ABB solar inverters

Grid Support Function
Application Guideline for UNO-DM and TRIO-TM 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

Contents

Introduction

Rule 21 and Rule 14H are the Source Requirement Documents (SRD) released by the States of California and Hawaii. These documents defines the settings and configuration required to be used on "SMART INVERTER GENERATING FACILITY" to be 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 UNO-DM-PLUS
  - UNO-DM-3.3-TL-PLUS-US-SB-RA
  - UNO-DM-3.8-TL-PLUS-US-SB-RA
  - UNO-DM-4.6-TL-PLUS-US-SB-RA
  - UNO-DM-5.0-TL-PLUS-US-SB-RA
  - UNO-DM-6.0-TL-PLUS-US-SB-RA

- Family TRIO-TM-50/60
  - TRIO-TM-60.0-US-480

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.

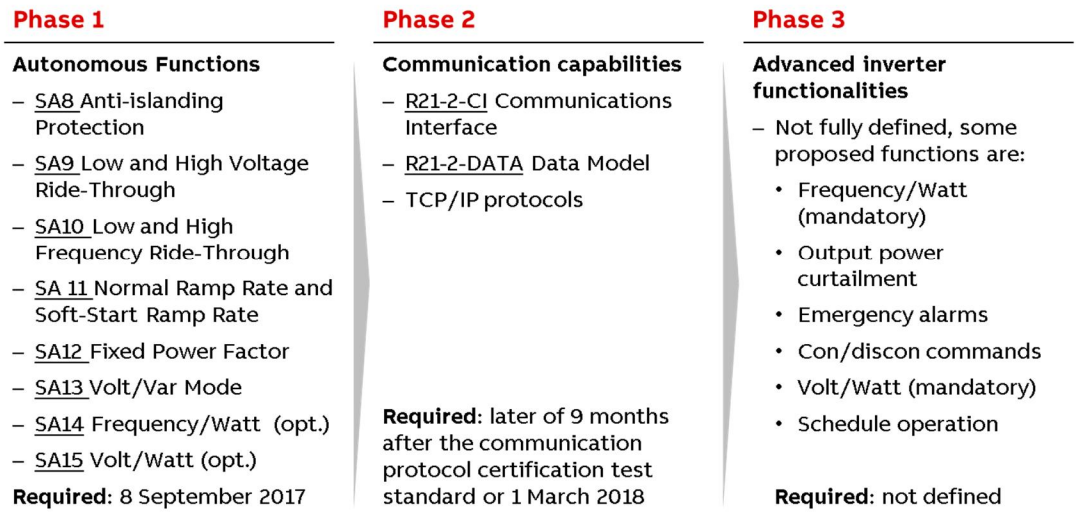

Figure 1: Rule 21 Roadmap

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.

Unintentional Island situation **Island Detection and Trip**

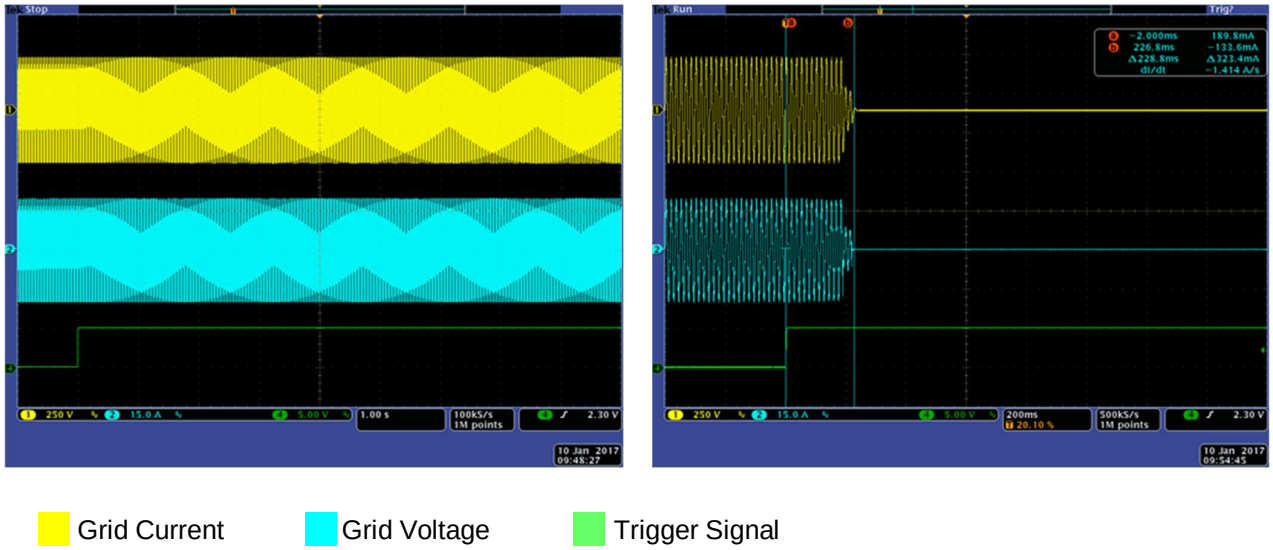

Figure2: Anti-Islanding test example

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 5 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	**ü**	**ü**				**O**	**O**
2	**ü**	**ü**	**ü**		**ü**	**O**	**O**
3	**ü**	**ü**		**ü**	**ü**	**O**	**O**

ü = 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 to change 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 particular 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.

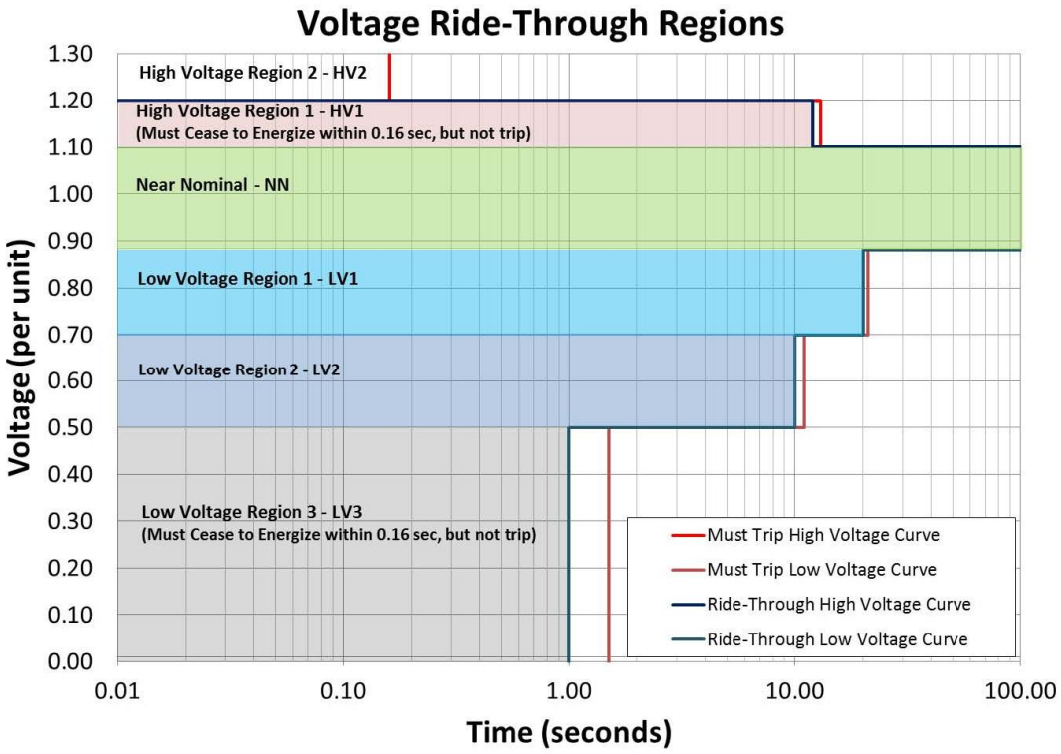

Figure 3: L/HVRT configuration example

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	

Region	Operating mode
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 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	
V>>	Enable	-	Enabled	Enabled	Enabled/Disabled
	Voltage	U/Un [%]	120	120	Fixed
	Time	s	0.16	0.16	[0.001– 0.16]
V>	Enable	-	Enabled	Enabled	Enabled/Disabled
	Voltage	U/Un [%]	110	110	[110 – 120]
	Time	S	13	1	[0.16 – 100]
V<	Enable	-	Enabled	Enabled	Enabled/Disabled
	Voltage	U/Un [%]	88	88	[70 – 88]
	Time	S	21	21	[0.16 – 100]
V<<	Enable	-	Enabled	Enabled	Enabled/Disabled
	Voltage	U/Un [%]	70	70	[50 – 70]
	Time	S	11	21	[0.16 – 100]
V<<<	Enable	-	Enabled	Enabled	Enabled/Disabled
	Voltage	U/Un [%]	50	50	Fixed
	Time	S	1.5	0.5	[0.16 – 50]
Momentary Cessation Threshold	HVRT Zero P	U/Un [%]	110	120	110 – 120
	LVRT Zero P	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.

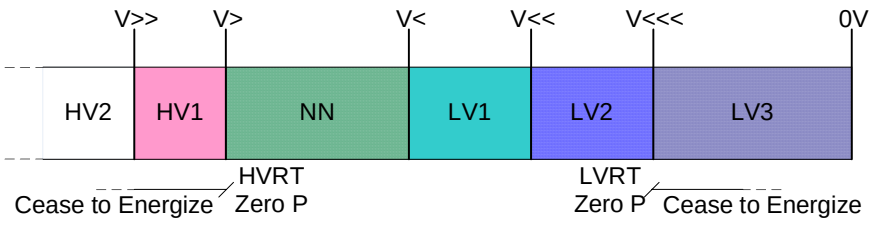

Figure 4: Inverter parameters and SA9 L/HVRT ranges

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.

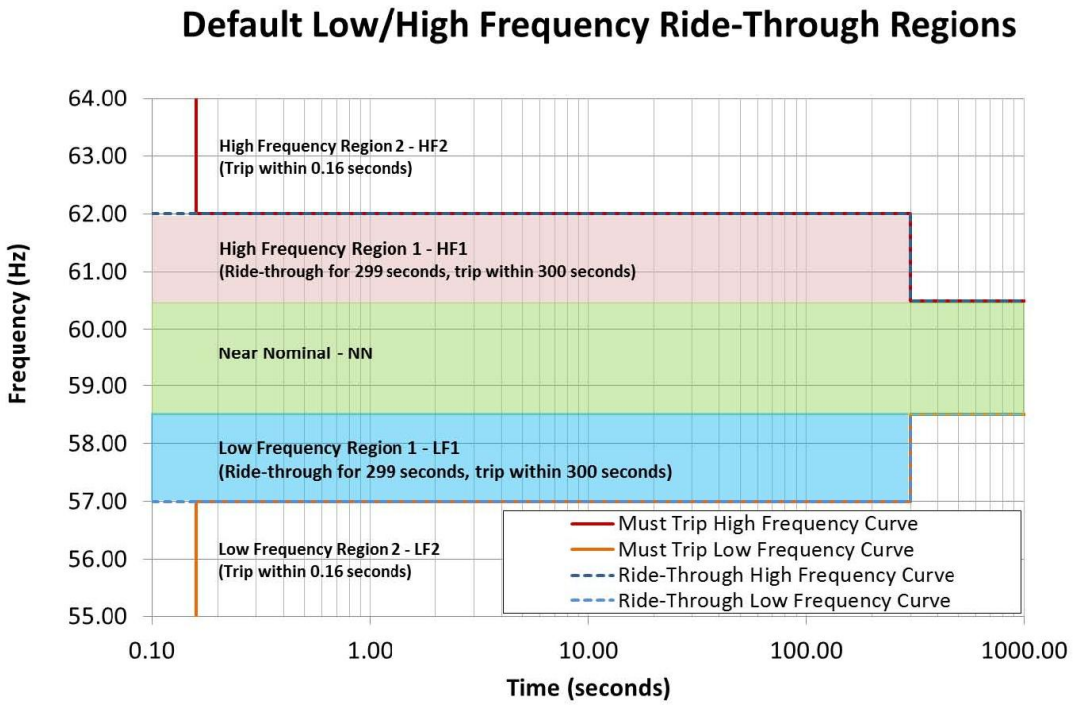

Figure 5: L/HFRT configuration example (Rule 21)

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>>	Frequency	Hz	62	64	[60.1 – 66]
	Time	s	0.16	0.16	[0.16 – 1000]
F>	Frequency	Hz	60.5	63	[60.1 – 66]
	Time	s	300	21	[0.16 – 1000]
F<	Frequency	Hz	58.5	57	[50 – 59.9]
	Time	s	300	21	[0.16 – 1000]
F<<	Frequency	Hz	57	56	[50 – 59.9]
	Time	s	0.16	0.16	[0.16 – 1000]
Momentary Cessation Threshold	HFRT Zero P	Hz	65	65	[60.1 – 66]
	LFRT Zero P	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

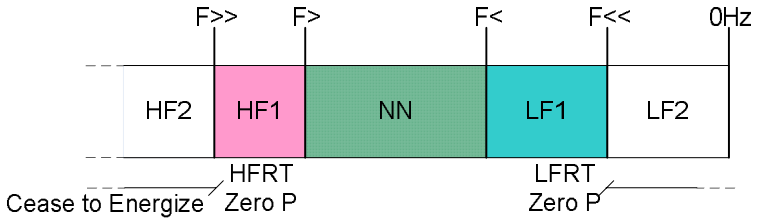

Figure 6: Inverter parameters and SA10 L/HFRT ranges

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.

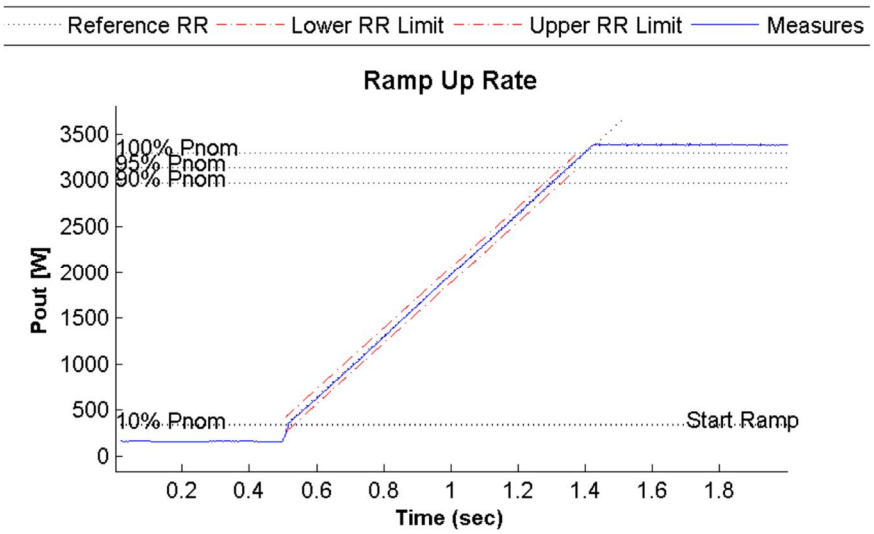

Figure 7: UNO-DM-PLUS-3.3, Normal Ramp Up @ 100% PN/s with upper and lower bound

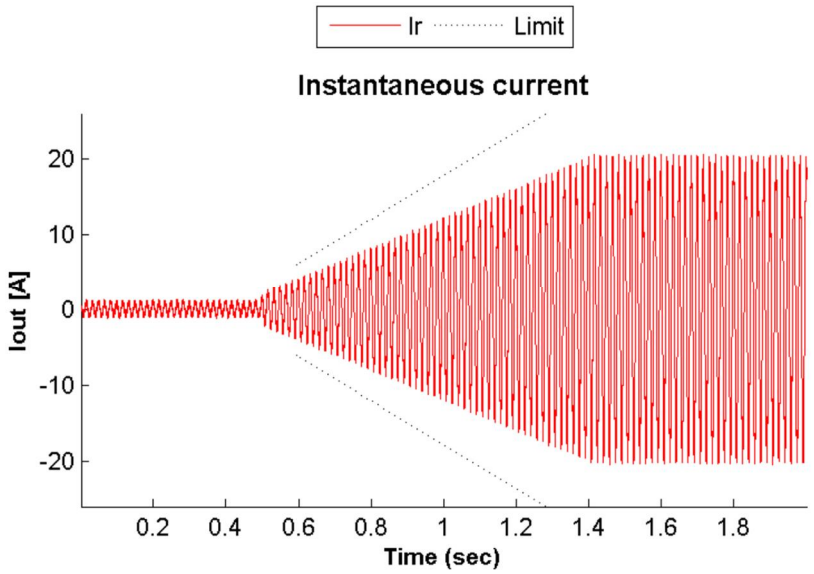

Figure 8: UNO-DM-PLUS-3.3, output current with upper and lower bound

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 factor shall be adjustable in the range 1.0 +/- 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

NOTE: Only reactive power priority mode available.

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.

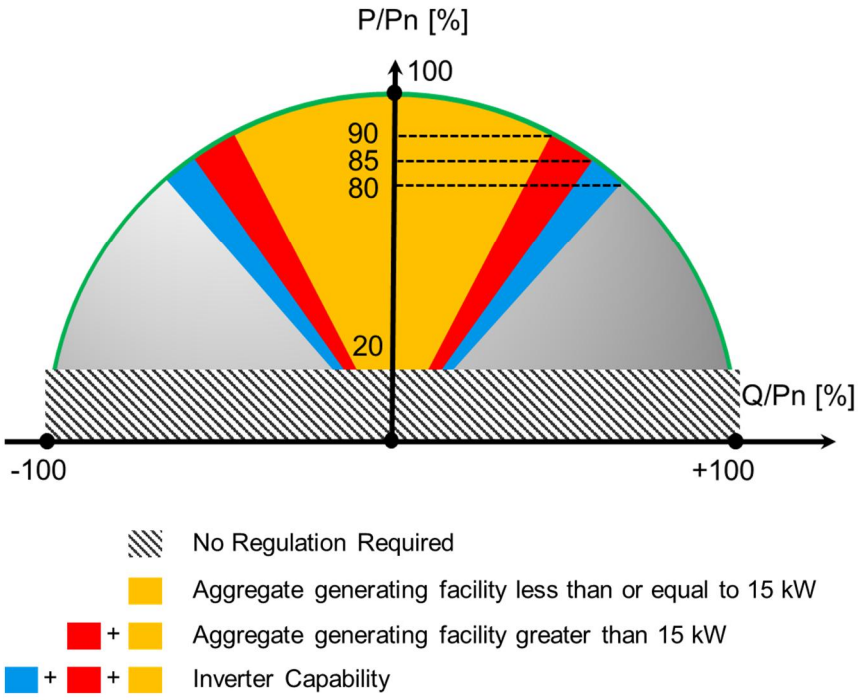

Figure 9: Inverter Capability and power factor required ranges

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/Vn]				Q(*) [Q/Pn]			
		V1	V2	V3	V4	Q1	Q12	Q3	Q4
1	Most Aggressive	0.9539	1.0000	1.0000	1.0461	1.00	0.00	0.00	-1.00
2	Average	0.9224	0.9549	1.0451	1.0776	0.50	0.00	0.00	-0.50
3	Least Aggressive	0.8823	0.9097	1.0903	1.1177	0.25	0.00	0.00	-0.25

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

Table 9: Volt-VAr Most and Least Aggressive points

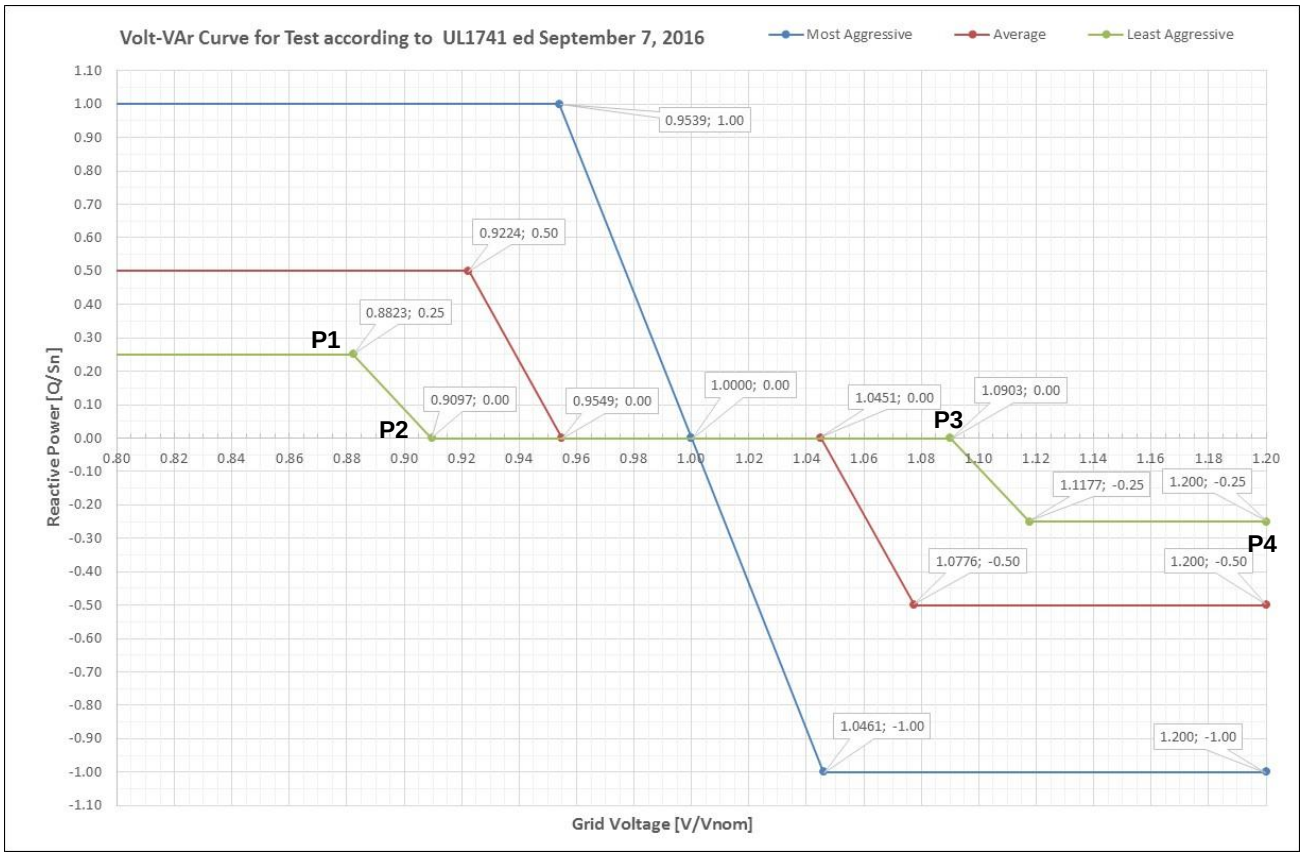

Figure 10: Volt-VAr Most (blue) and Least (grey) aggressive curves for ABB inverters

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 are shown on Table 10.

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Volt-VAr (Enabled)	SA13 VV	Flag	Enabled	Enabled	En./Dis.
Intentional Delay	SA13 VV	ms	0	0	[0 – 3000]
Voltage level trigger point P1	SA13 VV	% V/Vn	92	92	[70 – 115]
Reactive Power trigger point P1	SA13 VV	% Q/Sn	30	44	[0 - 100]
Voltage level trigger point P2	SA13 VV	% V/Vn	96.7	98	[75 – 115]
Reactive Power trigger point P2	SA13 VV	% Q/Sn	0	0	[-100 – 100]
Voltage level trigger point P3	SA13 VV	% V/Vn	103.3	102	[75 – 115]

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Reactive Power trigger point P3	SA13 VV	% Q/Sn	0	0	[-100 – 100]
Voltage level trigger point P4	SA13 VV	% V/Vn	107	106	[75 – 120]
Reactive Power trigger point P4	SA13 VV	% Q/Sn	- 30	- 44	[-100 – 0]
Active Power Lock In/Lock Out (Enabled)	SA13 VV	Flag	Disabled	Disabled	En./Dis.
Active Power Lock In	SA13 VV	P/Pn	0	0	0/1 (Dis./En)
Active Power Lock Out	SA13 VV	P/Pn	0	0	0/1 (Dis./En)
Response Time	SA13 VV	s	5	10	[0.5 – 120]

Table 10: SA13 VV Grid Support Utility Inverter settings

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 point 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 will be greater than the point P3 or less than the point P0 the inverter will keep the same reactive power reached at that points.

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.

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 over P2 or under P1 before to feed reactive power into the grid.
- **Active Power Lock In/Out Enable/Disable:** enable or disable the active power Lock In/Out function. When enabled the Volt-VAr mode will be active only if the active power exported by the inverter will be greater than the settled Lock In threshold. 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 be lower than the Lock Out threshold. Lock In threshold must always be greater than Lock Out to create a hysteresis range for Volt-VAr mode.
- **Active Power Lock-In:** exported active power threshold to enter on Volt-VAr mode
- **Active Power Lock-Out:** exported active power threshold to exit from Volt-VAr mode
- **Response Time:** The Volt-VAr function requires to filter the Voltage through an equivalent Low Pass Filter of the first order. Response time represents the time required to reach the 90% of the filter output.

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

- Minimum Power Factor $\cos\varphi = 0.8$
- 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) – Optional

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. 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.

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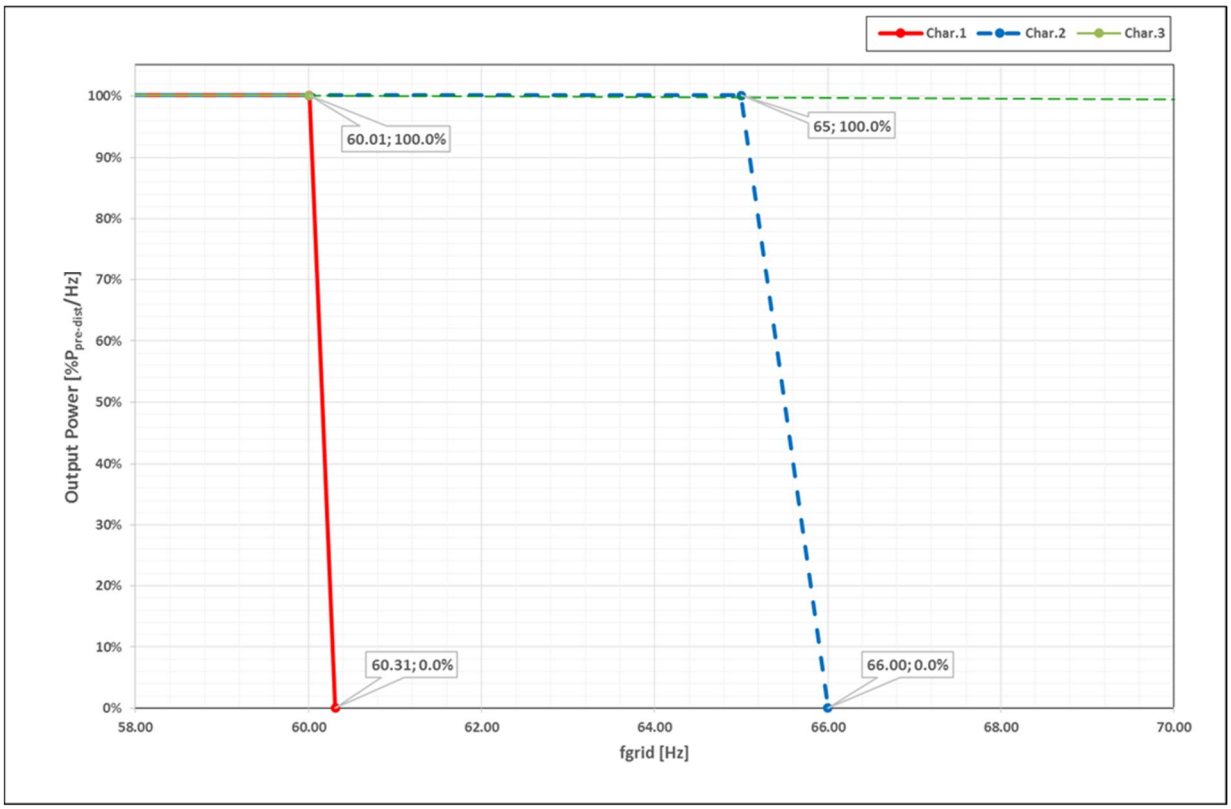


Figure 12: Frequency-Watt slope test

Test Number	Curve	Starting Frequency		Frequency Droop	
		fstart	Value [Hz]	Fstop [Hz]	Droop [%Pn/Hz]
1	Maximum Slope	max	65	66	100
2		min	60.1	60.3	333.33
3	Minimum Slope	min	60.1	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	
Frequency-Watt (Enabled)	SA14 FW	Flag	Disabled	Enabled	En./Dis.
Start Frequency Derating	SA14 FW	Hz	60.1	60.036	60.01 – 65
Stop Frequency Derating	SA14 FW	Hz	62.1	63.036	60.31 – 1000000*
Hysteresis Enable/Disable	SA14 FW	Flag	Disabled	Disabled	En./Dis.
Intentional delay	SA14 FW	msec	0	0	0 – 1000
Restore Frequency:upper limit	SA14 FW	Hz	60.1	60.036	60.01 – 65
Restore frequency :lower limit	SA14 FW	Hz	59.9	59.964	50 – 59.99
Restore Frequency: check time	SA14 FW	sec	1	1	0 – 300
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]
Response Time	SA14 FW	s	5	0.5	[0.05 – 10]

*Corresponds to a slope configurable in the range [0-333] %Pn/Hz

Table 12: SA14 FW Grid Support Utility Inverter settings

The frequency watt function is normally disabled on ABB Grid Support Utility Interactive Inverters that are certified according to UL1741-SA and Rule 21/14H SRDs.

ABB Grid Support Utility Interactive Inverters, with the Frequency-Watt function enabled, will reduce the active power output when the frequency exceed the **Frequency threshold for derating start**. The inverter output power will be curtailed with a slope (expressed as $\%P_{Nom}/Hz$) of:

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

Starting from the available output power of the inverter when the frequency-watt function triggers ($P_{FWstarting}$).

The Frequency-Watt behaviour for Grid Support Utility Interactive Inverters can be adjusted as follows:

- **Intentional delay:** defines the time the frequency need to continuously stay over **Frequency threshold for derating start** before to trigger the Frequency-Watt function.
- **Upper and Lower frequency limit to restore normal operation**: when the inverter follows the Frequency-Watt curve and the frequency fall back within this range, 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.

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

- **Restore Time after Frequency Watt derating**: define the minimum time in which the frequency shall permanently remain within the interval between **lower and upper frequency limit to restore normal operation,** before to start the restore routine. If the frequency move 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.
- **Standing Power**: when the inverter follows the Frequency-Watt curve and the frequency fall back within this range, then the power reference is maintained until 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.
- **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 $P_{FWstarting}$. 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 start to reduce the inverter stop to follow the curve keeping the minimum output power reached on the Frequency Watt curve. In case of frequency oscillation the inverter will always provide the 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 Time after Frequency Watt derating** and **Lower-Upper frequency limit to restore normal operation**, the inverter will restore the output power with a fixed slope (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) – Optional

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 voltage of the grid, 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.

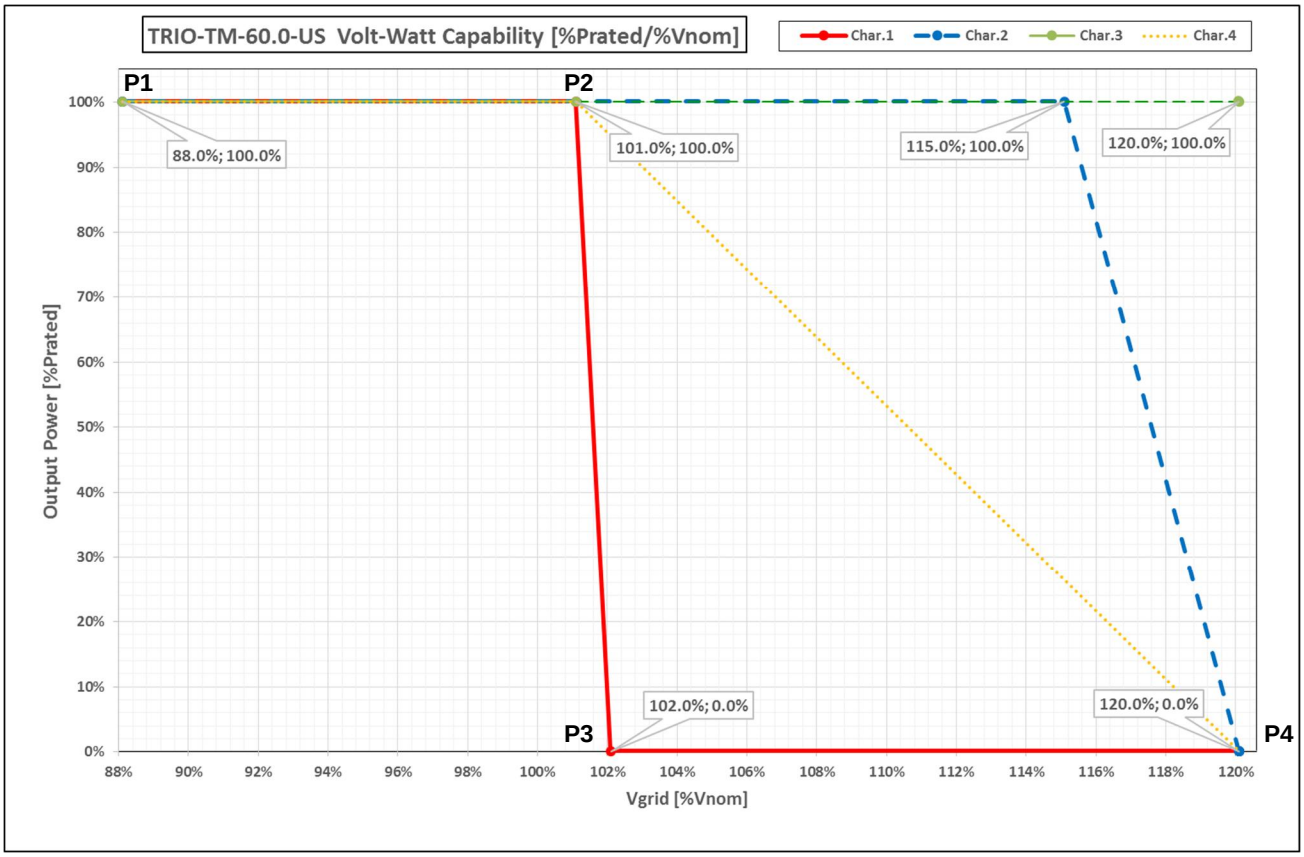


Figure 13: Test of Volt –Watt curve

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	
Volt-Watt (Enabled)	SA15 VW	Flag	Disabled	Disabled	En./Dis.
Voltage level trigger point P1	SA15 VW	% V/Vn	106	106	80 – 120
Active Power trigger point P1	SA15 VW	% P/P_{Max}	100	100	0 – 100
Voltage level trigger point P2	SA15 VW	% V/Vn	108	110	80 – 120
Active Power trigger point P2	SA15 VW	% P/P_{Max}	0	0	0 – 100

Parameter	Function Code (UL 1741-SA)	Unit	Default Settings		Inverter Range of Adjustment
			Rule 21	Rule 14H	
Voltage level trigger point P3	SA15 VW	% V/Vn	108	110	80 – 120
Active Power trigger point P3	SA15 VW	% P/P_{Max}	0	0	0 – 100
Voltage level trigger point P4	SA15 VW	% V/Vn	108	110	80 – 120
Active Power trigger point P4	SA15 VW	% P/P_{Max}	0	0	0 – 100
Response Time (*)	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 development of the Volt-Watt is equivalent to a first order Low Pass filter and the Response Time should be considered relative to this type of filtering mode.

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 AC Nominal Voltage and the Tariff to be applied. The Grid Code Selection procedure shall be realized during the installation of the inverter (first start-up) through web server, rotary switch, display or any other method described on the production manual of the inverter.

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 alternative configuration tools.

The tools available depending on the inverter model are listed in the following Table 15:

Inverter Model	Inverter Family	Configuration Tool Available			
		Display	Web Server	Aurora Manager Lite	Aurora Manager TL
UNO-DM-3.3-TL-PLUS-US-SB-RA	UNO-DM-PLUS	ü	ü	O	û
UNO-DM-3.8-TL-PLUS-US-SB-RA	UNO-DM-PLUS	ü	ü	O	û
UNO-DM-4.6-TL-PLUS-US-SB-RA	UNO-DM-PLUS	ü	ü	O	û
UNO-DM-5.0-TL-PLUS-US-SB-RA	UNO-DM-PLUS	ü	ü	O	û
UNO-DM-6.0-TL-PLUS-US-SB-RA	UNO-DM-PLUS	ü	ü	O	û
PVI-3.0-OUTD-S-US(-A);R21	PVI	ü	û	û	ü
PVI-3.6-OUTD-S-US(-A);R21	PVI	ü	û	û	ü
PVI-3.8-OUTD-S-US(-A);R21	PVI	ü	û	û	ü
PVI-4.2-OUTD-S-US(-A);R21	PVI	ü	û	û	ü
PVI-5000-TL-OUTD-S(-A);R21	PVI	ü	û	û	ü
PVI-6000-TL-OUTD-US(-A);R21	PVI	ü	û	û	ü
UNO-7.6-TL-OUTD-S-US-A	UNO	ü	û	ü	û
UNO-8.6-TL-OUTD-S-US-A	UNO	ü	û	ü	û
TRIO-50.0-TL-OUTD-US-480	TRIO-50/60-TL	û	û	ü	û
TRIO-60.0-TL-OUTD-US	TRIO-50/60-TL	û	û	ü	û
TRIO-TM-60.0-US-480	TRIO-TM-60	û	ü	ü	û

ü Configuration possible

û Configuration not possible

O Configuration available only with UNO DM Com Kit

Table 15: Configuration Tools available for inverter model

The interoperability table reports the autonomous function configurable by each tool.

Tool	SA8	SA9 L/HVRT	SA10 L/HFRT	SA12 Spec Pf	SA13 VV	SA11 RR	SA11 SS	SA14 FW	SA15 VW
Display	û	ü[2]	ü[2]	ü	ü[4]	û	ü[5]	ü[7]	û
Web Server	û	ü	ü	ü	ü	ü	ü	ü	ü
Manager Lite	ü[1]	ü[3]	ü[3]	ü	ü	û	ü	ü[8]	û
Manager TL	û	ü	ü	ü	ü	ü	ü[6]	ü[9]	û

[1] Possible to configure the AI Mode for both active and passive Anti Islanding functions
[2] Not possible to configure the settings for U<<<
[3] Not possible to configure the FRT and VRT thresholds where the inverter cease to energize
[4] Only possible to enable/disable the Volt-VAr mode and to restore the default Volt-VAr curve. Curve settings not available.
[5] Only possible to enable/disable the Soft Start Ramp-up Rate function
[6] Check the guide for parameter configuration to select the proper Soft Start mode
[7] Possible only to enable/disable the function and configure the Restore Ramp Mode and the Restore Time after Frequency Watt derating.
[8] Not Possible to enable/disable the Frequency-Watt function
[9] Possible only to configure Start Frequency Derating, Stop Frequency Derating (through Slope) and Restore Ramp Mode

Table 16: interoperability table

For each tool is possible to check the instructions to perform the required settings on the next chapters.

Configuration through Inverter Display

REQUIRED TOOL: Service level password.

To set a new configuration is required to access to the service menu of the display and consequently to retrieve the admin+ token (service password) to unlock the menu.

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:

The password will allow you to access to the service menu of the inverter: enter the "*settings*" menu of the "*inverter*" section (default password: "0000") and then select the option "*service*" with the password received by ABB Service. All the configuration available by display for the autonomous functions can be done from the Reactive Power menu or by the service sub menu according to fig. 14, refer to the table 17 for the options available on the service menu.

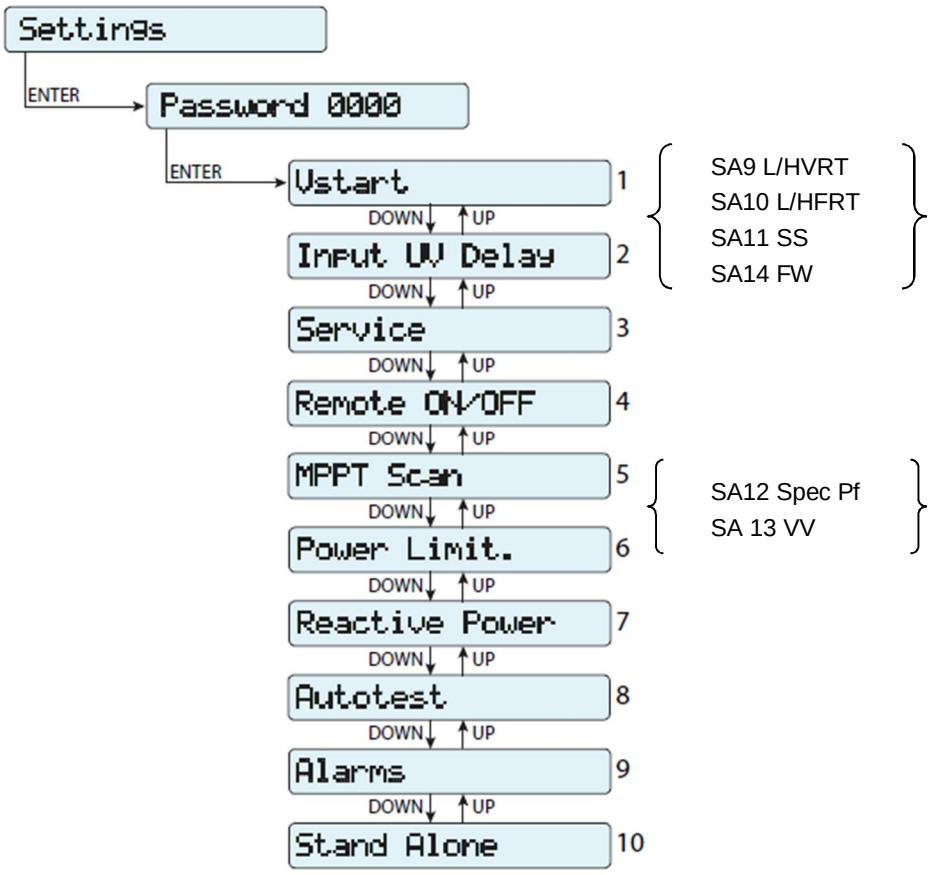


Fig. 14: Service Menu and Reactive Power Menu

Service Menu Parameter	Service Sub Menu Parameter	Autonomous function	Parameter Name	Description
Set U>>	æ	SA9 L/HVRT	V>>	Grid over-voltage (OV) threshold (HV2-HV1 region limit)
	En/Dis U>>		Enable	
	Value U>>		Voltage	
	Time U>>		Time	
Set U>	æ	SA9 L/HVRT	V>	Grid over-voltage (OV) threshold (HV1-NN region limit)
	En/Dis U>>		Enable	
	Value U>>		Voltage	
	Time U>>		Time	
Set U> (10Min)	-	û	û	Grid over-voltage (OV) threshold (average grid voltage value)
Set U<	æ	SA9 L/HVRT	V<	Grid under-voltage (UV) threshold (NN-LV1 region limit)
	En/Dis U>>		Enable	
	Value U>>		Voltage	
	Time U>>		Time	
Set U<<	æ	SA9 L/HVRT	V<<	Grid under-voltage (UV) threshold (LV1-LV2 region limit)
	En/Dis U>		Enable	
	Value U>		Voltage	
	Time U>		Time	
Set F>>	æ	SA10 L/HFRT	F>>	Grid over-frequency (OF) threshold (HV2- HV1 region limit)
	En/Dis F>>		Enable	
	Value F>>		Frequency	
	Time F>>		Time	
Set F>	æ	SA10 L/HFRT	F>	Grid under-frequency (OF) threshold (HV1-NN region limit)
	En/Dis F>		Enable	
	Value F>		Frequency	
	Time F>		Time	
Set F<	æ	SA10 L/HFRT	F<	Grid under-frequency (UF) threshold (NN-LF1 region limit)
	En/Dis F<		Enable	
	Value F<		Frequency	
	Time F<		Time	
Set F<<	æ	SA10 L/HFRT	F<<	Grid under-frequency (UF) threshold (LF1-LF2 region limit)
	En/Dis F<<		Enable	
	Value F<<		Frequency	
	Time F<<		Time	
Set Connect	-	û	û	Connection admitted grid range

Service Menu Parameter	Service Sub Menu Parameter	Autonomous function	Parameter Name	Description
Set Slow Ramp	æ	SA11 SS	Soft Start Ramp Rate	Enables gradual ramping up of power after the grid connection
	E/D Slow Ramp		Enabled	
Set OF Derating	æ	SA14 FW	Frequency-Watt	Selects the power derating mode in the event of grid over-frequency
	F Der. Mode		Restore Ramp	
	F Der. Res. T.		Restore Time after Frequency Watt derating	
Set VRT	æ	SA9 L/HVRT	Momentary Cessation Threshold	Set the voltage threshold for L/HVRT cease to energize
	Set Zero P TH æ Set LVRT Zero P		LVRT	
	Set Zero P TH æ Set HVRT Zero P		HVRT	
Set FRT	æ	SA10 L/HFRT	Momentary Cessation Threshold	Set the frequency threshold for L/HFRT cease to energize
	Set Zero P TH æ Set LFRT Zero P		LFRT	
	Set Zero P TH æ Set HFRT Zero P		HFRT	
Set Stand Alone	-	û	û	Allows the Stand Alone board accessory to be enabled/disabled
Reset Latch	-	û	û	Allows the Latch alarms present to be reset manually (Japan specific setting)

Table 17: Grid Support Parameters available on the Display

NOTE: to set a new value by display is necessary to select the parameter to be changed and press Enter to select the parameter, if it is admitted the operation the value will be blinking otherwise the display will show an error message. Change the value with the up and down arrows and press again enter to confirm.

Follow the autonomous function instructions to set the parameters according to the values required by the Utility

SA8

No configuration possible.

SA9 L/HVRT

To configure the L/HVRT profile access to the service menu and select the parameter to be changed: **U>>; U>**; **U<**; **U<<**; **VRT**.

The parameters: U>>; U>; U<; U<<; share the same sub menu options and for each parameter is possible to adjust:

- *Enable/Disable*: enable or disable the specific protection threshold
- *Value*: set the voltage threshold of the specific protection
- *Time*: set the trip time threshold of the specific protection

For the range of each L/HVRT regions refer to fig.4.

To configure the Momentary Cessation Threshold select “VRT” and then “Set Zero P TH” option of the Service Menu

- Write a new value on the option “Set LVRT Zero P” to define the upper limit of LVRT Momentary Cessation region
- Write a new value on the option “Set HVRT Zero P” to define the lower limit of HVRT Momentary Cessation region

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

SA10 L/HFRT

To configure the L/HFRT profile access to the service menu and select the parameter to be changed: **F>>; F>**; **F<**; **F<<**; **FRT**.

The parameters: F>>; F>; F<; F<<; share the same sub menu options and for each parameter is possible to adjust:

- *Enable/Disable*: enable or disable the specific protection threshold
- *Value*: set the voltage threshold of the specific protection
- *Time*: set the trip time threshold of the specific protection

For the range of each L/HFRT regions refer to the fig.6.

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

SA12 Specified Power Factor

To configure the fixed power factor enter on the “R*eactive Power*” panel of the setting menu (fig. 14).

- Configure “*Select PowerMode*” option to **cos-phi fixed** to enable the reactive power management
- Scroll down to write the required set point on the “*Set Value*” option

Refer to the **SA12 Specified Power Factor** chapter for details about the capability, sign of reactive power and description of the parameters.

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

To configure the Volt-VAr Mode enter on the “R*eactive Power*” panel of the setting menu (fig. 14).

- Configure “*Select PowerMode*” option to **Q = f(U)** to enable the Volt-VAr Mode

It is not possible to change the Volt-VAr settings other than the enable command.

NOTE: scrolling down it is possible to restore the default setting for the Volt-VAr curve through the option “*Load Std Curve*”

Refer to the **SA13 VV Volt-VAr Mode** for details about description of the default settings.

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.

SA11 SS

To enable or disable the Soft Start Ramp Up, enter on the "*Set Slow Ramp*" panel of the setting menu:

- Configure "***E/D Slow Ramp***" to enabled or disabled according to Utility requirements.

It is not possible to change other Soft Start Ramp Up settings.

SA14 FW

Enter on the sub menu "*Set OF Derating*" and adjust the specific settings below for SA14 FW function

To configure the Frequency-Watt mode enter on the "*Set OF Derating*".

- Configure "*F Der. Mode*" option to "*Mode 1 (BDEW)*", "*Mode 2 (VDE4105)*", "*Mode 3 (CEI021)*", "*Mode 4 (CEI016)*". The option will automatically configure the **Restore Ramp (Enabled)** to "*Enabled" and* **Restore Ramp (Mode)** to the selected operating mode.
- Select Configure "*F Der. Mode*" option to "*Mode Disabled*" to configure the **Restore Ramp (Enabled)** to "*Disabled"*
- Scroll down to write the required time for the parameter **Restore Time after Frequency Watt derating.**

For details about the above parameters refer to the Frequency-Watt curve description on chapter **SA14 Frequency-Watt (FW) – Optional**

SA15 VW

No configuration possible.

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 *Setup AC Side*, the available settings through web server are shown on figure 15.

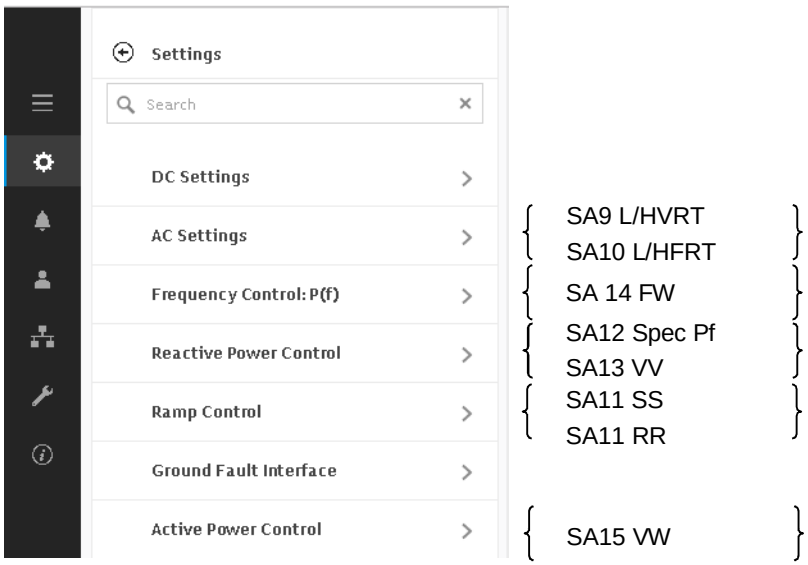


Fig. 15: Web Server – Settings Menu

SA8

No configuration possible.

SA9 L/HVRT

Enter on the sub menu AC Settings à *Grid Protection – VRT/FRT*

For each Variable MAX U>>; MAX U>; MIN U<; MIN U<<; MIN U<<<; MAX F>>; MAX F>; MIN F<; MIN F<< the following applies:

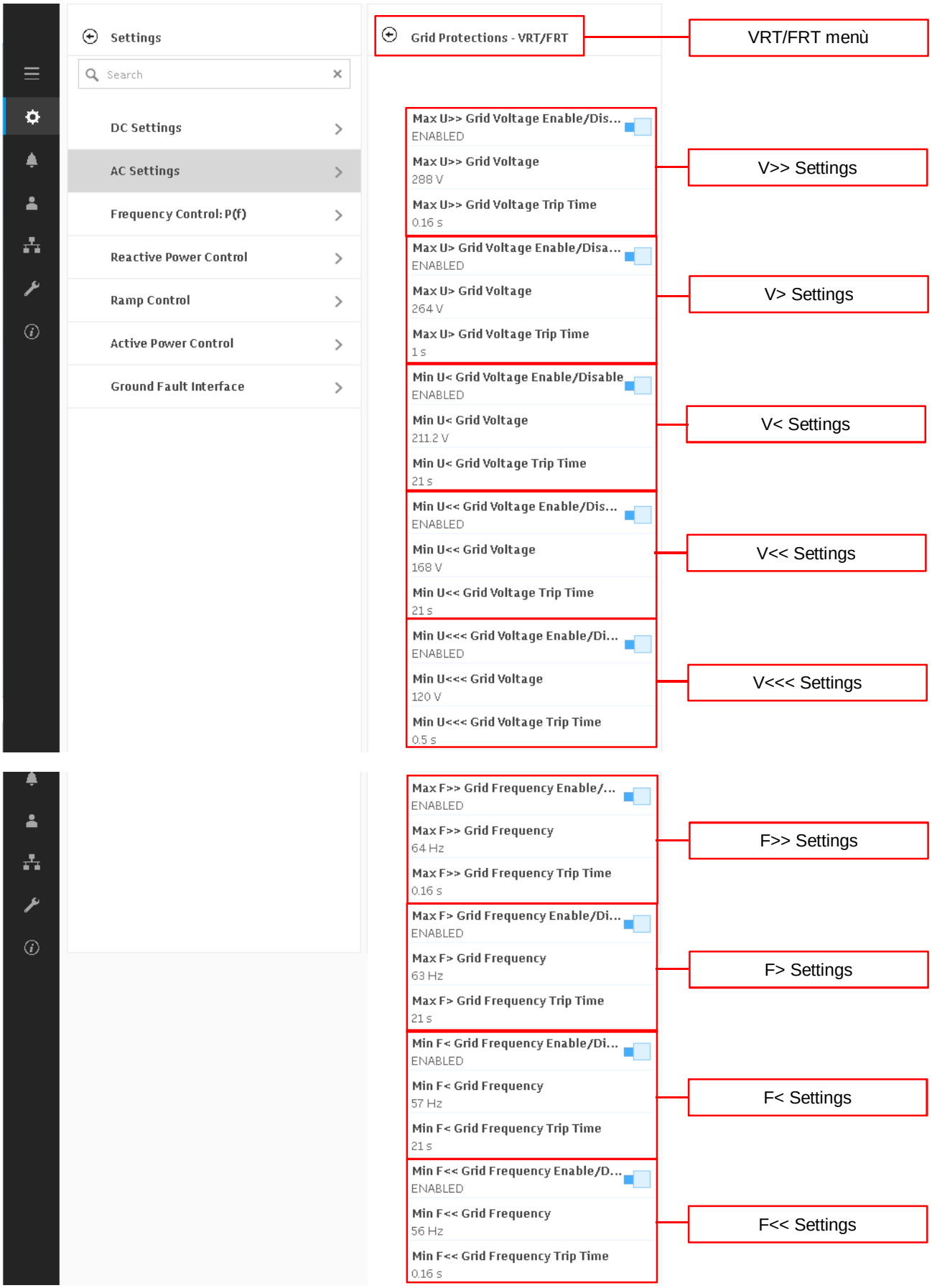
Grid Voltage Enable/Disable: to disable the specific protection

Grid Voltage: set the voltage threshold of the specific variable

Grid Voltage Trip Time: set the trip time threshold of the specific variable

The Momentary Cessation activation and range can be adjusted within this section.

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.


Settings
Search
DC Settings
AC Settings
Frequency Control: P(f)
Reactive Power Control
Ramp Control
Active Power Control
Ground Fault Interface
Grid Protections - VRT/FRT
VRT/FRT menù
Max U>> Grid Voltage Enable/Dis...
ENABLED
Max U>> Grid Voltage
288 V
Max U>> Grid Voltage Trip Time
0.16 s
V>> Settings
Max U> Grid Voltage Enable/Disa...
ENABLED
Max U> Grid Voltage
264 V
Max U> Grid Voltage Trip Time
1 s
V> Settings
Min U< Grid Voltage Enable/Disable
ENABLED
Min U< Grid Voltage
211.2 V
Min U< Grid Voltage Trip Time
21 s
V< Settings
Min U<< Grid Voltage Enable/Dis...
ENABLED
Min U<< Grid Voltage
168 V
Min U<< Grid Voltage Trip Time
21 s
V<< Settings
Min U<<< Grid Voltage Enable/Di...
ENABLED
Min U<<< Grid Voltage
120 V
Min U<<< Grid Voltage Trip Time
0.5 s
V<<< Settings
Max F>> Grid Frequency Enable/...
ENABLED
Max F>> Grid Frequency
64 Hz
Max F>> Grid Frequency Trip Time
0.16 s
F>> Settings
Max F> Grid Frequency Enable/Di...
ENABLED
Max F> Grid Frequency
63 Hz
Max F> Grid Frequency Trip Time
21 s
F> Settings
Min F< Grid Frequency Enable/Di...
ENABLED
Min F< Grid Frequency
57 Hz
Min F< Grid Frequency Trip Time
21 s
F< Settings
Min F<< Grid Frequency Enable/D...
ENABLED
Min F<< Grid Frequency
56 Hz
Min F<< Grid Frequency Trip Time
0.16 s
F<< Settings

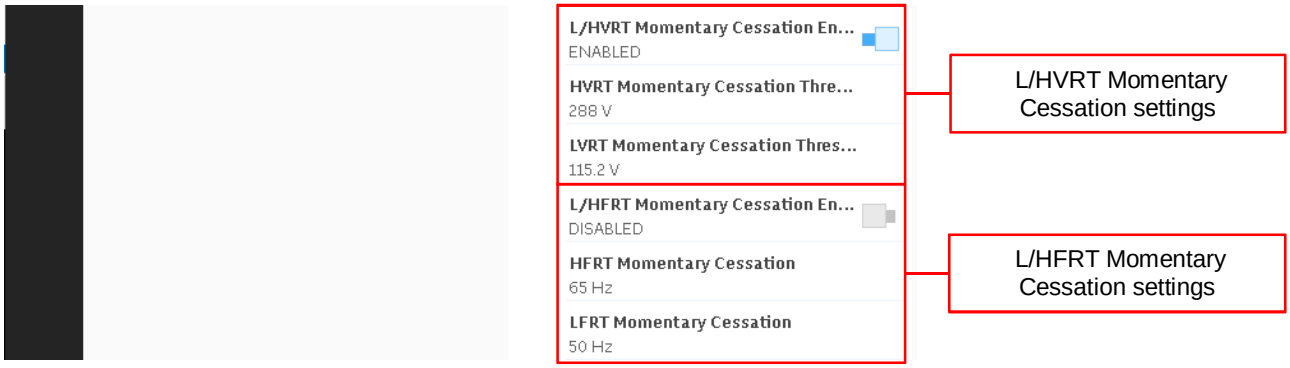


Figure 16: L/HVRT Configuration through Web Server

SA12 Specified Power Factor

Select the Reactive Power Control à CosΦ Set menu to configure the power factor according to Utility request.

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

Select the *Reactive Power Control* à *Volt-VAr Settings: Q(v)* menu to configure the Volt-Var mode according to Utility request

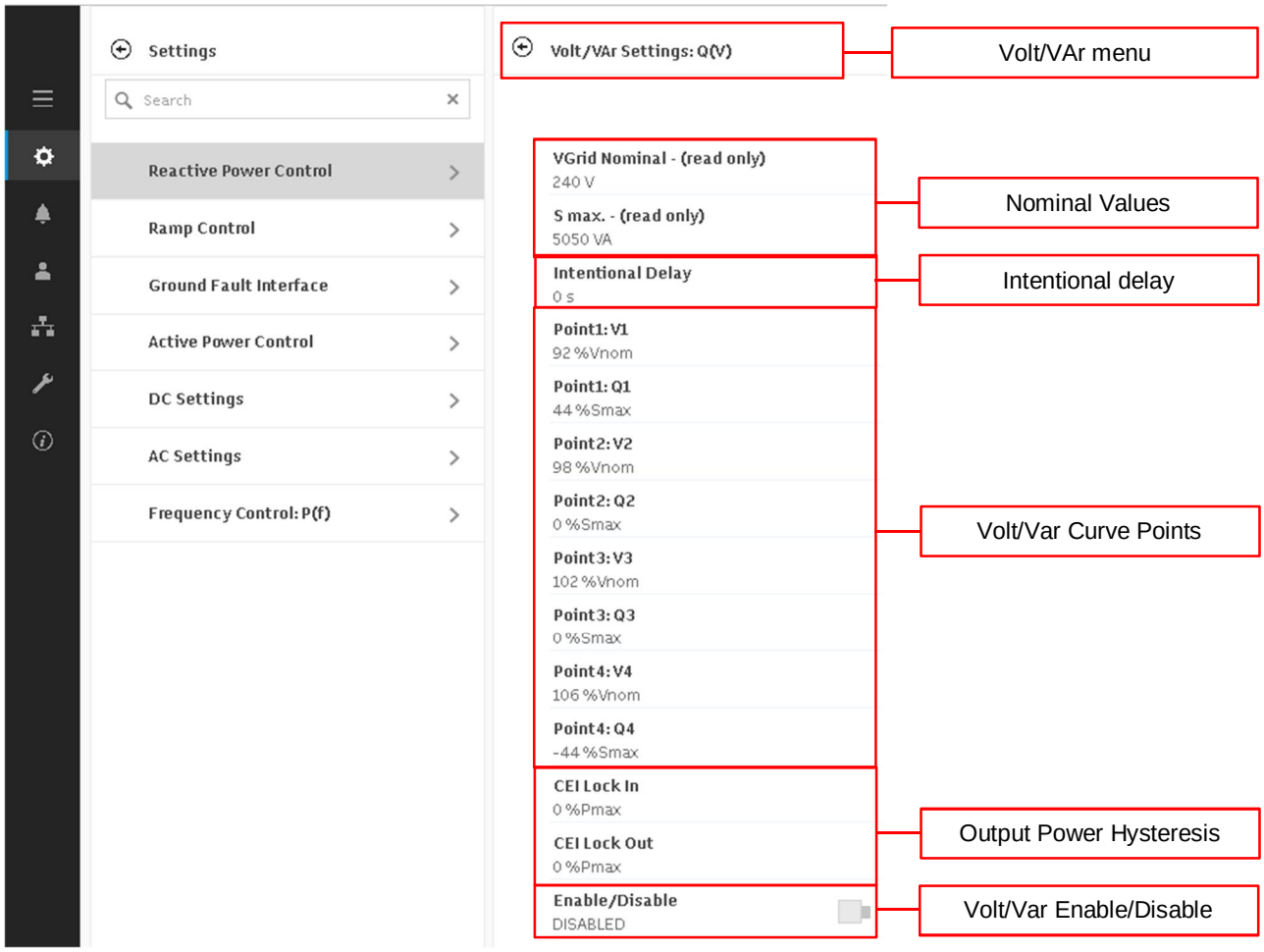


Figure 18: SA13 VV Configuration through Web Server

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 according 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.

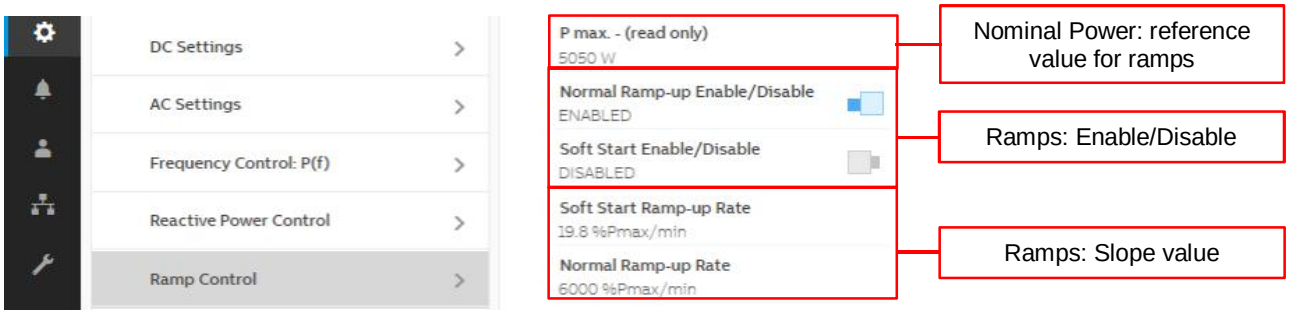


Figure 19: SA11 Normal Ramp Rate and Soft-Start Configuration through Web Server

NOTE: Rule 21 and Rule 14H requires to set 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 SS request of 50%Pn/s should be set on inverter as 3000%Pn/min.

SA14 FW

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

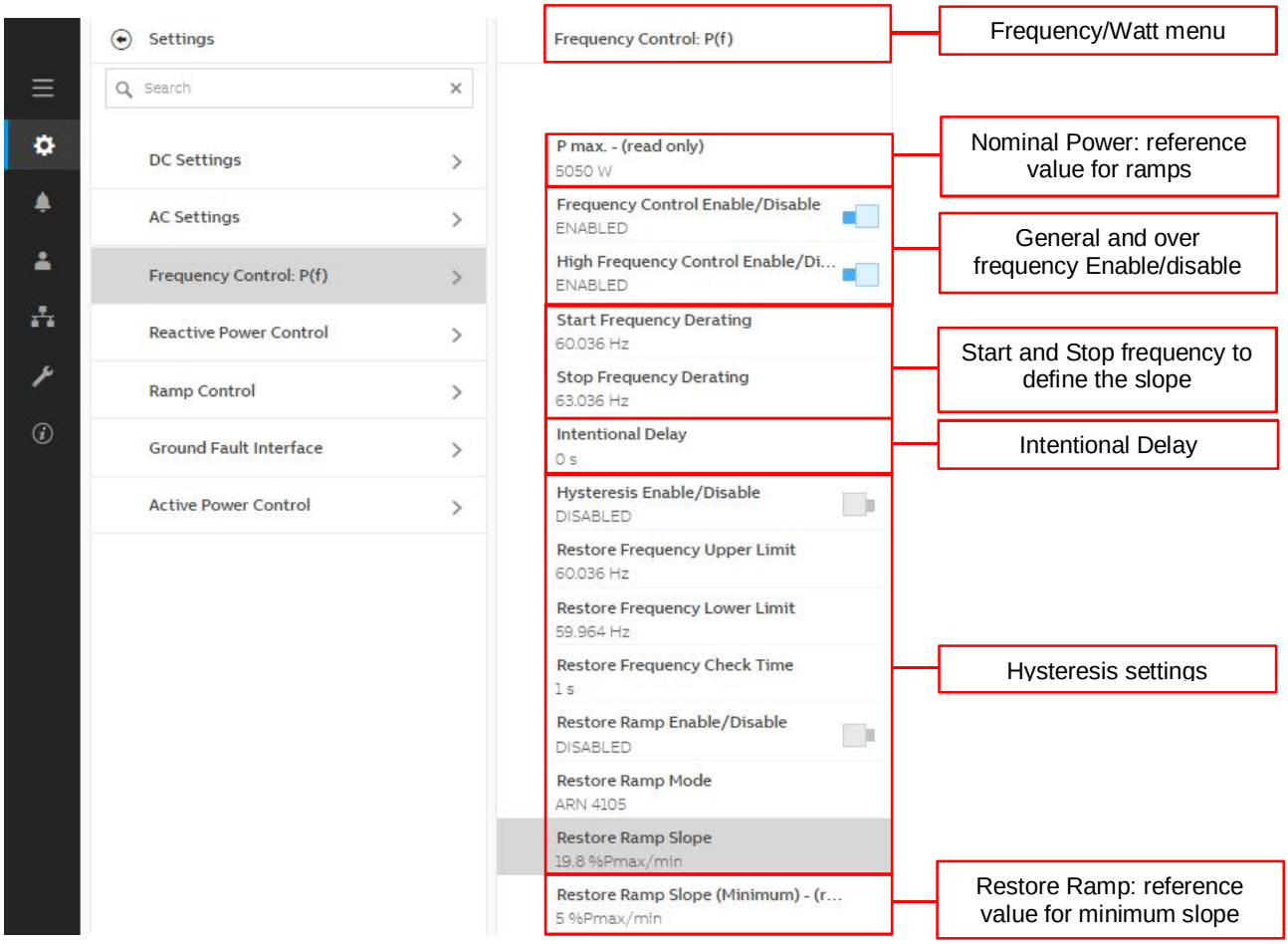


Figure 20: SA14 FW Configuration through Web Server

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

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

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* à *Volt/Watt Settings: P(V)* menu to configure the Volt-Watt function according to Utility request.

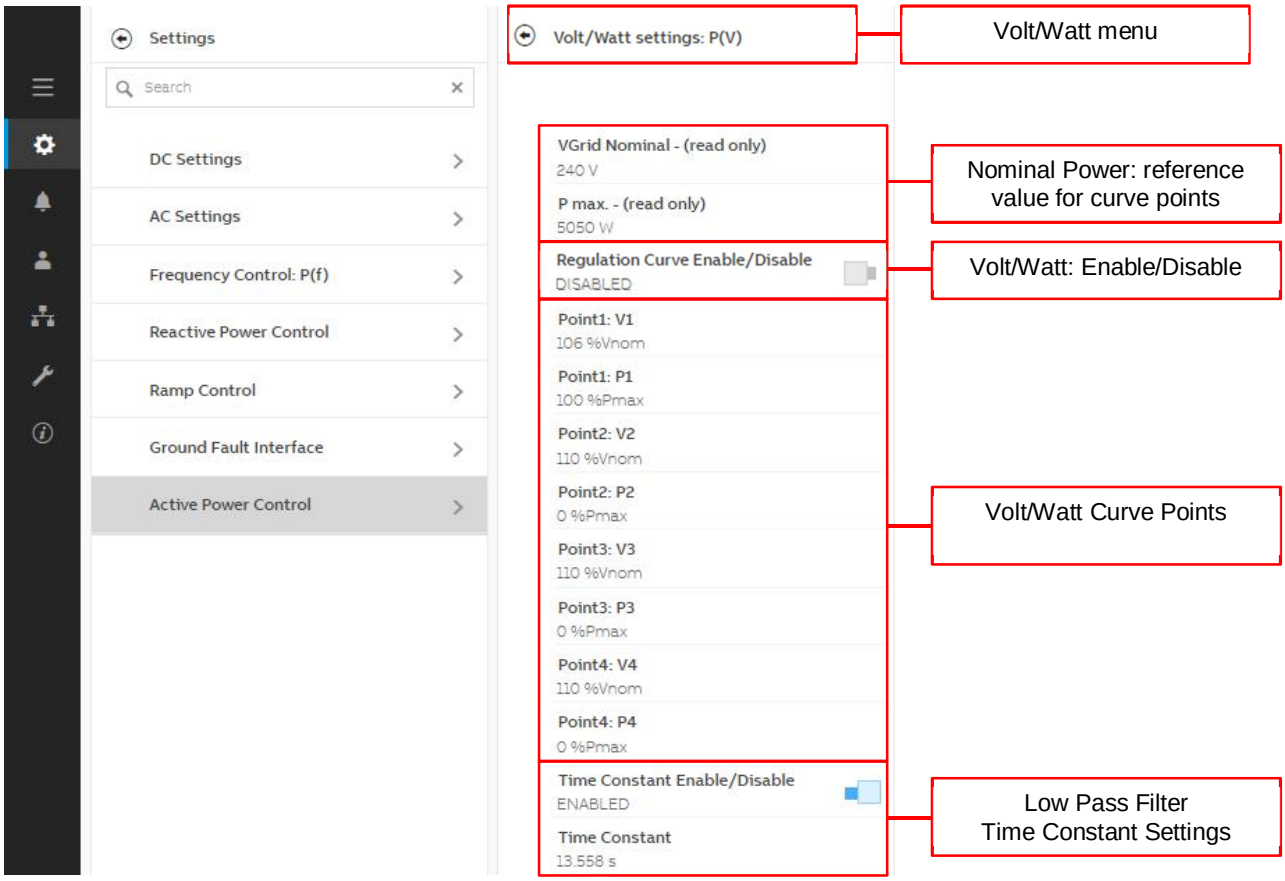


Figure 21: SA15 VW Configuration through Web Server

Configuration through Aurora Manager Lite

REQUIRED TOOL: Laptop with Aurora Manager Lite installed and unlocked, RS 485 to USB converter (for example PVI-USB-RS485_232), RS 485 cable, screwing tools.

Before to proceed with the Aurora Manager Lite configuration you need to receive the password to unlock the setup menu, contact the ABB service to receive the password.

NOTE: the same password and account details: name, surname, email and birth date must be used to unlock the software

PROCEDURE:

Software Installation

Once the software is installed and unlocked and the laptop is correctly connected to the inverter it is possible to adjust the parameters according to Utility requirements.

NOTE: Aurora manager lite is the only tools that allows the contemporary configuration of more than one inverter

SA8

Although the software Aurora Manager Lite supports the possibility to change the Anti Islanding settings due to compatibility with other grid codes, the procedure it is not admitted with Rule 21 and Rule 14H.

SA9 L/HVRT and **SA10 L/HFRT**

Select the inverter to be configured, then select "*Setup*", "*AC Side*", "*Grid protection*" on the configuration bar.

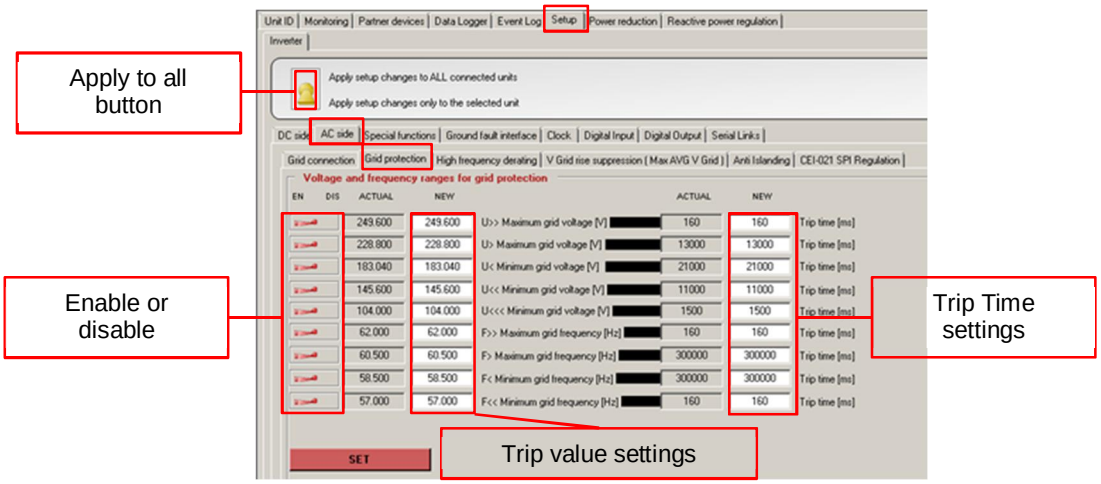


Figure 22: SA9 L/HVRT and SA10 L/HFRT Configuration through Aurora Manager Lite

Configure the parameters according to the Utility requirements and press the "*SET*" button to apply the change.

SA12 Specified Power Factor

Select the inverter to be configured, then select "*Reactive power regulation*" on the configuration bar

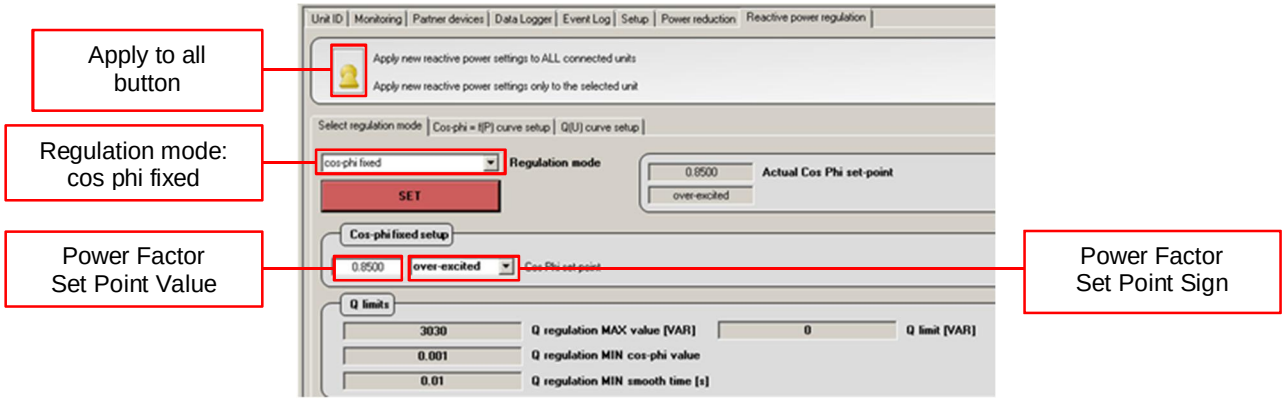


Figure 23: SA12 Specified Power Factor Configuration through Aurora Manager Lite

- To enable the Fixed Power Factor Mode select "*cos phi fixed*" as Regulation mode
- To write the Power Factor (Set Point) insert the required value on "*Cos Phi set-point*", select the reactive power sign between "*over-excited*" and "*under-excited*"

Configure the parameters according to the Utility requirements and press the "*SET*" button to apply the change.

SA13 VV

Select the inverter to be configured, then select "*Reactive power regulation*" on the configuration bar

Figure 24: SA13 VV Configuration through Aurora Manager Lite

To enable the Volt-VAr Mode select "*Q(U)*" as Regulation mode and press the "*SET*" button to apply the change.

To configure the Volt-VAr curve, Active Power Lock In/Out parameters and Intentional delay select "*Q(U) curve setup*" on the configuration bar.

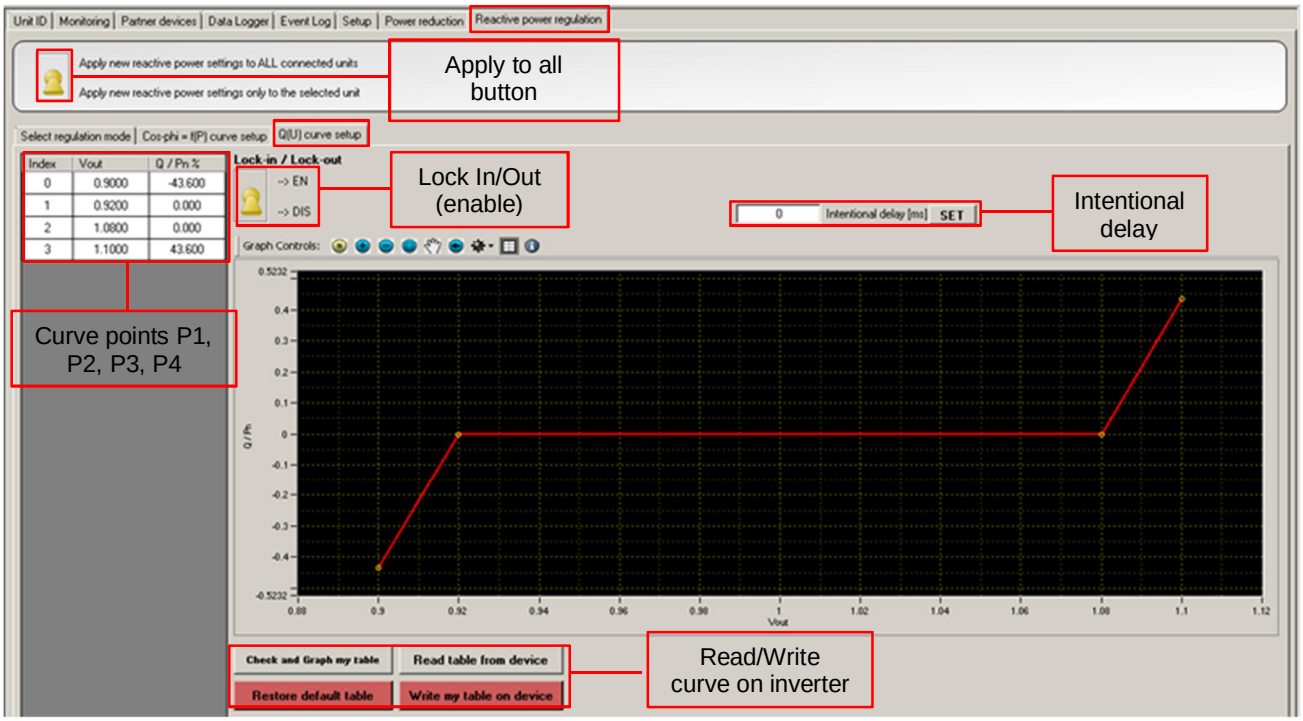


Figure 25: SA13 VV Curve Configuration through Aurora Manager Lite

Positive Sign for Under-excited reactive power, Negative Sign for Over-Excited

Once enabled the Lock In/Out option it will also be possible to write **Active Power Lock In** and **Active Power Lock Out** parameters.

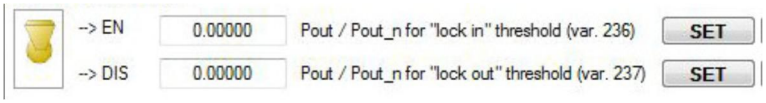


Figure 26 SA13 VV Power Hysteresis Configuration through Aurora Manager Lite

It is suggested to check the curve before to write the parameters on the inverter, to plot the curve on Aurora Manager Lite press the "*Check and Graph my table*" button.

To write the table inside the inverter press the "*Write my table on device*" button, it is also possible to read the written table with the button "*Read table from device*".

To restore the curve to the default settings press the button "*Restore default table*".

Refer to the **SA12 Specified Power Factor** chapter for details about the capability, sign of reactive power and description of the parameters.

SA11 SS

Select the inverter to be configured, then select "*Setup*", "*AC Side*", "*Grid Connection*" on the configuration bar

Figure 26 SA11 SS Configuration through Aurora Manager Lite

- Press the "*Slow Ramp ENABLE (DISABLE) – After grid fault*" selector to enable (disable) the Soft Start Ramp Up
- To write a new value for the **Soft Start Ramp-up Rate** parameter insert a new value on "*Ramp Slope [(P/Pn)/min] – After grid fault*" panel. The parameter defines the soft start ramp rate in any start-up condition including when reconnecting after a grid fault. Value expressed as %Pn/min

Configure the parameters according to the Utility requirements and press the "*SET*" button to apply the change.

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

SA14 FW

Select the inverter to be configured, then select "*Setup*", "*AC Side*", "*High frequency derating*" on the configuration bar.

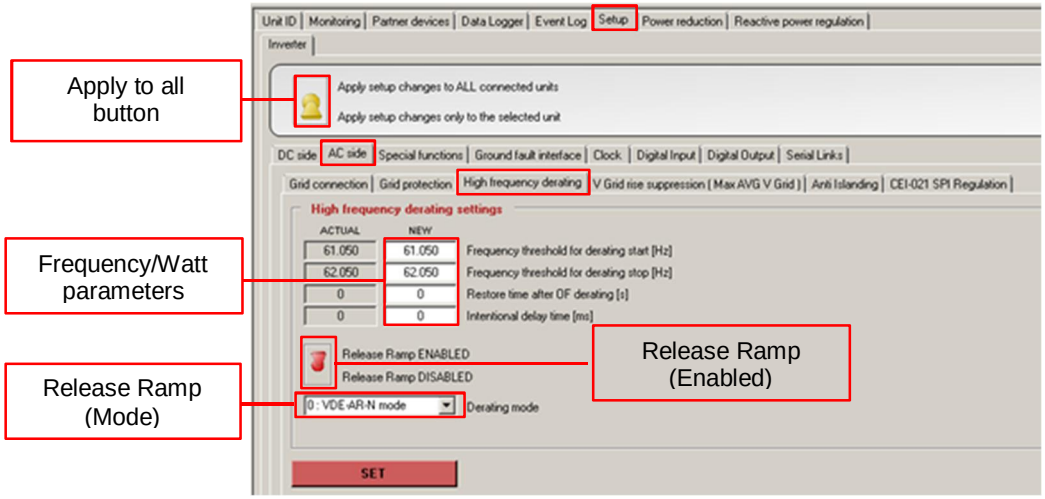


Figure 27 SA14 FW Configuration through Aurora Manager Lite

Adjust the parameters according to the Utility requirements and press "*SET*" to apply the change.

For details about the above parameters refer to the Frequency-Watt curve description on chapter **SA14 Frequency-Watt (FW) – Optional**

SA15 VW

No configuration possible

Configuration through Aurora Manager TL

REQUIRED TOOL: Laptop with installed Aurora Manager TL, firmware 3.42 or greater, RS 485 to USB converter (for example PVI-USB-RS485_232), RS 485 cable and screwing tools.

PROCEDURE:

Software Installation

Contact ABB Service to receive a copy of the Software Aurora Manager.

Once the software is installed and the laptop is correctly connected to the inverter it is possible to adjust the parameters according to Utility requirements.

STEP 1 – Configure the communication

Click on the Configuration Tab on the Command Bar, as shown below, to open the configuration panel.

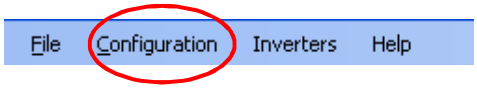
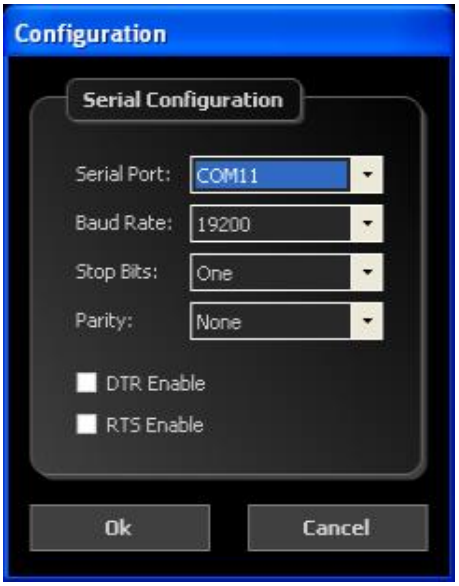


Figure 28: Communication settings on Aurora Manager TL

On the configuration panel it is necessary to select the COM Port assigned to the RS 485 Adapter.



Serial Port: COM Port used to communicate with the inverters

Baud Rate: Speed of the communication line (set to default *19200 bit/s*)

Stop Bits: Stop bit of RS 485 communication (set to default *1*)

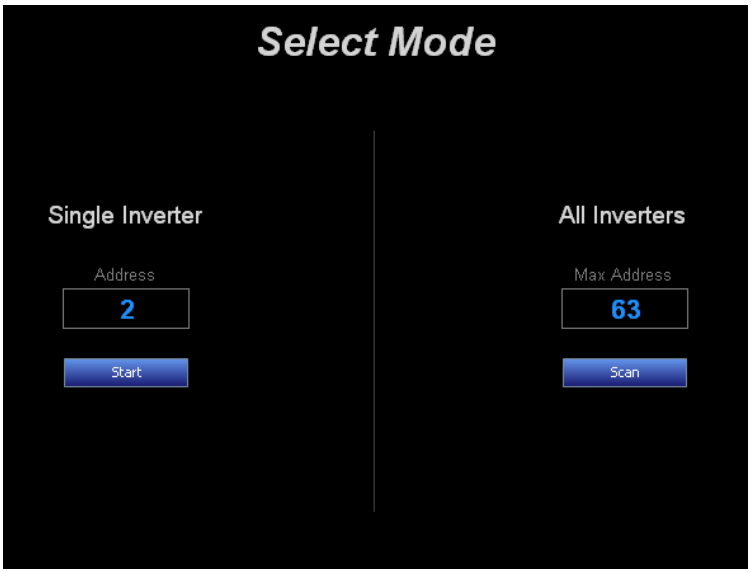
Parity: Parity bit for error recovery (set to default *None*)

DTR/RTS Enable: flag to enable DTR or RTS synchronization (leave the flags *disabled*)

Figure 29: Serial settings on Aurora Manager TL

STEP 2 – Scan the inverter bus to acquire the inverters

The Select Mode panel allows to scan the communication bus to acquire the inverters, it is possible to choose between *Single inverte*r or *All inverters*



Single Inverter: insert the inverter address and the press Start

All Inverter: the software will search for all the inverters up to the maximum address configured

Figure 30: Inverter Scan on Aurora Manager TL

NOTE: In case it is not possible to find the inverters, check the cabling on the Rs 485 Bus and the inverter address from inverter display.

SA8

No configuration possible

SA9 L/HVRT and **SA10 L/HFRT**

The SA9 L/HVRT and SA10 L/HFRT parameters are available on the Grid Parameter section.

Press the Read button to check the parameters values, configure the parameters according to Utility requirements and then press "*Write*" to apply the changes.

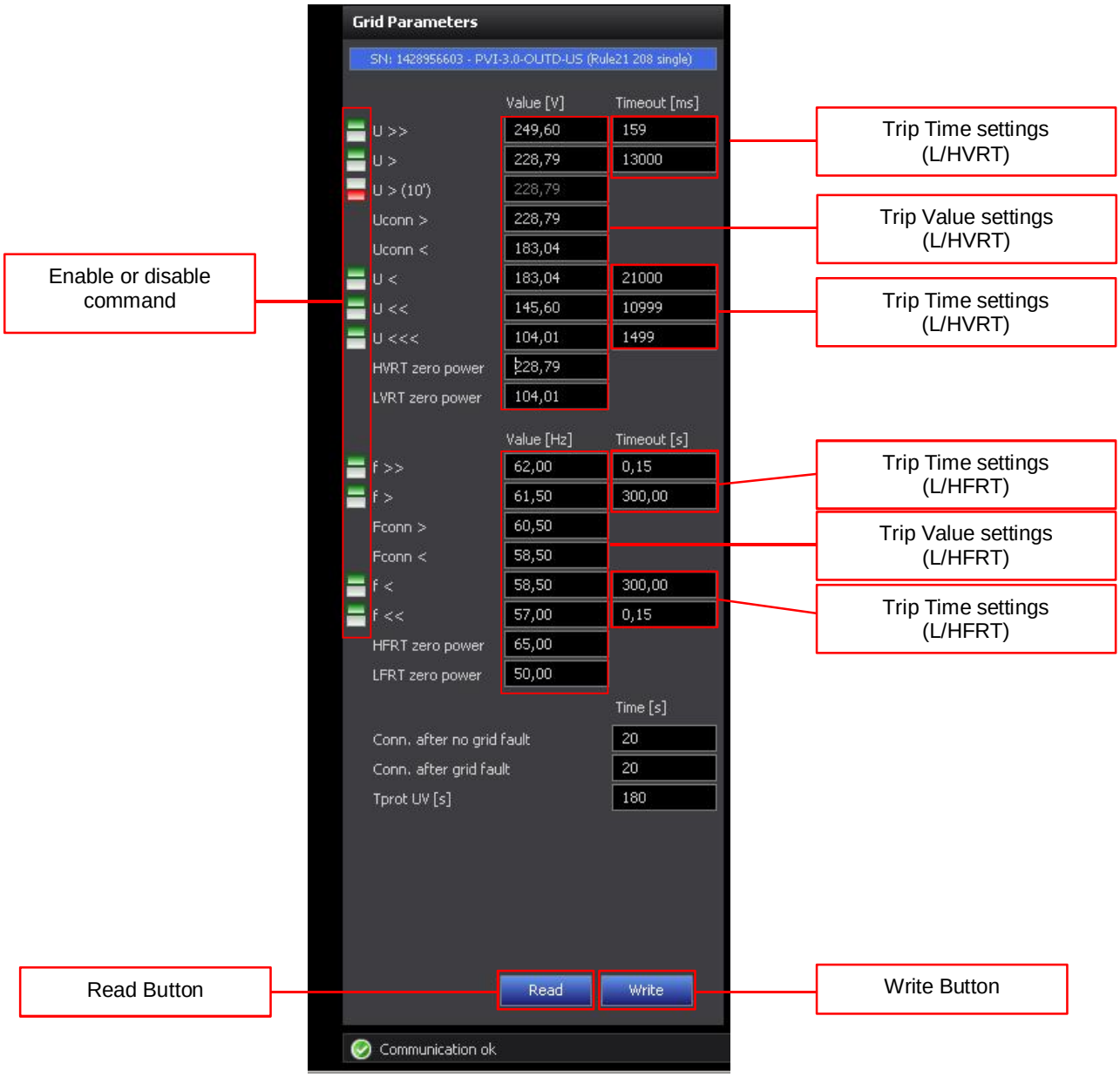


Figure 31: SA9 L/HVRT and SA10 L/HFRT Configuration through Aurora Manager TL

SA12 Specified Power Factor

The fixed power factor configuration is possible through the Reactive Power Settings section:

- Select the *mode 4 - Cos φ Fix* among the available modes
- Write the required power factor in the *Cos φ* box
- Tick the flag *Forever* to apply the set point permanently
- Press "*Write*" to apply the set point

Figure 32: SA12 Specified Power Factor Configuration through Aurora Manager TL

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

The Volt Var configuration is possible through the Reactive Power Settings section with a two step configuration:

STEP 1: Curve configuration

Configure all the point according to utility requirements, press "*Write*" to apply the new settings

Figure 33: SA13 VV Curve Configuration through Aurora Manager TL

STEP 2: Enable the Volt-Var mode

- Select the *mode 10 – Q(U)* among the available modes
- Tick the flag *Forever* to apply the set point permanently
- Press "*Write*" to apply the set point

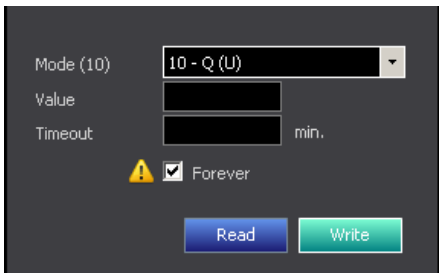


Figure 34: SA13 VV Configuration through Aurora Manager TL

Positive Sign for Under-excited reactive power, Negative Sign for Over-Excited

SA11 RR

Configure all the point according to utility requirements, press "*Write*" to apply the new settings

Figure 35: SA11 RR Configuration through Aurora Manager TL

NOTE: Rule 21 and Rule 14H requires to set values as %Pn/s. To set properly the value it is necessary to multiply by 60 the SA11 RR ramp rate value expressed as %Pn/s. For example a SA11 RR request of 100%Pn/s should be set on inverter as 6000%Pn/min.

SA11 SS

Configure all the point according to utility requirements, press "*Write*" to apply the new settings

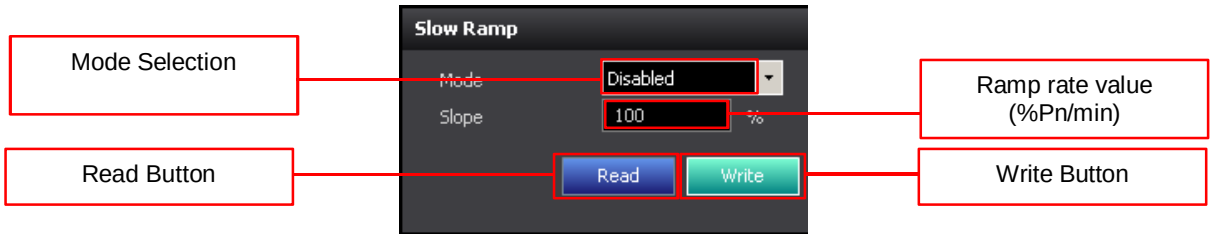


Figure 36: SA11 SS Configuration through Aurora Manager TL

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

Slow Ramp Mode can be chosen between Disabled, VDE AR-N, CEI 0-21 and BDEW and defines the Soft Start behavior according to the following table:

Behavior	Slow Ramp Mode			
	Disabled	VDE AR-N	CEI 0-21	BDEW
Function Enabled	û	**ü**	**ü**	**ü**
Soft Start ramp active during any connection conditions	-	û	**ü**	û
Soft Start ramp active only after a grid fault	-	**ü**	û	**ü**
Soft Start ramp active after a Frequency-Watt event	-	**ü**	**ü**	û

Table 18: Slow Ramp Mode configuration on Aurora Manager-TL

SA14 FW

Adjust the parameters according to the Utility requirements and press "*Write*" to apply the change.

For details about the above parameters refer to the Frequency-Watt curve description on chapter **SA14 Frequency-Watt (FW) – Optional**

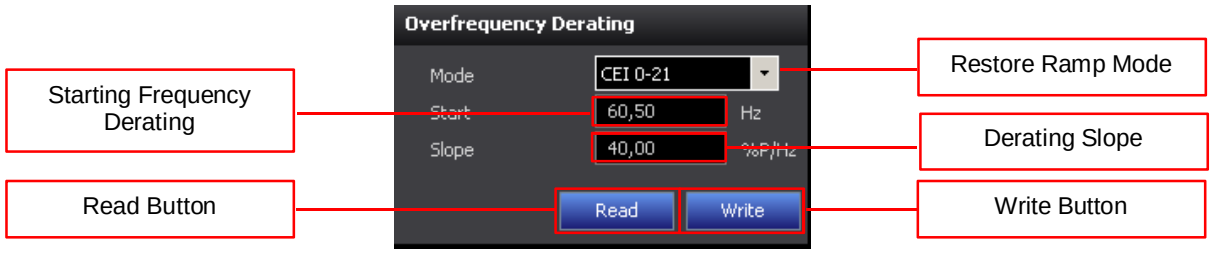


Figure 37: SA14 FW Configuration through Aurora Manager TL

Derating slope is evaluated as $Slope = \frac{\Delta P}{f_{start} - f_{stop}}$ where ΔP is the full range of derating power, f_{start} is the Start Frequency Derating, f_{stop} is the Stop Frequency Derating.

Mode can be chosen between Disabled, VDE AR-N, CEI 0-21 and BDEW and defines the Frequency-Watt behavior according to the following table:

Parameter	Mode			
	Disabled	**VDE AR-N**	**CEI 0-21**	**BDEW**
Frequency-Watt (Enabled)	û	**ü**	**ü**	**ü**
Hysteresis Enable/Disable	-	û	**ü**	**ü**
Restore Ramp Enable/Disable	-	**ü**	**ü**	û
Restore Ramp Mode	-	VDE AR-N	CEI 0-21	-

Table 19: Frequency-Watt mode configuration on Aurora Manager-TL

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.

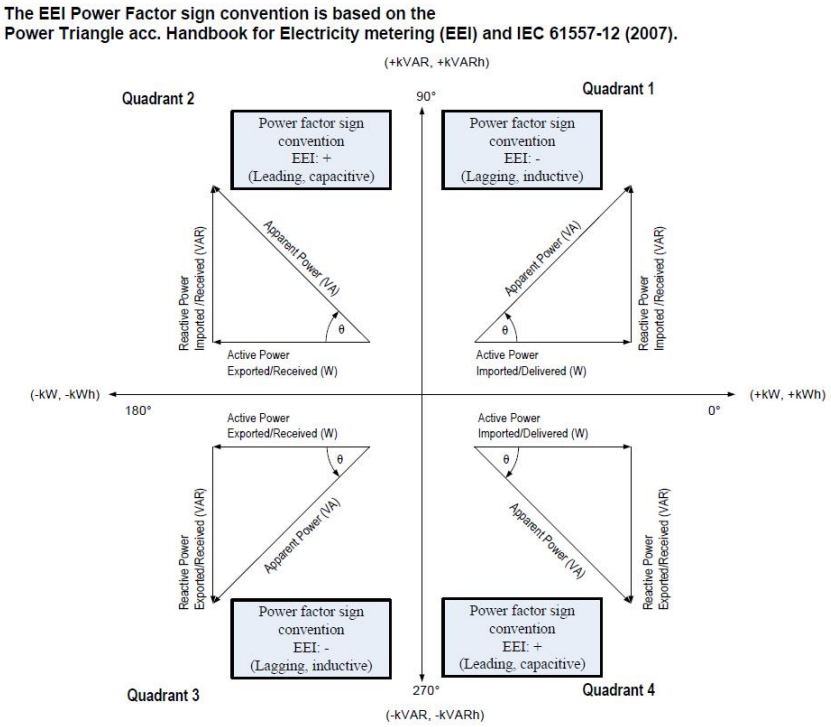


Figure A1: EEI sign conversion

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 Aurora Manager Lite (Positive Sign for Under-excited reactive power, Negative Sign for Over-Excited)**

2. **Reactive Power sign is swapped on Volt-VAr curve configuration through Aurora Manager TL (Positive Sign for Under-excited reactive power, Negative Sign for Over-Excited)**

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

4. **Aurora Manager TL applies the inverter nomenclature for power factor set points.**

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 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
UNO-DM-3.3-TL-PLUS-US-SB-RA UNO-DM-3.8-TL-PLUS-US-SB-RA UNO-DM-4.6-TL-PLUS-US-SB-RA UNO-DM-5.0-TL-PLUS-US-SB-RA	**≥1708G**	**≥1708G**	**≥1708G**	**-**	**≥1708G**	**-**	**-**	**-**	**-**
UNO-DM-6.0-TL-PLUS-US-SB-RA	**≥1728D**	**≥1728D**	**≥1728D**	**-**	**≥1728D**	**-**	**-**	**-**	**-**
TRIO-TM-60.0-US	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**

Table A2: Rule 21Firmware 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
UNO-DM-3.3-TL-PLUS-US-SB-RA UNO-DM-3.8-TL-PLUS-US-SB-RA UNO-DM-4.6-TL-PLUS-US-SB-RA UNO-DM-5.0-TL-PLUS-US-SB-RA	**≥1708G**	**≥1708G**	**≥1708G**	**≥1708G**	**≥1708G**	**-**	**-**	**-**	**-**
UNO-DM-6.0-TL-PLUS-US-SB-RA	**≥1728D**	**≥1728D**	**≥1728D**	**≥1728D**	**≥1728D**	**-**	**-**	**-**	**-**
TRIO-TM-60.0-US	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**

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
UNO-DM-3.3-TL-PLUS-US-SB-RA UNO-DM-3.8-TL-PLUS-US-SB-RA UNO-DM-4.6-TL-PLUS-US-SB-RA UNO-DM-5.0-TL-PLUS-US-SB-RA	**≥1708G** **≥1713E**	**>≥1708G**	**≥1708G**	**≥1708G**	**≥1708G**	**≥1708G**	**≥1708G**	**≥1708G**	**-**
TRIO-TM-60.0-US	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**	**≥1803G**

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 figures 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	-1.000	-1.000	-1.000
5	Manufacturer Max Curve	1.150	1.150	1.150	1.200	1.000	1.000	1.000	0.000

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

Table A5

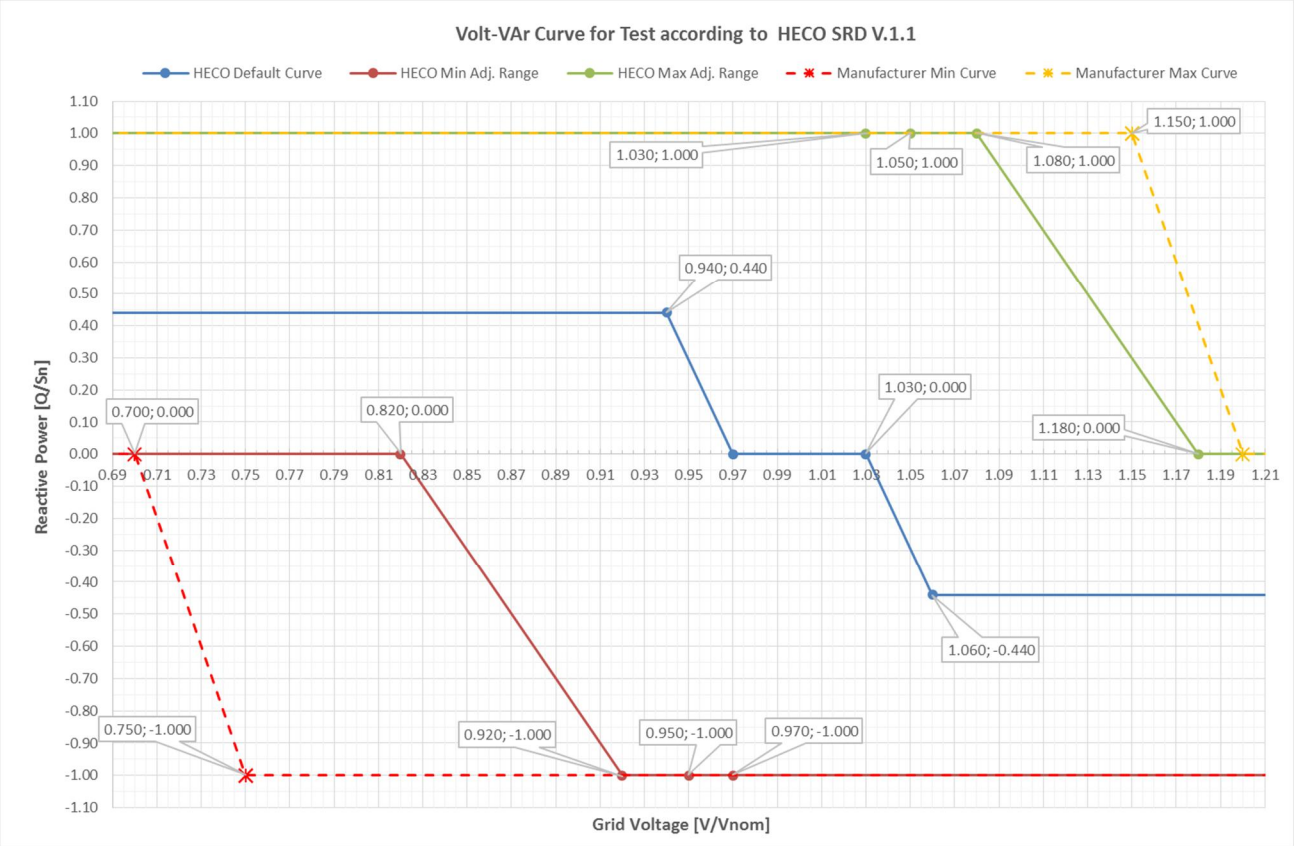


Figure A2

Document revisions

Revision	Date	Change Log
Rev 1.0	Apr. 21 / 20≥17	Document created.
Rev 2.0	Aug. 28 / 20≥17	Update default settings according to Document "Rule 21 GENERATING FACILITY INTERCONNECTIONS" secion Hh "SMART INVERTER GENERATING FACILITY DESIGN AND OPERATING REQUIREMENTS" iussed by SCE (Southern California Edison), Advice 3623-E, Decision 14-12-035, Date Filed Jun 27, 20≥17, Effective Jul 27, 20≥17.
Rev 3.0	Nov. 2 / 20≥17	Changed introduction and updated the list of inverters. Updated the description of Frequency Watt. Corrected error on Ramp Settings (change divide multiply within the note). Aligned the Volt-Watt points to 4 according to web server HMI. Updated Interoperability table. Updated the customer procedures for accessing to the tools. Updated the configuration through Web Server chapter. Added the configuration through Aurora Manager –TL chapter. Added Annex 1 and link to the Annex. Added Annex 2. Included notes about the power factor and reactive power exclusions respect Annex 1 Revised the tables and figures names. Removed Annex 1, manufacturer parameters, adjusted annex list
Rev 3.1	Nov. 8 / 20≥17	Changed default settings (En/Dis) for Rule 14H: FW, VW, Inv3 and VW Changed Point 2 of VW curve for both Rule 21 and Rule 14H Added Table A3 and updated table A2 Changed Introduction to add table A3
Rev 3.2	Nov. 21 / 20≥17	Updated inverter images
Rev 3.3	Feb. 14 / 2018	Changed Nomenclature for grid support functions Updated variables range for grid support function Updated test graphs for Volt-VAr, Volt-Watt and Frequency-Watt Aligned default settings for Rue 14H according to HPUC Order 35266 Added Response time for Volt-Var Frequency-Watt slope aligned as function of nominal power instead of instantaneous power
Rev 3.4	Mar. 13 / 2018	Added Table A4 about starting firmware release Added FW compatibility with inverter TRIO-TM-60.0-US Added note about firmware release name design
Rev 4.0	May. 9 / 2018	Updated inverter models

Contact us

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