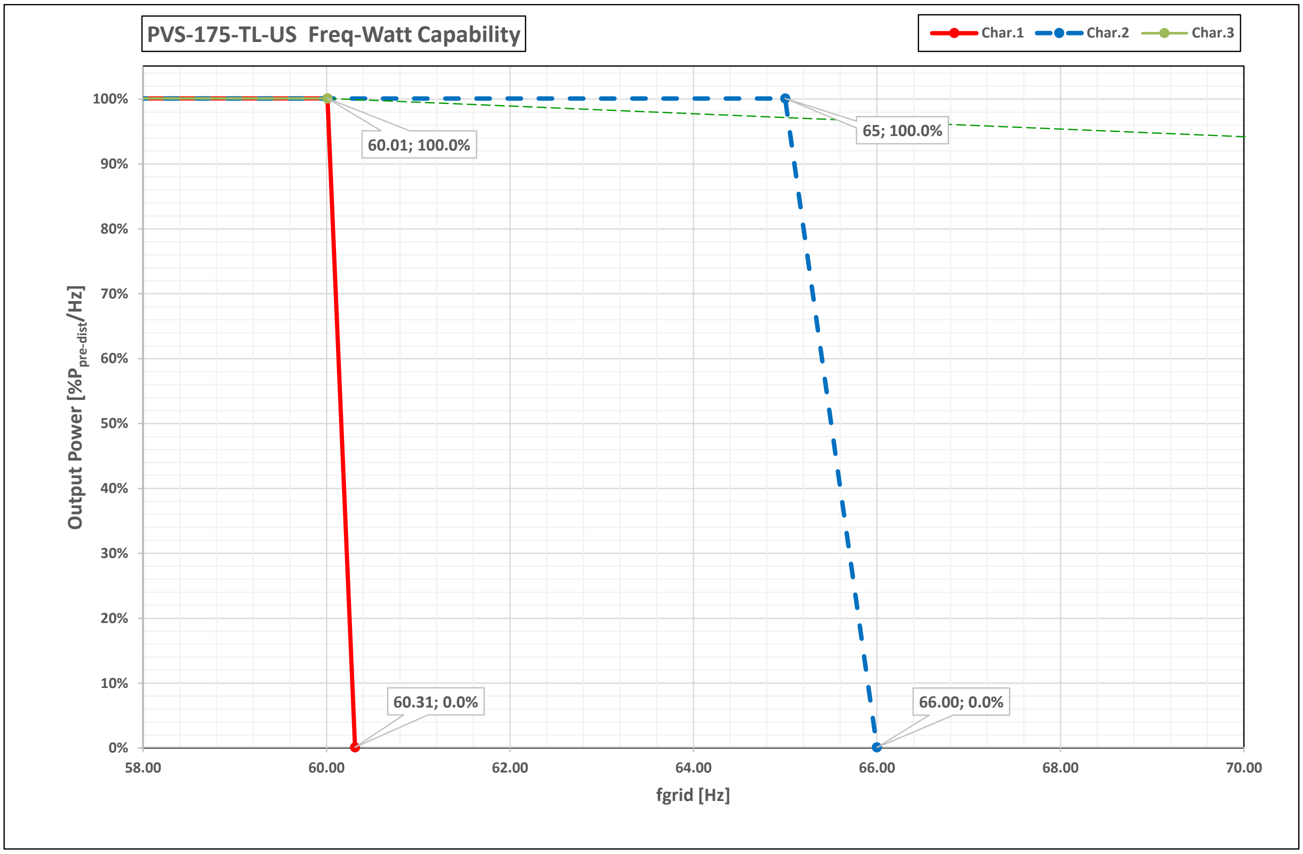


Figure 12: Frequency-Watt slope test

Test Number	Curve	Starting Frequency		Frequency Droop	
		fstart	Value [Hz]	Fstop [Hz]	Droop [%Pn/Hz]
1	Maximum Slope	max	65	66	100
2		min	60.01	60.31	333.33
3	Minimum Slope	min	60.01	1000000	≈ 0

Table 11: Frequency Watt parameters for maximum and minimum slope curves

The default parameter’s setting for the Frequency-Watt function and their adjustment range are listed in Table 12

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Freq. Derating General En/Dis	SA14 FW	Flag	Enabled	Enabled	En./Dis.
High Freq. Derating En/Dis	SA14 FW	Flag	Disabled	Enabled	En./Dis.
Low Freq. Derating En/Dis	SA14 FW	Flag	Disabled	Disabled	En./Dis.
Start Frequency Derating (O.F.)	SA14 FW	Hz	60.1	60.036	60.01 – 65

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Stop Frequency Derating (O.F.)	SA14 FW	Hz	62.1	63.036	60.31 – 1000000(*)
Start Frequency Derating (U.F.)	SA14 FW	Hz	57	59.964	55 – 59.99
Stop Frequency Derating (U.F.)	SA14 FW	Hz	54.5	56.964	55 – 59.99
Hysteresis Enable/Disable	SA14 FW	Flag	Disabled	Disabled	En./Dis.
High Freq. Droop Reference Power	SA14 FW	-	Pmax	Pmax	Pref_OF=Pmom (Snapshot mode) Pref_OF=Pmax
Low Freq. Droop Reference Power	SA14 FW	-	Pmom	Pmom	Pref_UF=Pmom (Snapshot mode) Pref_UF=Pmax
Intentional Delay (O.F.)	SA14 FW	msec	0	0	0 – 1000
Intentional Delay (U.F.)	SA14 FW	msec	0	0	0 – 1000
Restore Frequency: upper limit	SA14 FW	Hz	60.1	60.036	60.01 – 66
Restore frequency : lower limit	SA14 FW	Hz	59.9	59.964	50 – 59.99
Restore Frequency: check time (O.F.)	SA14 FW	sec	1	1	0 – 300
Restore Frequency: check time (U.F.)	SA14 FW	sec	1	1	0 – 300
Restore Ramp Enable/Disable	SA14 FW	Flag	Disabled	Disabled	En./Dis.
Restore Ramp Mode	SA14 FW	-	VDE-AR-N	VDE-AR-N	DISABLE or BDEW VDE-AR-N CEI 0-21 CEI 0-16
Restore Ramp Slope	SA14 FW	%Pn/s	2	0.33	[0.1 – 100]
P(f) Low Pass Input Filter En/Dis	SA14 FW	Flag	Disabled	Disabled	En./Dis.
P(f) Input Filter Time Constant 3τ (**)	SA14 FW	s	5	0.5	[0.05 – 10]

(*) Corresponds to a slope configurable in the range [0-333] %Pn/Hz
(**) Time to reach 95% of the new frequency value

Table 12: SA14 FW Grid Support Utility Inverter settings

The frequency watt function is normally enabled on ABB Grid Support Utility Interactive Inverters that are certified according to UL1741-SA, Rule 21 and Rule 14H SRD (see the default value of the “High Freq. Derating En/Dis” parameter on Table 12, except under-frequency control on Rule 14H).

ABB Grid Support Utility Interactive Inverters, with the Frequency-Watt function enabled, will respectively:

- Reduce the active power output when the frequency exceeds the **Start Frequency Derating (O.F.)**.
- Increase the active power output (when available) when the frequency fall below the **Start Frequency Derating (U.F.)**.

Taking as an example the over-frequency control, the inverter output power will be curtailed with a droop that may be expressed as a fixed percentage of Pmax (the nameplate rated power of the inverter) or as a percentage of the instantaneous power injected at the time the frequency has reached the **Start Frequency Derating (O.F.)** limit (the so-called “Snapshot mode”)

Having defined:

F_{start} = **Start Frequency Derating (O.F.)**

F_{stop} = **Stop Frequency Derating (O.F.)**

The droop will be respectively:

$$K_{Power-Freq} = \frac{P_{max}}{F_{start} - F_{stop}}$$

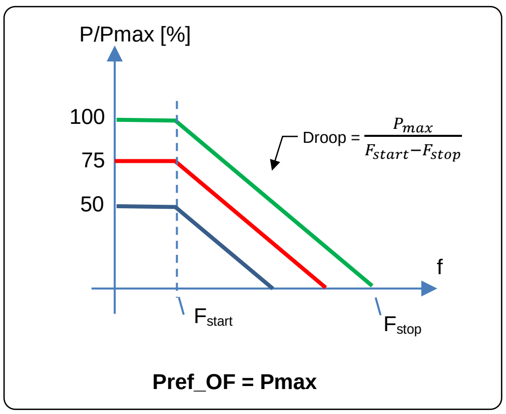
When **High Freq. Droop Reference Power (Pref_OF) = P_{max}**

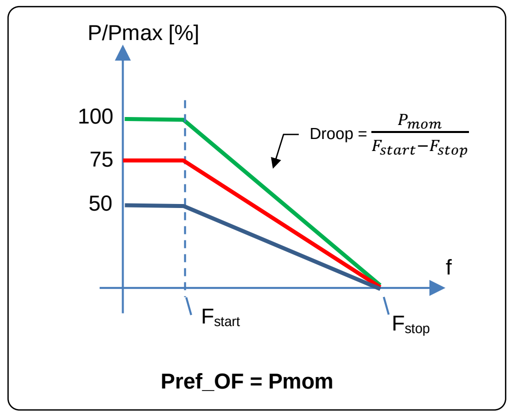
Or:

$$K_{Power-Freq} = \frac{P_{mom}}{F_{start} - F_{stop}}$$

When **High Freq. Droop Reference Power (Pref_OF) = P_{mom}**

For the same values of "F_{start}" and "F_{stop}", depending on the configuration of the "High Freq. Droop Reference Power" parameter, the Frequency-Watt response during an over-frequency transient with initial "pre-fault" power respectively at 100% (green curve), 75% (red curve) and 50% (blue curve) of rated power may be graphically summarized as follows:



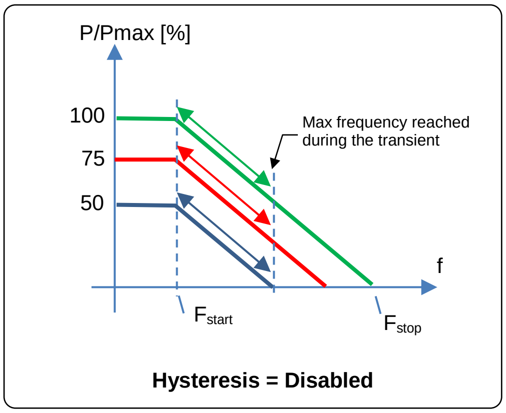


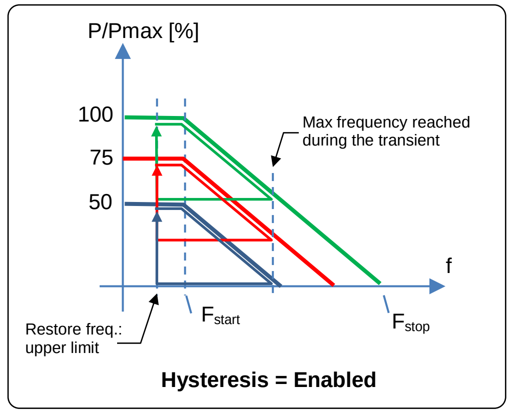
The function described so far and specified in the UL1741_SA, Rule 21/14H is limiting the power during high frequency transients. The inverters also integrate a similar function to release any available extra-power to the grid in response to frequency drops below the rated value.

To discriminate the specific parameters that are controlling the under-frequency behaviour the suffix "U.F." (Under Frequency) or "Low Freq. (Low Frequency) have been included in the parameter nomenclature.

The (O.F. = Over Frequency) Frequency-Watt behaviour for Grid Support Utility Interactive Inverters can be adjusted as follows:

- **Intentional Delay (O.F.):** defines the time the frequency need to continuously stay over **Start Frequency Derating (O.F.)** before to trigger the Frequency-Watt function.
- **P(f) Input Filter Time Constant 3τ:** the grid frequency value used for controlling the output power in accordance with the Frequency-Watt curve may be filtered by 1st order low pass filter (when **P(f) Low Pass Input Filter En/Dis = Enabled**). The time constant may be adjusted through this parameter, and its value will represent the time required for the value of the frequency used for the calculation of the P(f) function to settle to 95% of its target value in response to a step change of the grid frequency.
- **Upper and Lower frequency limit to restore normal operation**: when the inverter follows the Frequency-Watt curve and the frequency permanently fall back within this range for a time exceeding the **Restore Frequency: check time (O.F.)**, then the Grid Support Utility Interactive Inverter consider closed the transient for over-frequency and start the routine to restore the output power to the normal operating conditions.
- **Hysteresis Enable/Disable**: during overfrequency transients the control will operate according to the following graph depending on the status of the Hysteresis parameter:





The following parameters define the behaviour of the routine to restore the output power to normal operating conditions:

- **Restore Frequency: check time (O.F.)**: define the minimum time in which the frequency shall permanently remain within the interval between **Restore frequency: lower limit** and **Restore frequency: upper limit,** before to start the restore routine. If the frequency moves outside the lower to upper frequency limit to restore normal operation before the restore time is elapsed, then the timer is reset, and the inverter keep to follow the Frequency-Watt curve until the restore time and normal operating range are both satisfied.
- **Restore Ramp Enable/Disable:** when enabled, the unit will restore the power available when frequency recovers within the restore frequency upper-lower limits following the selected "**Restore Ramp Mode**" as described below. When disabled the active power will be restored after the frequency transient with a rate of change limited by the SA11 Normal Ramp Rate (SA11 RR).
- **Restore Ramp Mode**: the parameter defines the behaviour of the inverter during the restore routine, it is possible to select one of the following modes:
  - **VDE-AR-N**: the inverter will act according to the german AR-N4105 grid code and will immediately restore the output power to $P_{FWstarting}$ (Hysteresis = Disabled). If the available power is greater than $P_{FWstarting}$ the inverter will increase the output power up the available power with a fixed ramp (defined by parameter "**Restore Ramp Slope**" expressed as Prated/min).
  - **CEI 0-21**: the inverter will act according to the Italian CEI 0-21 grid code. When the frequency exceeds the $P_{FWstarting}$ for a time greater than the intentional delay the inverter will start to reduce the output power according to Frequency-Watt curve. If the frequency starts to reduce the inverter stop to follow the curve keeping the minimum output power reached on the Frequency Watt curve (Hysteresis = Enabled). In case of frequency oscillation, the inverter will always provide the minimum output power at the maximum frequency reached by the grid according to the Frequency-Watt curve. The restore routine will start as usual according with **Restore Frequency: check time (O.F.)** and **Lower-Upper limit of the Restore Frequency**, the inverter will restore the output power with a fixed ramp rate (defined by parameter "**Restore Ramp Slope**" expressed in $P_{FWstarting}$/min) up to the available power. The minimum slope of $5\% \, P_{Nom}/min$ still applies.
  - **CEI 0-16**: the inverter will act according to the Italian CEI 0-16 grid code. The behavior of this mode is the same as for CEI 0-21 with the following exception: the fixed slope will be runtime calculated in order to restore the output power to $P_{FWstarting}$ in exactly 100/ **Restore Ramp Slope** per minutes. The minimum slope of 5%Pn/min still applies.
  - **DISABLE** or **BDEW**: the inverter will act according to the German BDEW grid code. The behavior of this mode is to disable the ramp and the inverter will immediately restore the output power to $P_{FWstarting}$.
- **Restore Ramp Slope**: the slope applied to the restore ramp, the parameter is expressed as Prated/min

SA15 Volt-Watt (VW)

The context for the inclusion of this function includes a variety of needs that were expressed by, for example:

- **High Penetration at the Distribution Level, Driving Feeder Voltage Too High**: Some utilities described circumstances where high PV output and low load is causing feeder voltage to go too high at certain times. Existing distribution controls are not able to prevent the occurrence.

- **Localized High Service Voltage**: Several utilities described circumstances where a large number of customers served by the same distribution transformer have PV, causing local service voltage that is too high. The result is certain PV inverters that do not turn on at all.

In order to support the grid voltage, an inverter may change its active power output with changes in grid voltage. As voltage increases, the desired response of the inverter is to shed power. Likewise, as voltage decreases it is desired for the inverter to increase power output. This increase in power may not always be possible depending on the energy source and the mode of operation. This active power response to a change in voltage is referred to as a Volt-Watt response function

The relationship between active power and voltage can be established by a "curve" (ref. fig. 13) defining voltage versus percentage of active power, ABB Grid Support Utility Interactive Inverter are certified according to UL1741-SA and Rule 14H SRDs to work on any possible scenario between the maximum and minimum slope configurations listed in table 13.

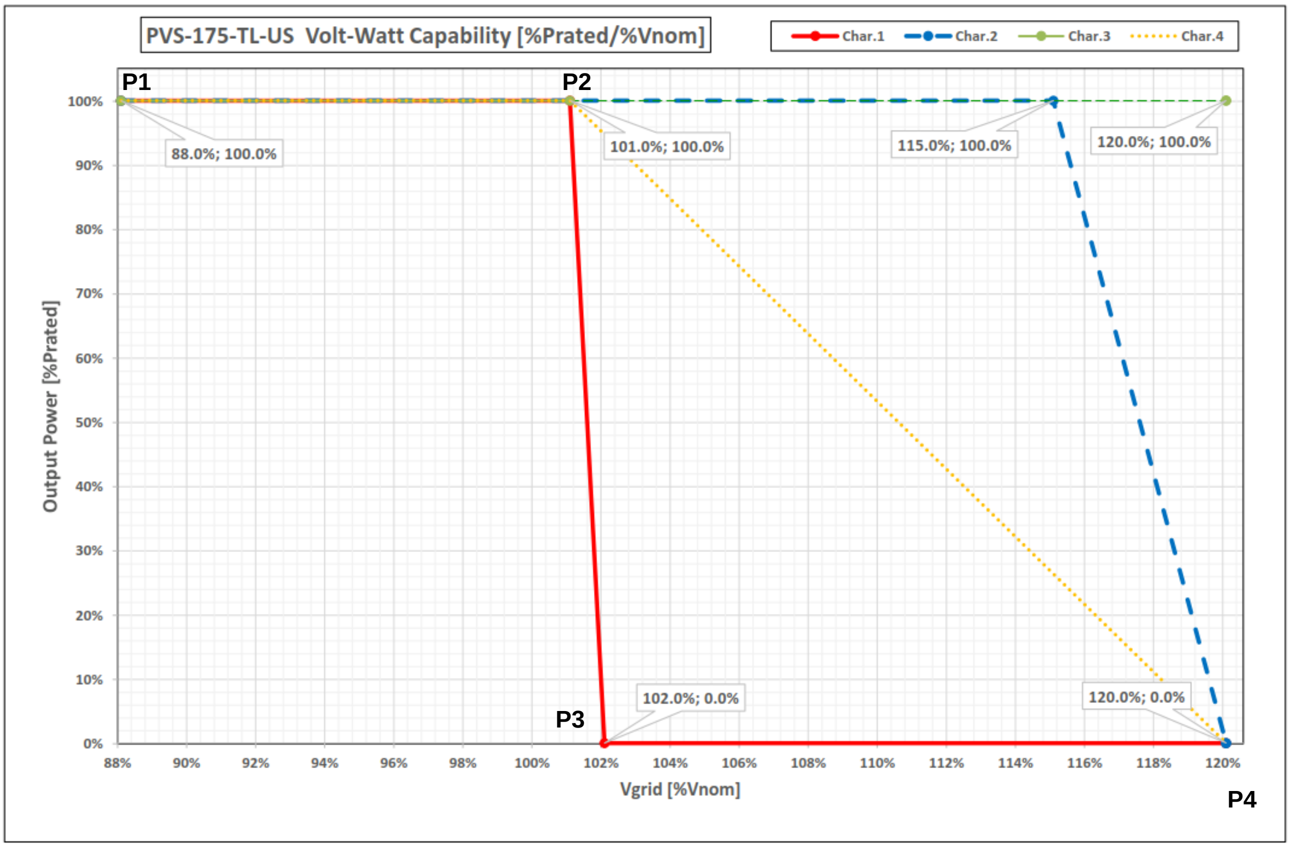


Figure 13: Test of Volt –Watt curve

Point#	Char1		Char2		Char3		Char4	
	Vgrid [V]	P [W]	Vgrid [V]	P [W]	Vgrid [V]	P [W]	Vgrid [V]	P [W]
1	88.0%	100.0%	88.0%	100.0%	88.0%	100.0%	88.0%	100.0%
2	101.0%	100.0%	115.0%	100.0%	101.0%	100.0%	115.0%	100.0%
3	102.0%	0.0%	120.0%	0.0%	120.0%	100.0%	120.0%	100.0%
4	120.0%	0.0%	120.0%	0.0%	120.0%	100.0%	120.0%	100.0%

Table 13: test configuration of Volt-Watt profile

The Volt-Watt function integrated in the ABB Grid Support Utility Interactive inverters is a piecewise P-V curve based on 16 points.

The default parameter's setting for the Volt-Watt function and their adjustment range are listed in Table 14

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Regulation Curve Enable/Disable	SA15 VW	Flag	Disabled	Disabled	En./Dis.
Point 1: V1	SA15 VW	% V/Vn	106	106	80 – 120
Point 1: W1	SA15 VW	% P/P_{Max}	100	100	0 – 100
Point 2: V2	SA15 VW	% V/Vn	108	110	80 – 120
Point 2: W2	SA15 VW	% P/P_{Max}	0	0	0 – 100
Point 3: V3	SA15 VW	% V/Vn	108	110	80 – 120
Point 3: W3	SA15 VW	% P/P_{Max}	0	0	0 – 100
Point 4: V4	SA15 VW	% V/Vn	108	110	80 – 120
Point 4: W4	SA15 VW	% P/P_{Max}	0	0	0 – 100
High Voltage Droop Reference Power	SA15 VW	-	Pmom	Pmax	Pref_OV=Pmom (Snapshot mode) Pref_OV=Pmax
P(V) Low Pass Input Filter En/Dis	SA15 VW	Flag	Enabled	Enabled	En./Dis.
P(V) Input Filter Time Constant 3τ (*)	SA15 VW	sec	5	10	[0.5 – 120]

(*) The control function, in accordance to Rule 21 and R14H, is based on a first order low-pass filter with adjustable time constant.

Table 14: SA15 VW Grid Support Utility Inverter settings

Once the Volt-Watt mode is enabled then Grid Support Utility Interactive Inverter will curtail the maximum active power according to the Voltage level at the inverter terminal output. The points P1, P2, P3, P4 define the Volt-Watt curve and the relationship between maximum active power and voltage, when the voltage level at inverter output will be greater than the point V3 or less than the point V0 the inverter will keep the same maximum active power reached at that point.

NOTE: the points P1…P4 must be kept with incremental voltage settings, the inverter will not accept any configuration if the above precedence is not kept.

The inverter will always follow the curve on both directions when voltage increase or decrease.

The inverter output power will be curtailed with a droop that may be expressed as a fixed percentage of Pmax (the nameplate rated power of the inverter) or as a percentage of the instantaneous power injected at the time the voltage has reached the **Point 2: V2** limit (the so-called "Snapshot mode")

The droop will be respectively:

$$K_{Power-Volt} = \frac{P_{max}}{V_2 - V_3}$$

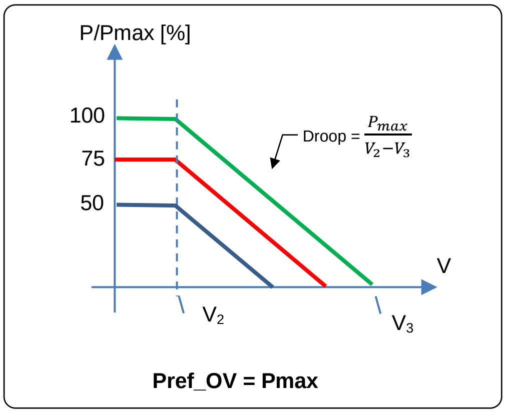
When **High Voltage Droop Reference Power (Pref_OV) = P_{max}**

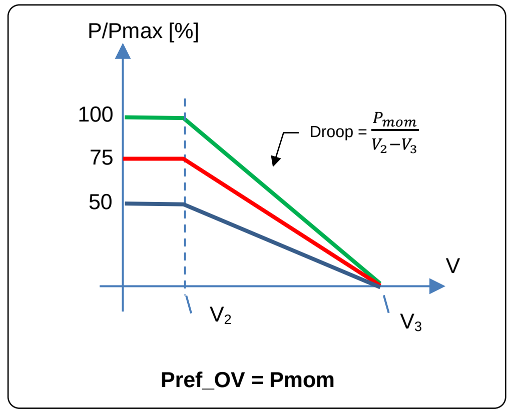
Or:

$$K_{Power-Volt} = \frac{P_{mom}}{V_2 - V_3}$$

When **High Voltage Droop Reference Power (Pref_OV) = P_{mom}**

For the same values of "V_{2t}" and "V_3", depending on the configuration of the "High Voltage Droop Reference Power" parameter, the Volt-Watt response during an over-voltage transient with initial "pre-transient" power respectively at 100% (green curve), 75% (red curve) and 50% (blue curve) of rated power may be graphically summarized as follows:





As mentioned earlier, the purpose of Volt-Watt operations is to use DER systems to help limit grid voltage levels within their near-normal ranges, responding to slow voltage rises with a proportional reduction of active power. This method is proven to be particularly effective on highly resistive lines.

However, the use of this control function when applied with very fast response times, may be counterproductive, as it will react to voltage glitches and short-term voltage transients that are induced during the start-up or disconnection of loads. While it is beneficial to counteract to the long-term (several seconds) effects of the voltage changes induced by loads, it is not required an immediate response, because even small delays in the control may generate voltage oscillations and deteriorate the voltage quality.

In order to prevent the side effects induced by the application of Volt-Watt control to the feeder voltage profile, the control function integrated in the Grid Support Utility Interactive Inverter is integrating a 1st order low pass filter applied to the AC voltage measured at the output terminals of the unit, that may be adjusted as described below through the "P(V) Input Filter Time Constant 3τ" parameter.

P(V) Input Filter Time Constant 3τ: the grid voltage value used for controlling the active power in accordance with the Volt-Watt curve may be filtered by a 1st order low pass filter (when **P(V) Low Pass Input Filter En/Dis = Enabled**). The time constant may be adjusted through this parameter, and its value will represent the time required for the value of the voltage used for the calculation of the P(V) function to reach 95% of its target value in response to a step change of the grid voltage.

Grid Standard Selection

Rule 21 and Rule 14H are the Source Requirement Document (SRD) released by the States of California and Hawaii, respectively and define the default settings required for autonomous functions.

To correctly apply the default settings described on this document the Grid Support Utility Interactive Inverter shall be configured according to the Tariff to be applied. The Grid Code Selection procedure shall be realized during the installation and commissioning of the inverter through the integrated web server or via mobile application ("ABB Ability Installer for solar inverters").

Parameter Adjustment

In case utility requires to adjust the parameters for the autonomous functions to values different form the default settings, it is possible to use the integrated web server in accordance to the following interoperability table.

Tool	SA8	SA9 L/HVRT	SA10 L/HFRT	SA12 Spec Pf	SA13 VV	SA11 RR	SA11 SS	SA14 FW	SA15 VW
Web Server	✘	✓	✓	✓	✓	✓	✓	✓	✓

Table 16: interoperability table

Configuration through Web Server

REQUIRED TOOL: Device capable to connect to internet for example laptop or smart phone, LAN/WiFi name and password, IP configuration of the inverter, admin account password and admin+ token (service password).

Before to proceed with the Web Server configuration you need to receive the token to enable the admin+ account, contact the ABB service with the Serial Number and week/year of production of each inverter to be configured.

Serial Number and week/year of production can be retrieved from the inverter label or from web server.

PROCEDURE:

Connect the networking device to the same WiFi or LAN of the Inverter then open a browser and insert the inverter IP address on the browser address bar then login to the inverter with the admin account.

Select *Settings* and then *Ine*, the available settings through web server are shown on figure 15.

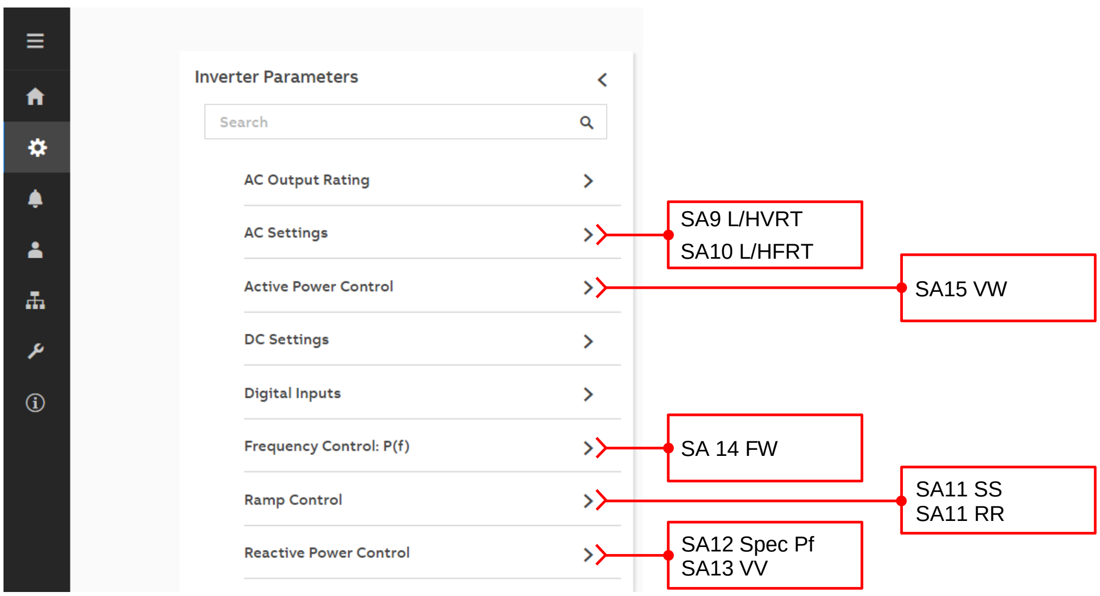


Fig. 15: Web Server – Settings Menu

SA8

No configuration possible.

SA9 L/HVRT

Enter on the sub menu AC Settings →*Grid Protections – VRT/FRT*

For each Variable OV2, OV1, UV1, UV2, UV3, the following applies:

Vgrid Voltage – En / Dis: to disable and enable the specific protection

Vgrid Voltage - Value: set the voltage threshold of the specific variable

Vgrid Trip Time: set the trip time threshold of the specific variable

When the "Momentary Cess. General En / Dis" parameter is set to "Enabled", the activation and trigger points of the Momentary Cessation function associated to voltage transients can be adjusted within this section as follows:

L/HVRT Momentary Cess. En / Dis: to disable and enable the momentary cessation function associated to LVRT and HVRT transients.

HVRT Momentary Cess. Threshold: set the voltage threshold that triggers the momentary cessation during grid overvoltage transients

LVRT Momentary Cess. Threshold: set the voltage threshold that triggers the momentary cessation during grid undervoltage transients

NOTE: In case voltage protection limits or trip times are modified, please obey the following rules:

OV2 ≥ OV1; Trip time_OV1 ≥ Trip time_OV2

UV1 ≥ UV2 ≥ UV3; Trip time_UV1 ≥ Trip time_UV2 ≥ Trip time_UV3

SA10 L/HFRT

Enter on the sub menu AC Settings →*Grid Protections – VRT/FRT*

For each Variable OF2, OF1, UF1, UF2 the following applies:

Grid Frequency – En / Dis: to disable and enable the specific protection

Grid Frequency: set the frequency threshold of the specific protection

Grid Frequency Trip Time: set the trip time threshold of the specific protection

When the "Momentary Cess. General En / Dis" parameter is set to "Enabled", the activation and trigger points of the Momentary Cessation function associated to frequency transients can be adjusted within this section as follows:

L/HFRT Momentary Cess. En / Dis: to disable and enable the momentary cessation function associated to LFRT and HFRT transients.

HFRT Momentary Cessation: set the frequency threshold that triggers the momentary cessation during grid overfrequency transients

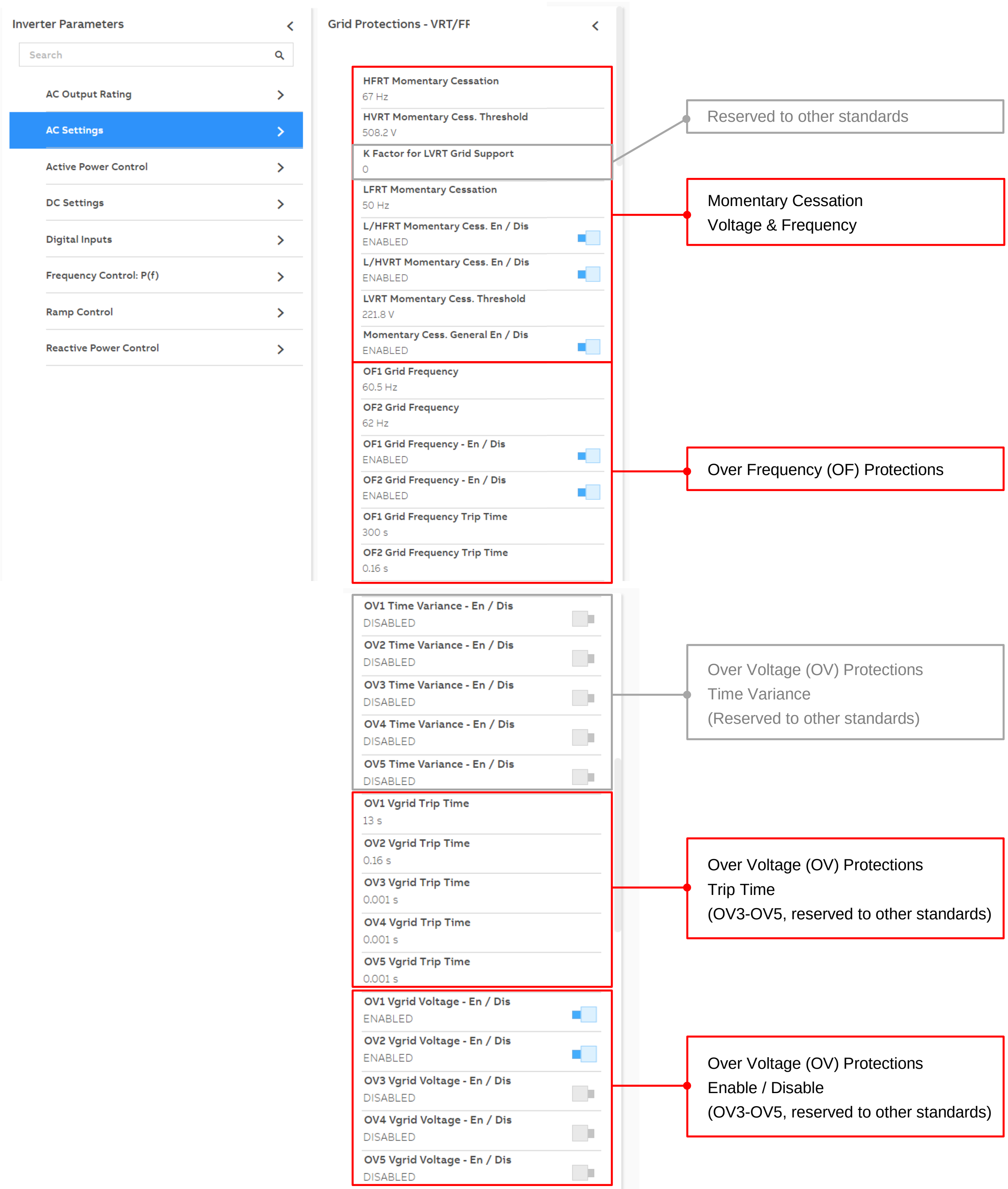
LFRT Momentary Cessation: set the frequency threshold that triggers the momentary cessation during grid underfrequency transients

NOTE: In case frequency protection limits or trip times are modified, please obey the following rules:

OF2 ≥ OF1; Trip time_OF1 ≥ Trip time_OF2

UF1 ≥ UF2; Trip time_UF1 ≥ Trip time_UF2

Refer to the **SA9 Low and High Voltage Ride Through and SA10 Low and High Frequency Ride Through** chapters for details about the description of the parameters.


Inverter Parameters
Search
AC Output Rating
AC Settings
Active Power Control
DC Settings
Digital Inputs
Frequency Control: P(f)
Ramp Control
Reactive Power Control
Grid Protections - VRT/FF
HFRT Momentary Cessation
67 Hz
HVRT Momentary Cess. Threshold
508.2 V
K Factor for LVRT Grid Support
0
LFRT Momentary Cessation
50 Hz
L/HFRT Momentary Cess. En / Dis
ENABLED
L/HVRT Momentary Cess. En / Dis
ENABLED
LVRT Momentary Cess. Threshold
221.8 V
Momentary Cess. General En / Dis
ENABLED
OF1 Grid Frequency
60.5 Hz
OF2 Grid Frequency
62 Hz
OF1 Grid Frequency - En / Dis
ENABLED
OF2 Grid Frequency - En / Dis
ENABLED
OF1 Grid Frequency Trip Time
300 s
OF2 Grid Frequency Trip Time
0.16 s
OV1 Time Variance - En / Dis
DISABLED
OV2 Time Variance - En / Dis
DISABLED
OV3 Time Variance - En / Dis
DISABLED
OV4 Time Variance - En / Dis
DISABLED
OV5 Time Variance - En / Dis
DISABLED
OV1 Vgrid Trip Time
13 s
OV2 Vgrid Trip Time
0.16 s
OV3 Vgrid Trip Time
0.001 s
OV4 Vgrid Trip Time
0.001 s
OV5 Vgrid Trip Time
0.001 s
OV1 Vgrid Voltage - En / Dis
ENABLED
OV2 Vgrid Voltage - En / Dis
ENABLED
OV3 Vgrid Voltage - En / Dis
DISABLED
OV4 Vgrid Voltage - En / Dis
DISABLED
OV5 Vgrid Voltage - En / Dis
DISABLED
Reserved to other standards
Momentary Cessation Voltage & Frequency
Over Frequency (OF) Protections
Over Voltage (OV) Protections Time Variance (Reserved to other standards)
Over Voltage (OV) Protections Trip Time (OV3-OV5, reserved to other standards)
Over Voltage (OV) Protections Enable / Disable (OV3-OV5, reserved to other standards)

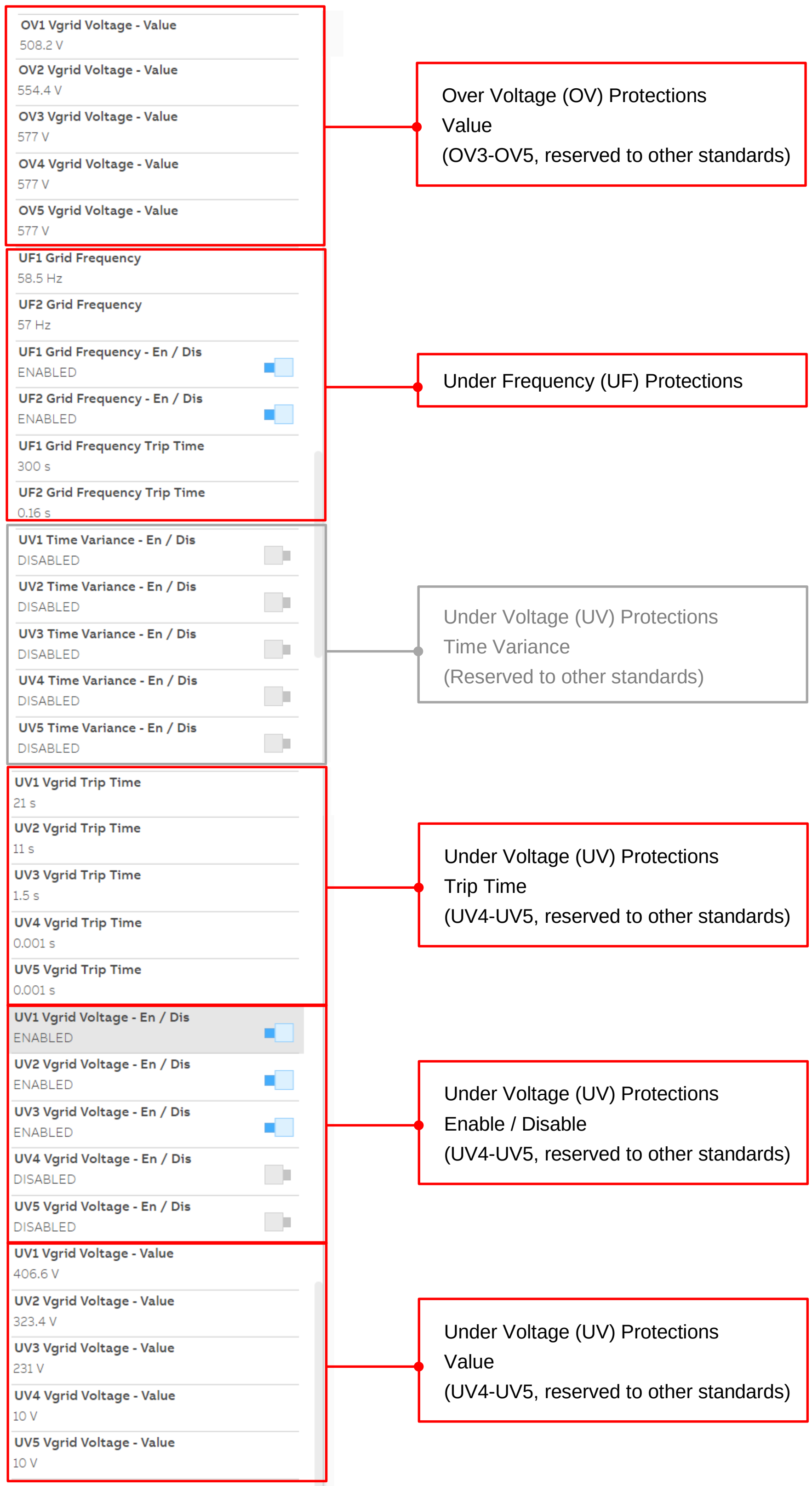
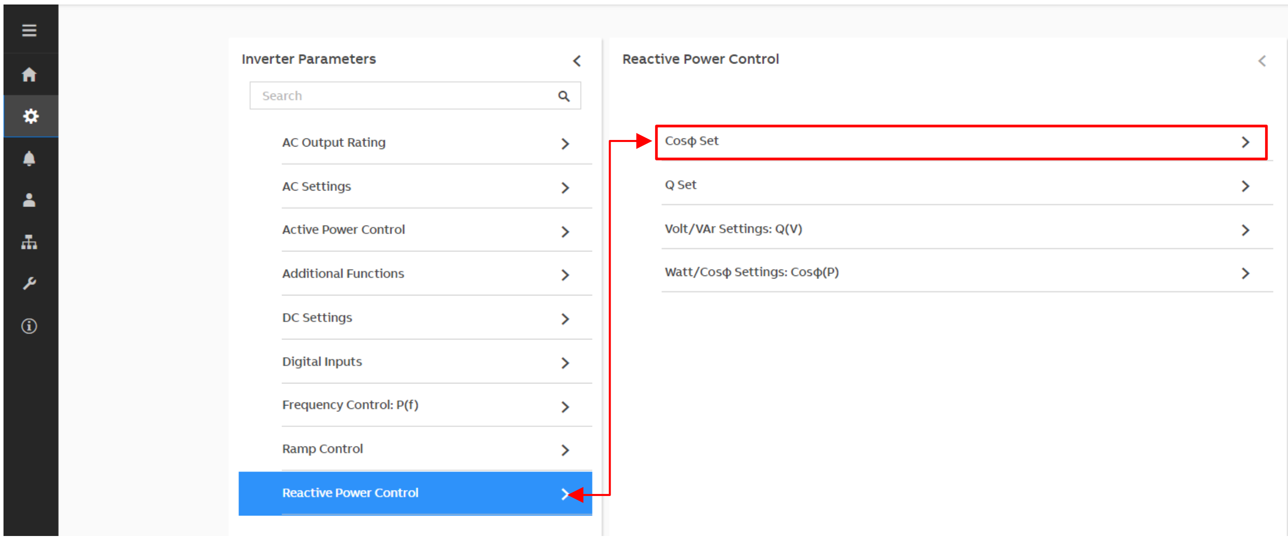


Figure 16: L/HVRT Configuration through Web Server

SA12 Specified Power Factor

(1) Select the **Reactive Power Control → CosΦ Set** menu from the Inverter Parameters section of the Settings Menu to configure the power factor according to Utility request.



(2) **CosΦ Set** sub-menu will allow you to Enable/Disable the control of the reactive power output of the unit based on a fixed cosΦ and define the value of the cosΦ within the capability limits of the inverter [0.8 (0.75) Lead to 0.8 (0.75) Lag for PVS-175 (PVS-166)].

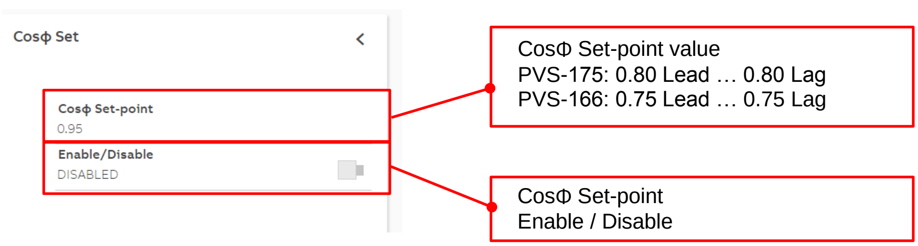


Figure 17: SA12 Specified Power Factor Configuration through Web Server

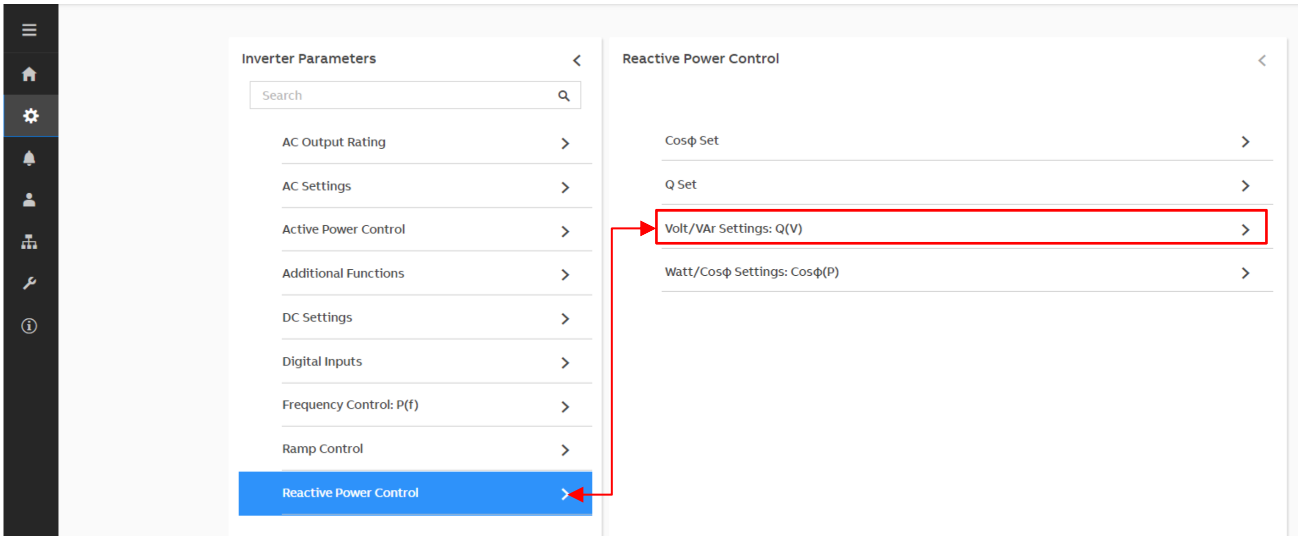
For details about the above parameters or inverter capability, refer to the description on chapter **SA12 Specified Power Factor Mode**

NOTE: Enabling the Power Factor control mode it will automatically disable any other reactive power mode.

NOTE: the sign of the power factor is assigned according to the reactive power sign and NOT according to EEI, as described on Annex 1.

SA13 VV

(1) Select the **Reactive Power Control → Volt/Var Settings: Q(V)** menu from the Inverter Parameters section of the Settings Menu to configure the Volt-Var mode according to Utility request.



(2) **Volt/Var Settings: Q(V)** sub-menu will allow you to Enable/Disable the control of reactive power based on the AC terminal voltage by a user(utility)-defined piecewise linear control curve.

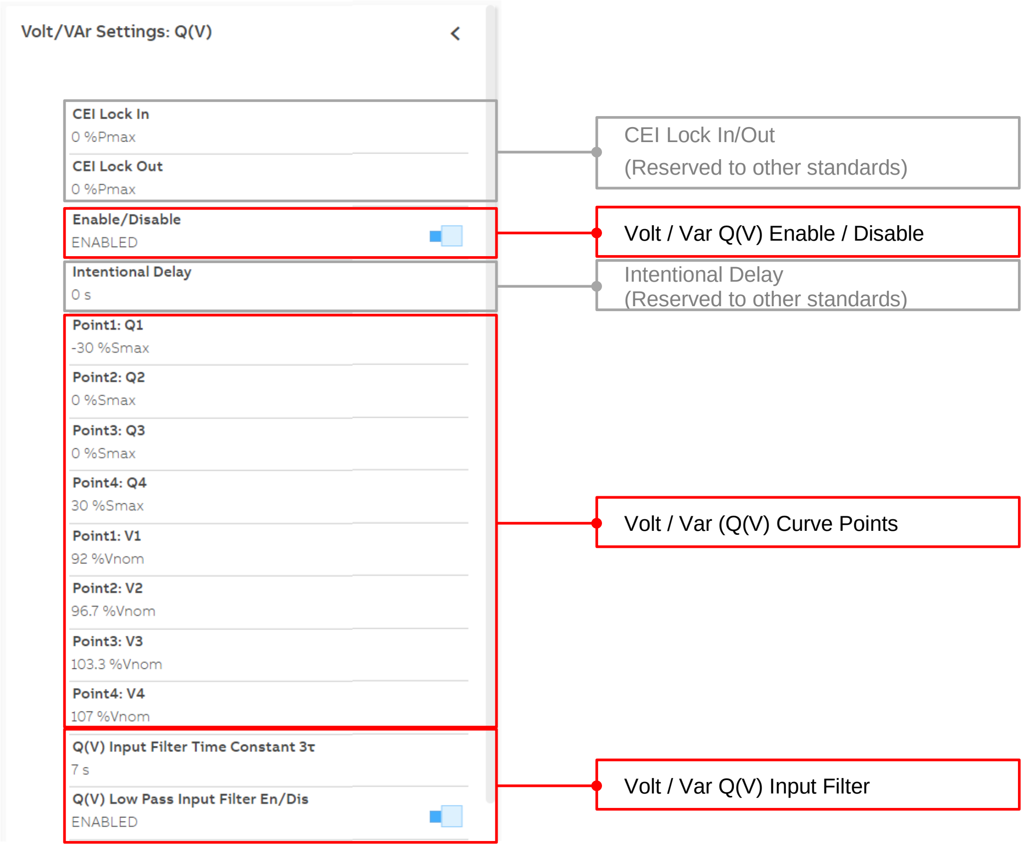


Figure 18: SA13 VV Configuration through Web Server

For details about the above parameters or inverter capability, refer to the description on chapter **SA13 VV Volt VAr Mode**

NOTE: the sign of the reactive power is assigned with REVERSE values with respect to the EEI reference system specified in Annex 1.

SA11 SS and **SA11 RR**

Select the Ramp Control menu to configure the soft start and normal ramp up according to Utility request.

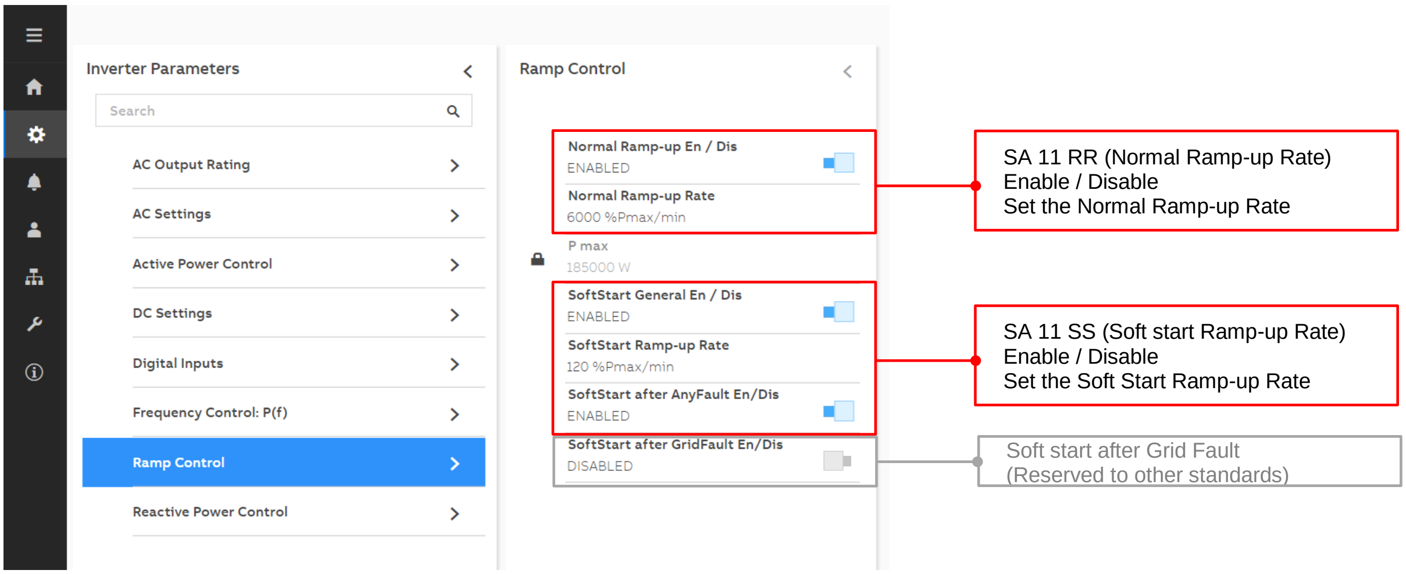


Figure 19: SA11 Normal Ramp Rate and Soft-Start Configuration through Web Server

NOTE: Rule 21 and Rule 14H requires setting the values as %Pn/s. To set properly the value it is necessary to multiply by 60 the SA11 SS and SA11 RR ramp rate values expressed as %Pn/s. For example, a SA11 RR request of 50%Pmax/s should be set on inverter as 3000%Pmax/min.

SA14 FW

Select the Frequency Control: P(f) menu to configure the Frequency - Watt according to Utility request.

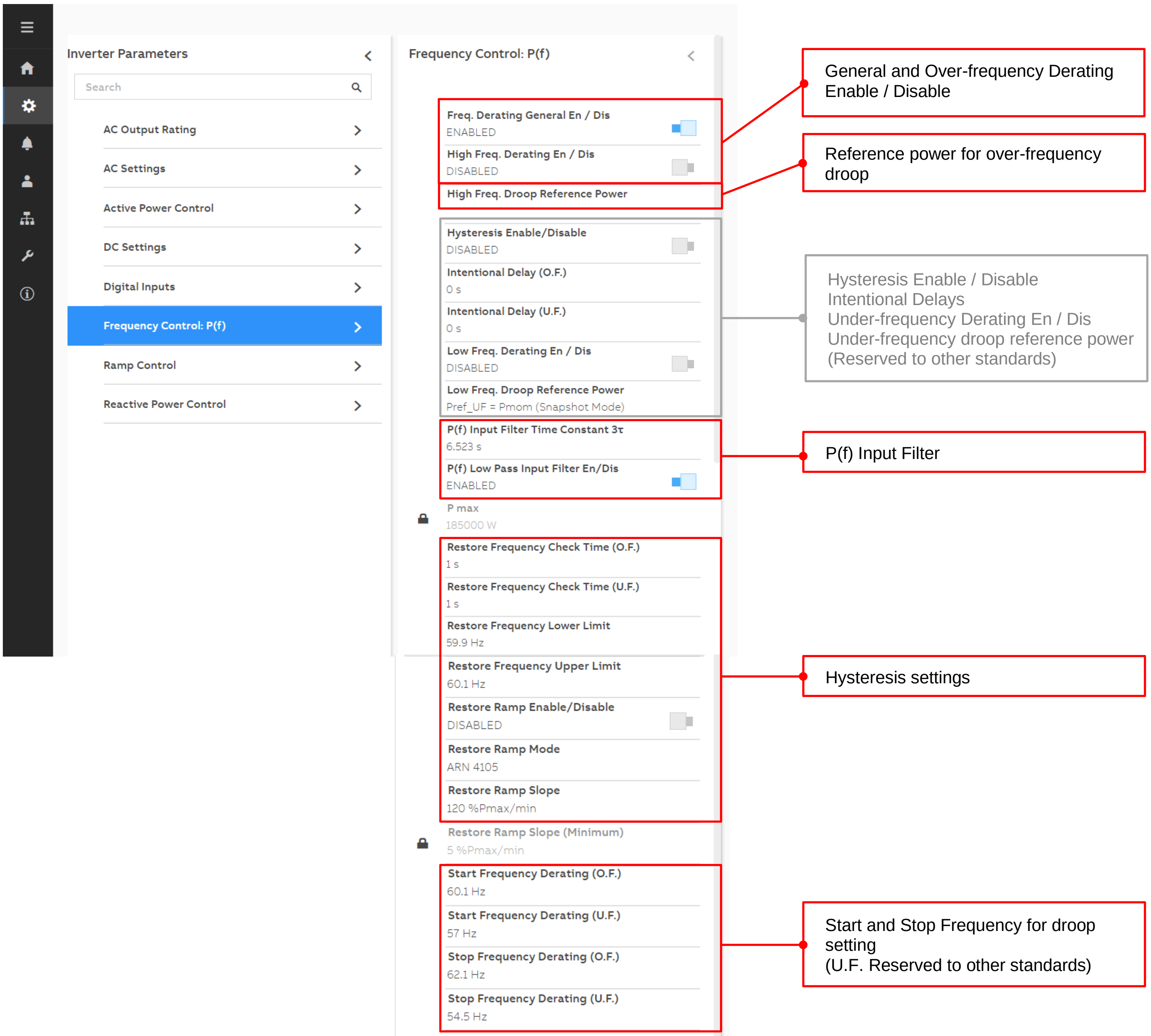


Figure 20: SA14 FW Configuration through Web Server

Start and Stop frequency defines also the slope of the Frequency – Watt curve. The slope is defined as:

$$Slope = P_{max} \,/\, (f_{start} - f_{stop})$$

To deactivate the Frequency - Watt, it is sufficient to disable one between the frequency and the high frequency control flag.

To enable the Frequency - Watt, both general and high frequency control flags must be enabled.

SA15 VW

Select the *Active Power Control* → *Volt/Watt Settings: P(V)* menu to configure the Volt-Watt function according to Utility request.

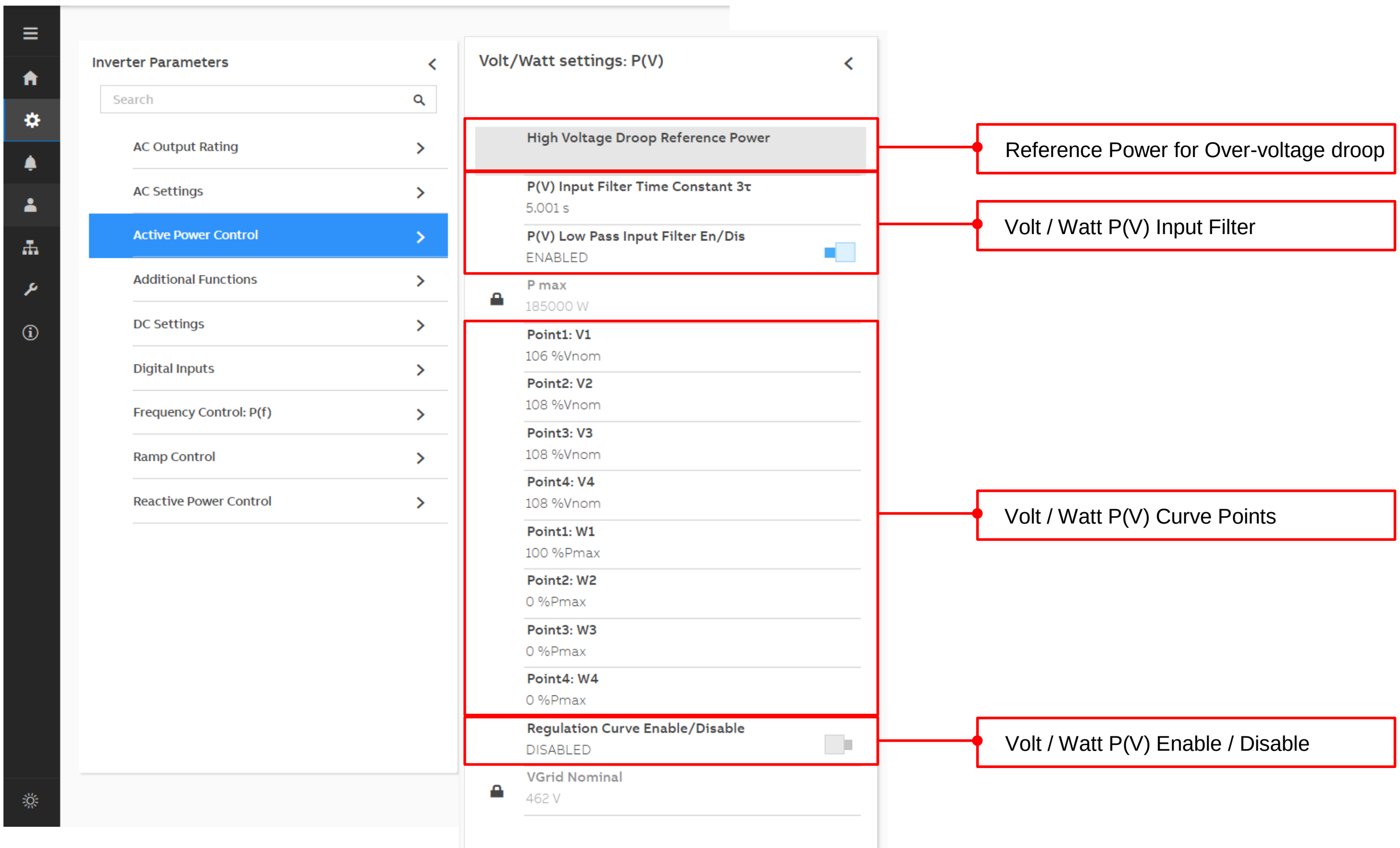


Figure 21: SA15 VW Configuration through Web Server

Annex 1: Sign of Power Set Points

ABB solar inverters manage the power with a Producer Reference Convention with positive sign for both active and reactive when power, is delivered.

The power factor shares the sign with the reactive power, so a power factor is positive when the inverter delivers positive reactive power.

Rule 21 and Rule 14H adopts the EEI sign convention for reactive power, the sing conversion between inverter and EEI conventions is available on the following table.

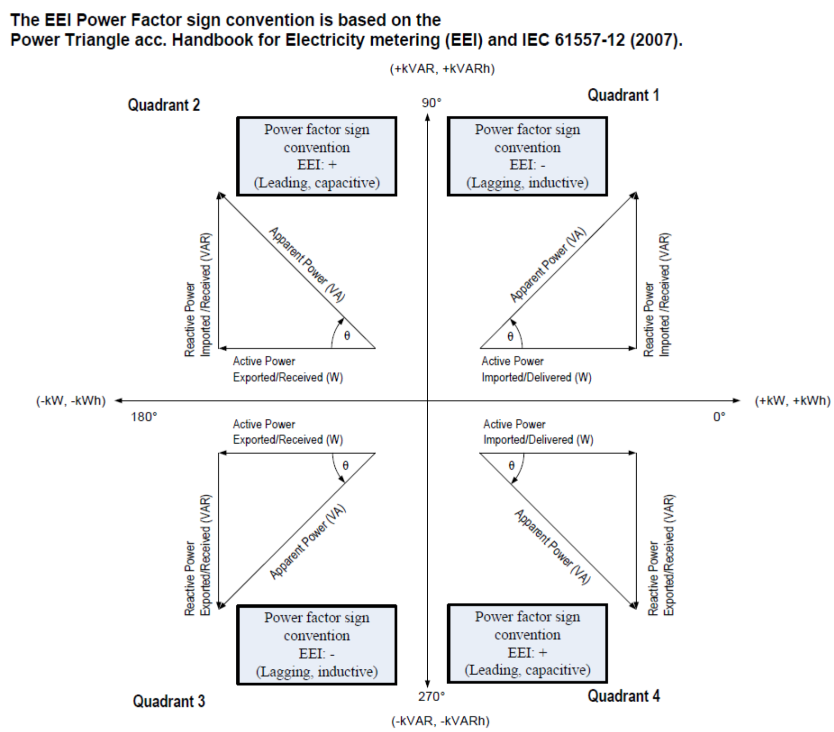


Figure A1: EEI sign conversion

Quadrant	Active Power	Reactive Power	Effect on Voltage	Inverter Sign P	Inverter Sign Q	Inverter Sign P.F.	EEI PF Sign P.F.
1	Delivered	Over-Excited (Delivered)	Increase	Positive	Positive	Positive	Negative
2	Absorbed	Over-Excited (Delivered)	Increase	Negative	Positive	Positive	Positive
3	Absorbed	Under-Excited (Absorbed)	Decrease	Negative	Negative	Negative	Negative
4	Delivered	Under-Excited (Absorbed)	Decrease	Positive	Negative	Negative	Positive

Table A1: Producer Reference Convention, EEI and Inverter signs

All the inverter families listed on the introduction chapter apply active Power, reactive power and power factor signs convention for all the Grid Support Utility Functions described within this document.

The following exception applies:

1. **Reactive Power sign is swapped on Volt-VAr curve configuration through Web Server (Positive Sign for Under-excited reactive power, Negative Sign for Over-Excited)**

2. **Web server applies the inverter nomenclature for power factor set points.**

NOTE: Only reactive power priority mode is available for all the grid support functions which provide reactive power.

Annex 2: Firmware Compatibility Matrix to Rule 21/14H

This Annex correlate the inverter firmware with the default settings included on this guideline.

If your inverter is not updated to the firmware release within this table then the inverter could have a different default settings with respect to the documents.

In case it is suggested to use the Parameter Adjustment chapter to update the inverter to Rule21 or Rule 14H Utility settings.

Inverter model	SA8	SA9 L/HVRT	SA10 L/HFRT	SA11 SS	SA11 RR	SA12 Spec P f	SA 13 VV	SA 14 FW	SA15 VW
PVS-166-TL-US	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**
PVS-175-TL-US	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**

Table A2: Rule 21 Firmware Compatibility Matrix

Inverter model	SA8	SA9 L/HVRT	SA10 L/HFRT	SA11 SS	SA11 RR	SA12 Spec P f	SA13 VV	SA 14 FW	SA15 VW
PVS-166-TL-US	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**
PVS-175-TL-US	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**

Table A3: Rule 14H Firmware Compatibility Matrix

Tables A2 and A3 define, for each grid support function, the minimum FW release that satisfy the Rule 21/14H default settings described on this application guideline.

Inverter with older firmware could not be aligned, in case the chapter *Parameter Adjustment* describes the procedure to update the inverter settings.

Table A4 defines the starting firmware release of inverters that includes all the Rule 21 function and that can be configured to satisfy the requirements of Rule 21/14H.

Inverter model	SA8	SA9 L/HVRT	SA10 L/HFRT	SA11 SS	SA11 RR	SA12 Spec P f	SA 13 VV	SA 14 FW	SA15 VW
PVS-166-TL-US	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**
PVS-175-TL-US	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**	**1922D**

Table A4: Inverter FW compatible with Rule 21/14H

Firmware XXYYK is encoded as follows:

XX: represents the latest two digit for year of release, for example 18 means 2018

YY: represents the week of release within the year, for example 1803 means 3rd week of 2018

K: represents the day of release within the week, for example 1803G means 7th day (Sunday) of the 3rd day of 2018 and corresponds to 21 January 2018

A firmware is greater than another one if it is released on a later date.

Annex 3: HECO Rule 14H Test

Rule 14H certification procedure requires additional tests to be realized on SA13 Volt/Var grid support function.

Curve settings and results are shown on table A5 and figure A2

TEST#	Curve	Voltage [V/Vn]				Q(*) [Q/Pn]			
		V1	V2	V3	V4	Q1	Q12	Q3	Q4
4	Manufacturer Min Curve	0.700	0.750	0.750	0.750	0.000	-0.600	-0.600	-0.600
5	Manufacturer Max Curve	1.150	1.150	1.150	1.200	0.600	0.600	0.600	0.000

(*) Positive = Over-excited = producing / Negative = Under-excited = absorbing

Table A5

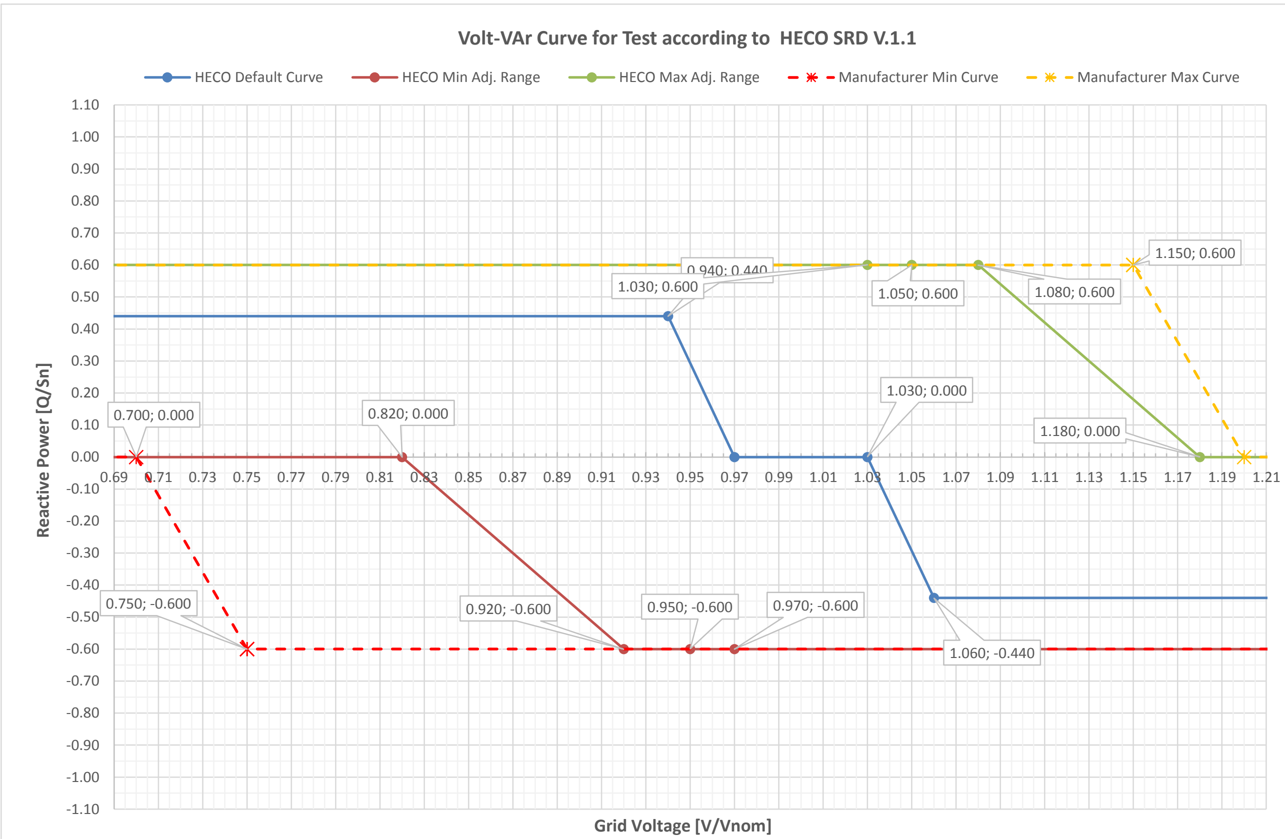


Figure A2

Document revisions

Revision	Date	Change Log
Rev 1.0	Jul. 08 / 2019	Specific revision including only PVS-166-TL-US and PVS-175-TL-US inverters

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