REFU*sol* 350K-8T

PV Inverter Technical Digest



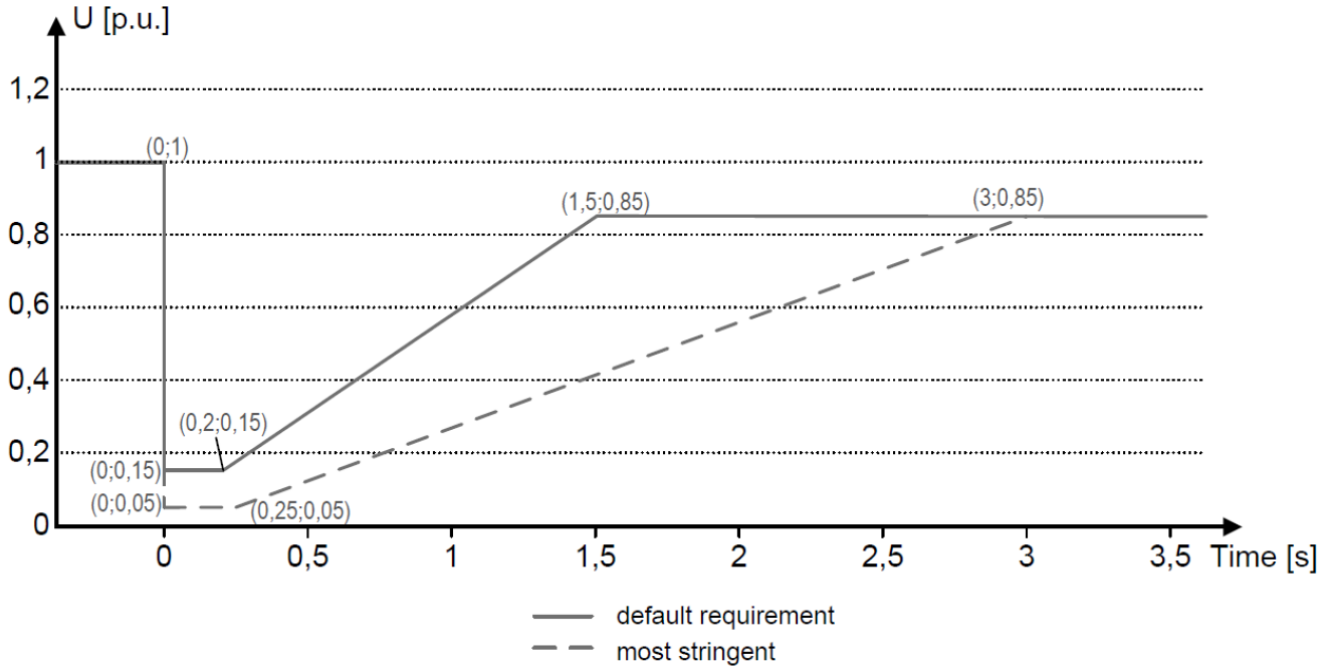
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• Under- voltage ride through (UVRT)

The UVRT for the PV inverters is governed by EN50549-1/2 : 2019, clause number 4.5.3, which explain the requirement that the inverter should withstand the voltage drop with respect to time and should not disconnect immediately as soon as the voltage drop occurs due to any fault insertion, hence it should be capable to ride through short term voltage sag from 0% to 100% for a specified duration of time, The REFUsol 350K-8T is certified to stated standard requirement.

The UVRT curve of the PV inverter can be referred to as below:

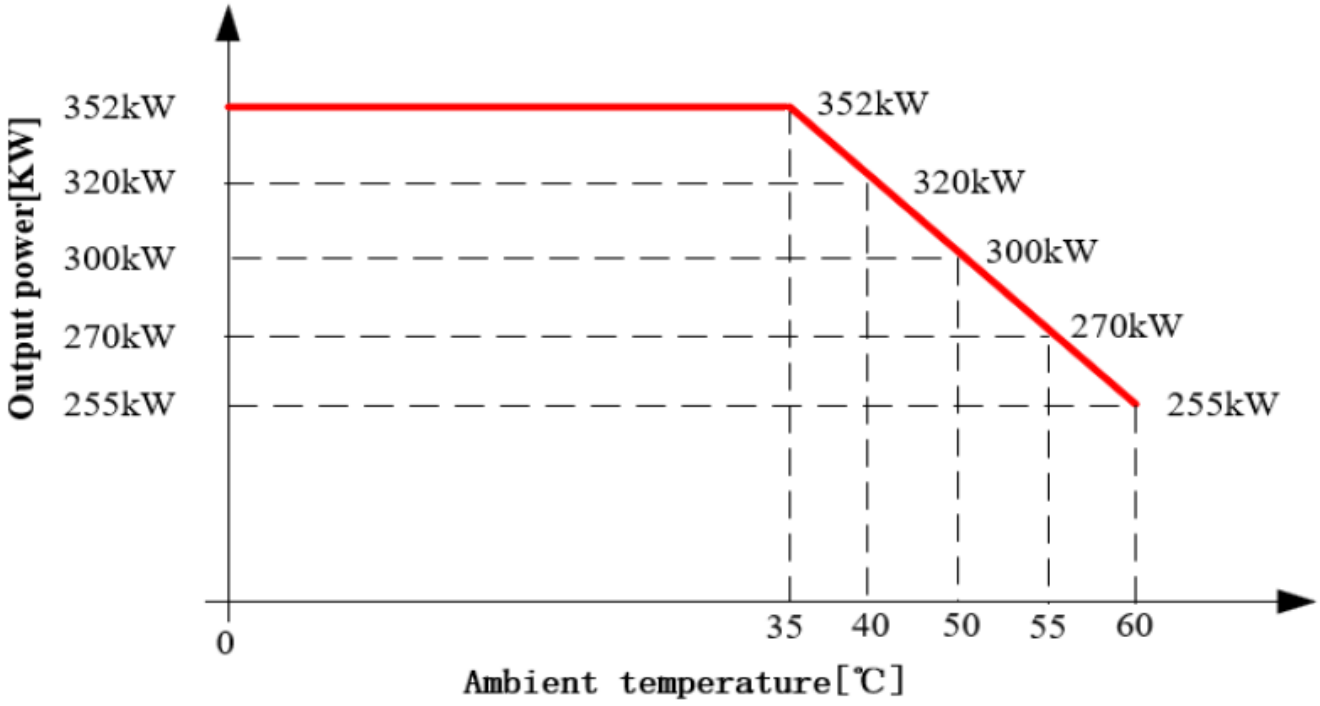


• PV inverter characteristic curves

The REFUsol 350K-8T PV inverter is meant to operate at various adverse conditions, it could be high temperature, different altitudes, lower operating DC voltage or different range of AC voltages.

This inverter automatically adjusts its output to deal with different environmental and electrical conditions for longer life. The curves below explain different performance characteristics which change based on different operating parameters.

◦ Temperature vs Power output (at Pf = 1)

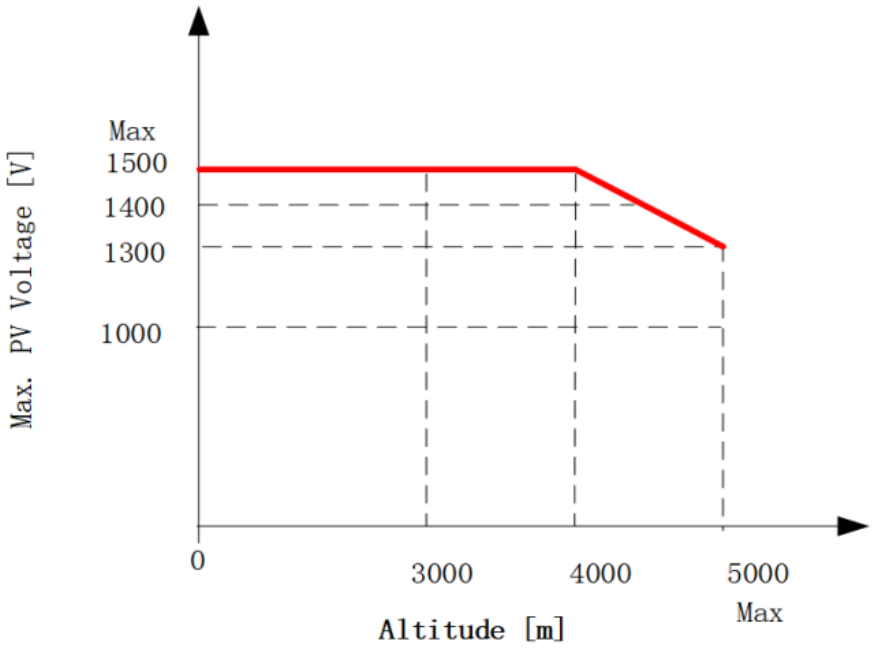


When the ambient temperature is high, the inverter will appropriately reduce the output power to ensure safe and long-term operation.

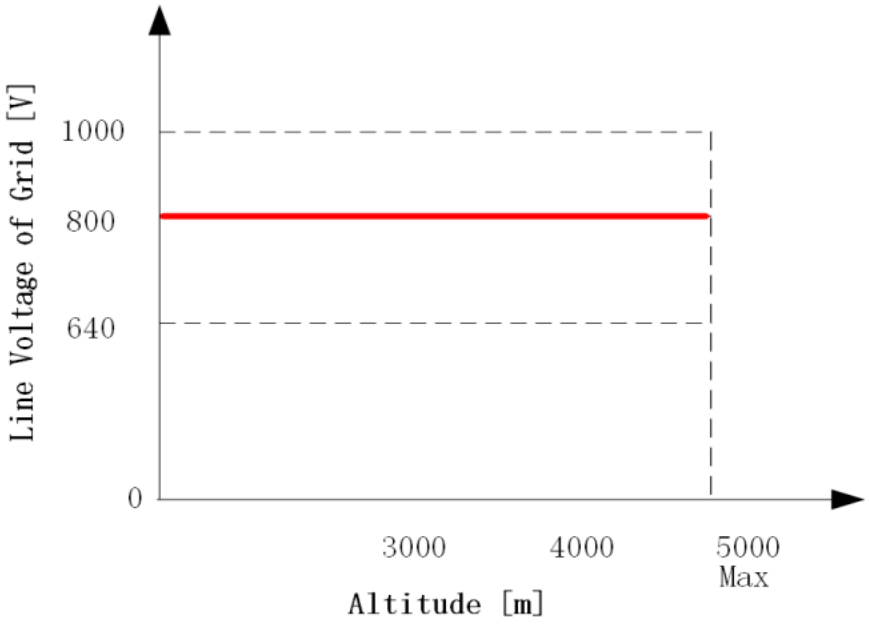
Voltage vs Altitude

In high-altitude areas, the air density is low, and charged particles are more vulnerable to ionization in thin air. When the gap and creepage distance between the internal components of the inverter are fixed, it is necessary to limit the DC voltage, according to the following curve in the design stage of the power station to ensure electrical safety.

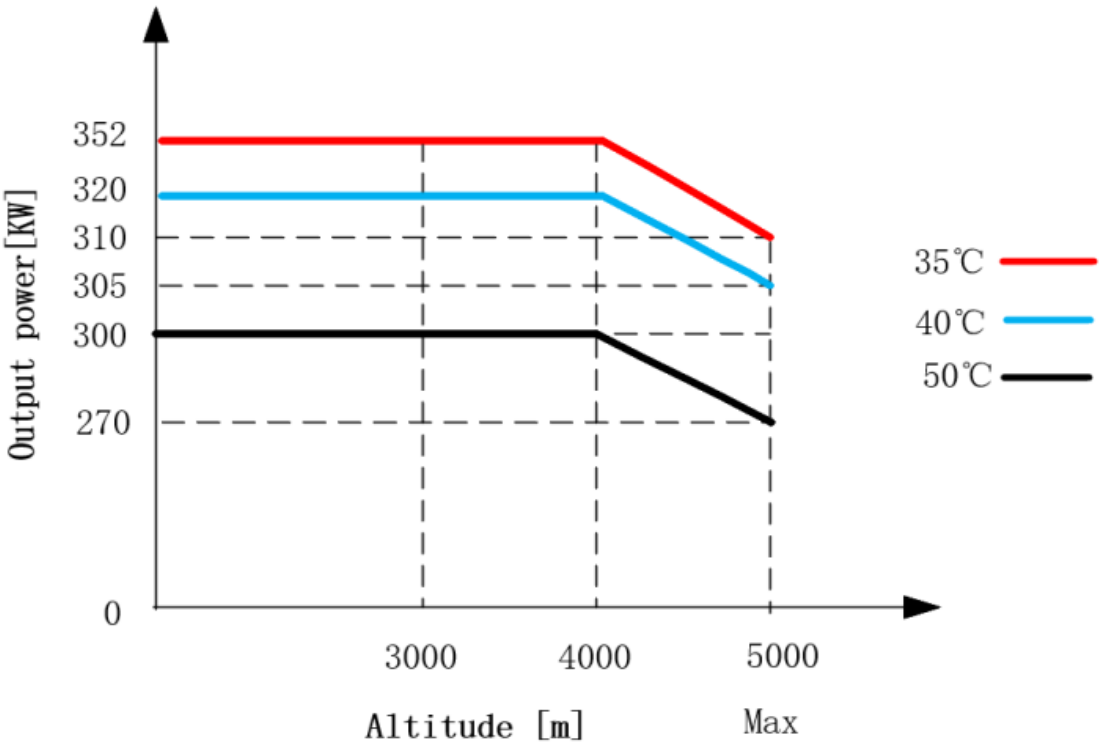
Input DC voltage vs Altitude



Line Grid voltage vs Altitude

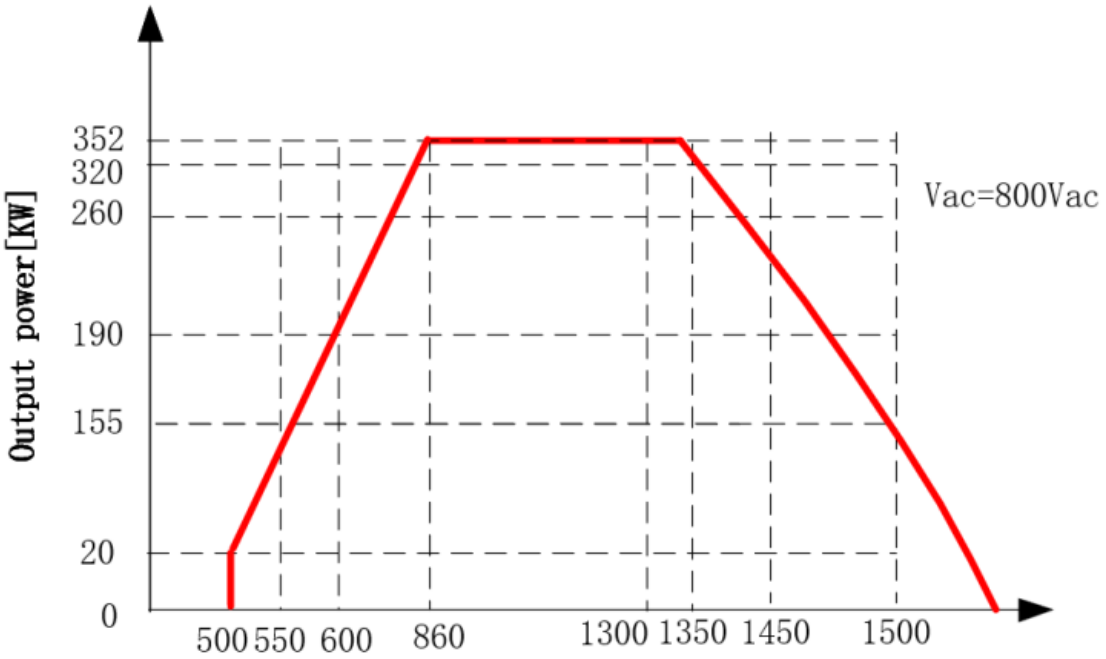


○ Output Power vs Altitude (at different temperatures)



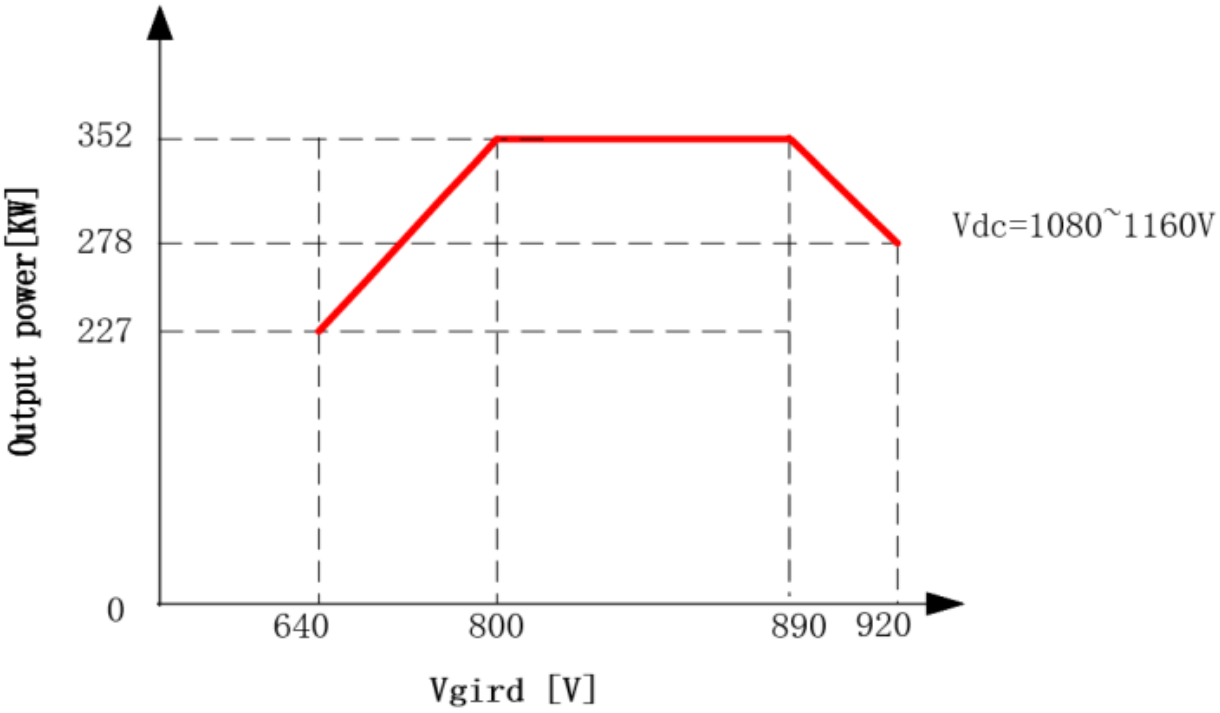
○ Connection point AC vs Power output (at Pf = 1)

The inverter will output different load reductions under different input voltages. When the input voltage is between 860V and 1300V, the inverter can ensure sufficient power output. With higher input voltage, the power will gradually decrease to ensure the machine's long-term reliable operation. To get the best efficiency and power generation, it's best to input the rated voltage at 1160V and the open circuit voltage at 1350V.



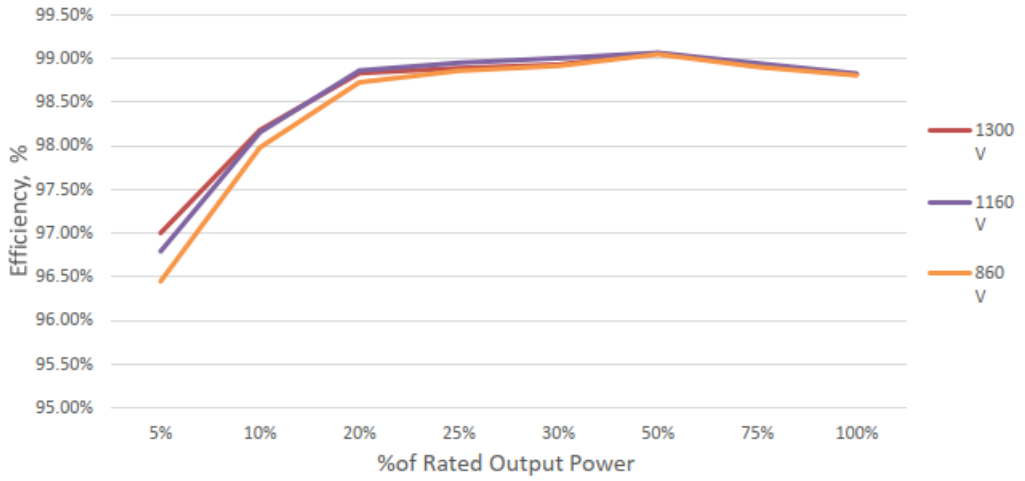
○ Input DC voltage vs Power output (at Pf = 1)

The inverter can handle voltages between 640V and 920V, and is designed to operate at a set voltage of 800V. When the grid voltage drops (VAC>640V), the inverter will reduce the output power.
This can lead to overheating in some parts of the inverter, which can pose safety risks. In this case, the inverter automatically adjusts the output power according to the grid voltage. This ensures that the AC output current is within the allowable range and that the equipment operates safely. It is generally recommended that users configure it at the rated voltage of 800V to get the most energy, refer the curve below to see the change in the power with respect to the grid voltage.



• Efficiency Curve

Efficiency curve is the Eff% vs %Of Rated power curve with a pre-condition of the minimum MPP voltage (UDCMIN=860V), and the maximum MPP voltage (UDCMAX=1300V) and the rated input voltage (UDC, R=1160V) for REFUsol 350K-8T.



Max. efficiency	99.06%
European efficiency	98.83%

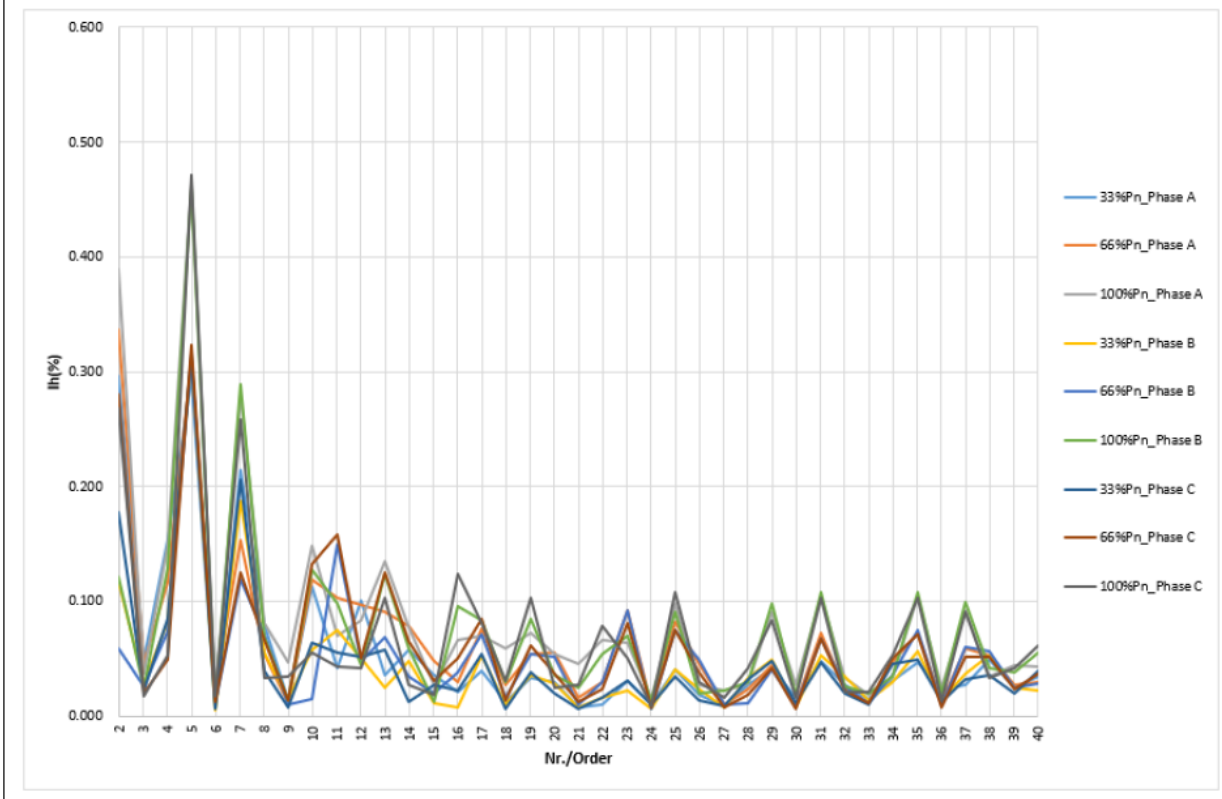
• Harmonic Emissions

As per the clause number 4.8 of the standard EN61000-3-12:2011-05 the harmonics tests were conducted, the measured result values are as tabulated below:

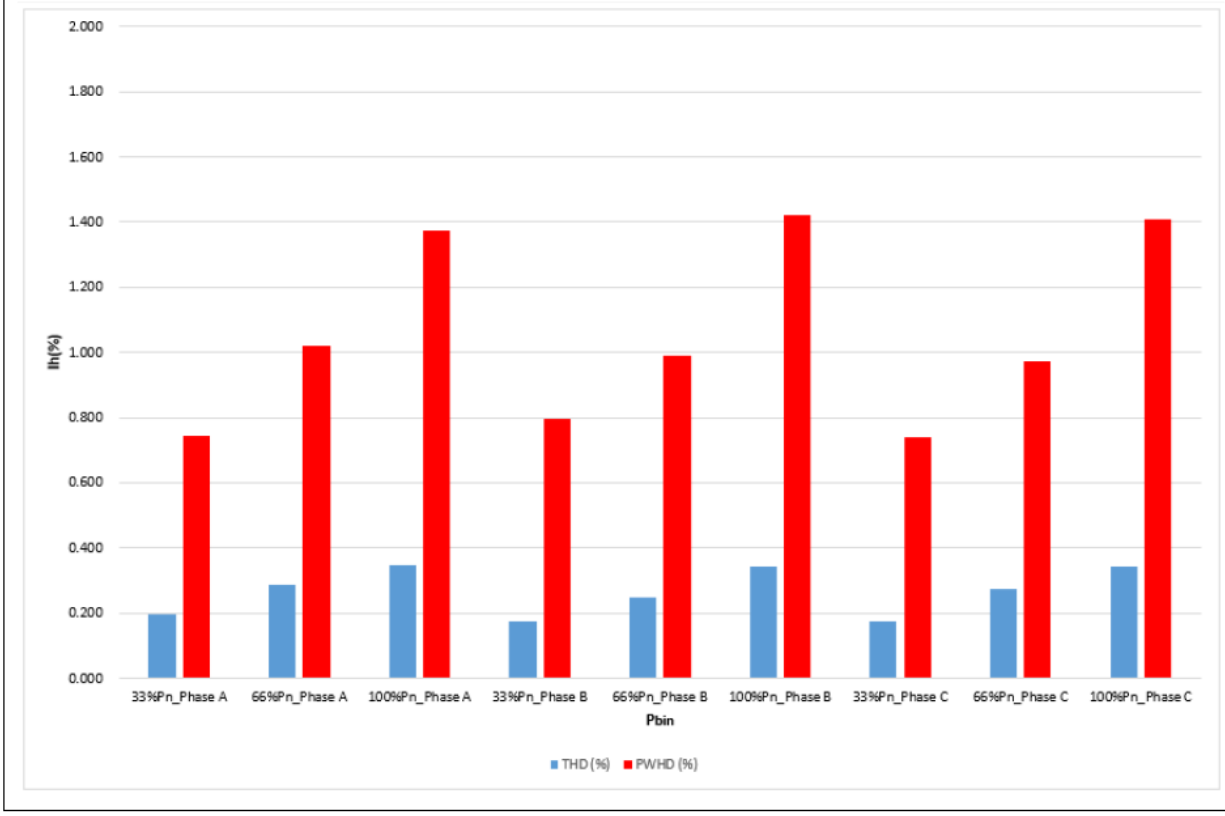
Pn (%)	Phase A			Phase B			Phase C			Limit (%)
	33	66	100	33	66	100	33	66	100	
Nr./Order	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	
2	0.296	0.337	0.389	0.118	0.058	0.121	0.178	0.280	0.269	8.000
3	0.049	0.046	0.037	0.028	0.025	0.024	0.022	0.020	0.018	--
4	0.153	0.117	0.149	0.082	0.073	0.129	0.085	0.049	0.053	4.000
5	0.294	0.310	0.464	0.311	0.311	0.461	0.316	0.323	0.471	10.700
6	0.006	0.022	0.019	0.006	0.012	0.011	0.006	0.012	0.017	2.700
7	0.214	0.154	0.280	0.188	0.119	0.289	0.206	0.125	0.259	7.200
8	0.080	0.054	0.081	0.055	0.072	0.068	0.040	0.067	0.033	2.000
9	0.013	0.011	0.046	0.015	0.010	0.014	0.007	0.013	0.035	--
10	0.113	0.119	0.148	0.057	0.015	0.128	0.064	0.132	0.055	1.600
11	0.042	0.103	0.070	0.075	0.149	0.098	0.055	0.158	0.043	3.100
12	0.100	0.096	0.083	0.050	0.048	0.044	0.051	0.050	0.042	1.300
13	0.036	0.090	0.135	0.024	0.069	0.124	0.057	0.125	0.103	2.000
14	0.058	0.079	0.077	0.049	0.034	0.059	0.012	0.065	0.027	--
15	0.036	0.048	0.027	0.011	0.019	0.013	0.027	0.031	0.019	--
16	0.022	0.030	0.066	0.007	0.039	0.095	0.022	0.050	0.123	--
17	0.040	0.077	0.070	0.053	0.071	0.083	0.054	0.084	0.081	--
18	0.012	0.027	0.059	0.011	0.016	0.030	0.006	0.014	0.031	--
19	0.034	0.054	0.072	0.035	0.054	0.084	0.038	0.062	0.103	--
20	0.030	0.055	0.054	0.028	0.052	0.035	0.019	0.037	0.025	--
21	0.008	0.016	0.045	0.008	0.010	0.024	0.006	0.013	0.027	--
22	0.010	0.029	0.066	0.017	0.030	0.054	0.016	0.023	0.078	--
23	0.031	0.092	0.064	0.023	0.092	0.071	0.031	0.081	0.050	--
24	0.010	0.010	0.015	0.006	0.007	0.013	0.010	0.007	0.009	--
25	0.040	0.082	0.098	0.040	0.075	0.091	0.035	0.075	0.108	--
26	0.019	0.045	0.027	0.023	0.049	0.019	0.014	0.039	0.030	--
27	0.009	0.010	0.023	0.007	0.009	0.023	0.009	0.008	0.016	--
28	0.027	0.023	0.028	0.034	0.011	0.030	0.032	0.019	0.042	--
29	0.042	0.044	0.090	0.049	0.041	0.098	0.048	0.041	0.084	--
30	0.016	0.010	0.027	0.008	0.009	0.018	0.011	0.006	0.016	--
31	0.047	0.073	0.104	0.053	0.067	0.108	0.047	0.067	0.104	--
32	0.027	0.024	0.033	0.035	0.026	0.026	0.020	0.022	0.020	--
33	0.015	0.011	0.019	0.014	0.012	0.020	0.010	0.011	0.020	--
34	0.031	0.047	0.034	0.029	0.036	0.034	0.046	0.051	0.052	--
35	0.047	0.072	0.104	0.056	0.075	0.108	0.049	0.071	0.103	--
36	0.024	0.013	0.024	0.014	0.009	0.019	0.012	0.008	0.014	--
37	0.027	0.059	0.092	0.037	0.060	0.099	0.032	0.051	0.091	--
38	0.049	0.053	0.035	0.052	0.057	0.041	0.036	0.051	0.034	--
39	0.024	0.027	0.045	0.024	0.025	0.039	0.020	0.024	0.042	--
40	0.034	0.030	0.043	0.022	0.028	0.055	0.039	0.038	0.061	--
THD (%)	0.195	0.286	0.349	0.176	0.247	0.342	0.173	0.274	0.345	13.000
PWHD(%)	0.742	1.022	1.374	0.798	0.991	1.419	0.740	0.972	1.408	22.000

The diagrammatic representation is as shown below:

Current Harmonics



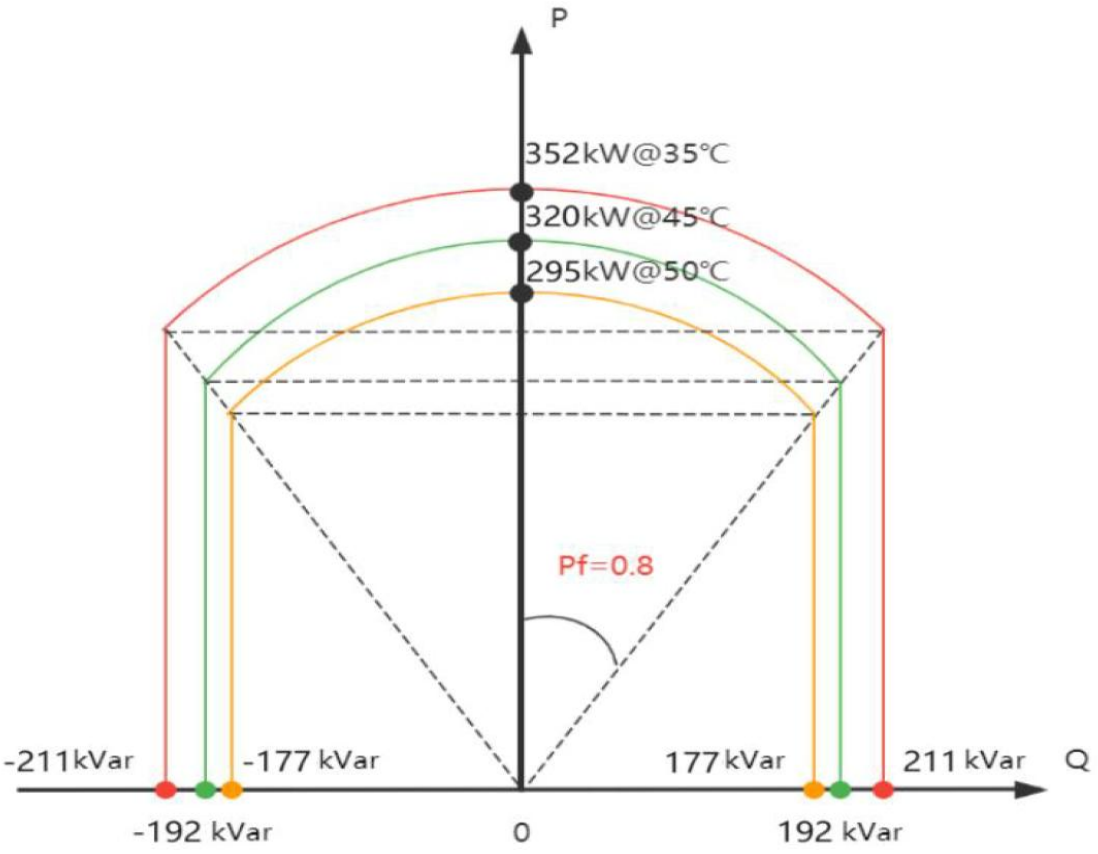
THD and PWHD



- ## PQ and Q at Night

Inverter supports the grid by providing reactive power in different ways.

Mode I: Reactive power regulation through fixed power factor.
The adjustable range of power factor PF is 0.8 to 1, -1 to -0.8. After the fixed power factor is set, the reactive power is calculated according to the current active power. The shaded part of the figure below shows the reactive power calculated from the fixed power factor and active power:



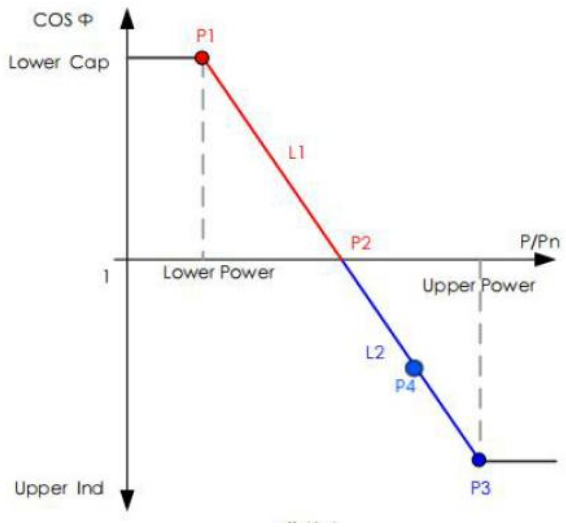
Mode II: Reactive power regulation through fixed reactive power percentage.

The adjustable range of reactive power percentage is -60% to 60%. In this mode, set a fixed reactive power percentage, and the system will calculate the power factor angle according to the set reactive power percentage, and then calculate the corresponding reactive power according to the current active power.

For example, the rated active power of REFUsol 350K-8T is 352KW. If the reactive power percentage is set to 40%, the reactive power output is 352 * 40%= 140.8kvar.

Mode III: Reactive power of inverter will follow the change of active power.

By setting the four-level active power load reduction point, the reactive power is calculated according to the power factor corresponding to the set active power. When the active power changes, the corresponding reactive power also changes. The corresponding relationship between active power and power factor is shown in the figure:

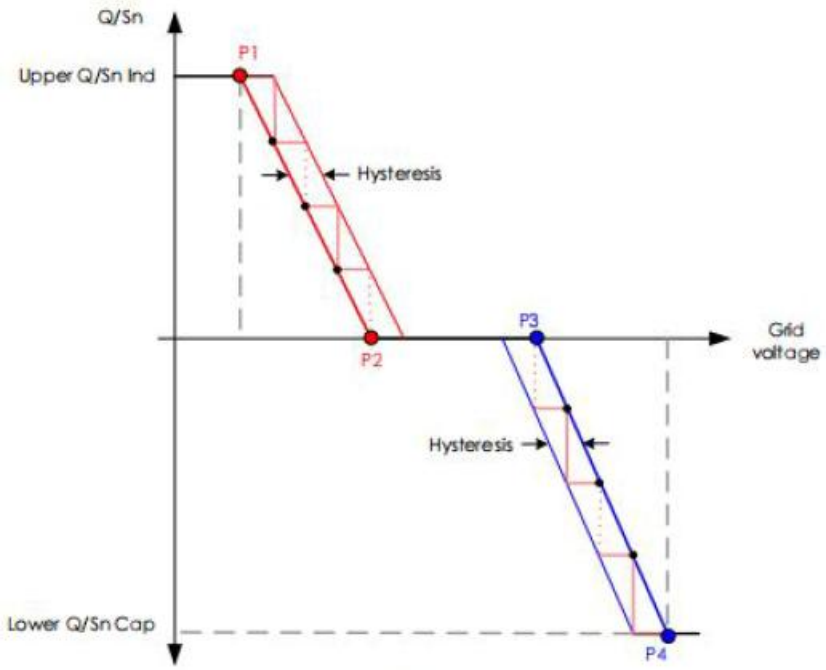


Parameter	Explain	Range
P_P1	Cos φ (P) Output active power at point p1 on the mode curve	Optional
P_P2	Cos φ (P) Output active power at point P2 on the mode curve	Optional
P_P3	Cos φ (P) Output active power at point P3 on the mode curve	Optional
P_P4	Cos φ (P) Output active power at point P4 on the mode curve	Optional
Cosφ_P1	Cos φ (P) Power factor angle at point p1 on the mode curve	0.8~1
Cosφ_P2	Cos φ (P) Power factor angle at point p2 on the mode curve	0.8~1
Cosφ_P3	Cos φ (P) Power factor angle at point p3 on the mode curve	-1~-0.8
Cosφ_P4	Cos φ (P) Power factor angle at point p4 on the mode curve	-1~-0.8
Sgn(Cosφ)_P1	Cos φ (P)Symbol of the power factor angle at point p1 on the mode curve	leading
Sgn(Cosφ)_P2	Cos φ (P)Symbol of the power factor angle at point p2 on the mode curve	leading
Sgn(Cosφ)_P3	Cos φ (P)Symbol of the power factor angle at point p3 on the mode curve	lagging
Sgn(Cosφ)_P4	Cos φ (P)Symbol of the power factor angle at point p4 on the mode curve	lagging

Note: this mode has a voltage entry enable bit. If it is enabled, it is necessary to set the lockinv voltage percentage and lockoutv voltage percentage. When the grid voltage percentage is greater than the lockinv voltage percentage, this mode is normally enabled; When the grid voltage percentage is less than the lockoutv voltage percentage, the reactive power is 0.

Mode IV: Reactive power of inverter continuously changes with the change in grid voltage.

The reactive power is adjusted by setting the high-voltage starting point, high-voltage ending point, low-voltage starting point and low-voltage ending point of the grid voltage, in which the grid voltage changes continuously. The following figure shows the relationship between reactive power and grid voltage:



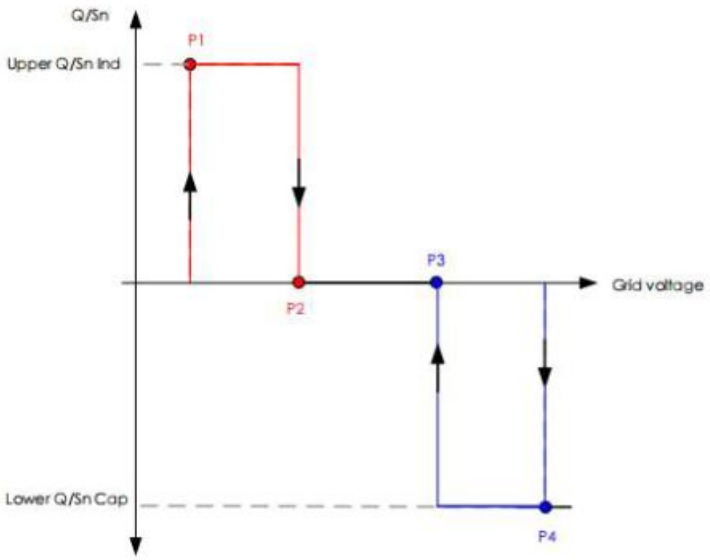
Parameter	Explain	Range
P1	P1 on the Q (U) mode curve is the starting voltage point of low voltage	Optional
P2	P2 on the Q (U) mode curve is the starting voltage point of low voltage	Optional
P3	P3 on the Q (U) mode curve is the starting voltage point of low voltage	Optional
P4	P4 on the Q (U) mode curve is the starting voltage point of low voltage	Optional

Note: this mode has a voltage entry enable bit. If it is enabled, it is necessary to set the lockinv voltage percentage and lockoutv voltage percentage. When the grid voltage percentage is greater than the lockinv voltage percentage, this mode is normally enabled; When the grid voltage percentage is less than the lockoutv voltage percentage, the reactive power is 0. (response waiting time during detection can be set)

Among them, the reactive power at point P1 is the maximum lagging reactive power, the reactive power at point P2 is the reactive power at the low voltage starting voltage point, the reactive power at point P3 is the reactive power at the high voltage starting voltage point, and the reactive power at point P4 is the maximum leading reactive power.

Mode V: Reactive power of inverter continuously changes with the change in grid voltage.

The reactive power is adjusted by setting the high-voltage starting point, high-voltage ending point, low-voltage starting point and low-voltage ending point of the grid voltage, in which the grid voltage changes step by step. The following figure shows the relationship between reactive power and grid voltage:



Parameter	Explain	Range
P1	P1 on the Q (U) mode curve is the starting voltage point of low voltage	Optional
P2	P2 on the Q (U) mode curve is the starting voltage point of low voltage	Optional
P3	P3 on the Q (U) mode curve is the starting voltage point of low voltage	Optional
P4	P4 on the Q (U) mode curve is the starting voltage point of low voltage	Optional

Note: this mode has a voltage entry enable bit. If it is enabled, it is necessary to set the lockinV voltage percentage and lockoutV voltage percentage. When the grid voltage percentage is greater than the lockinV voltage percentage, this mode is normally enabled; When the grid voltage percentage is less than the lockoutV voltage percentage, the reactive power is 0. (response waiting time during detection can be set).

Among them, the reactive power corresponding to P1 and P4 points is the maximum reactive power point. (both can be set by self selection).

Mode VI: The inverter calculates the current output reactive power through constant apparent power.
That is, when the active power does not reach the rated value, the reactive power is calculated according to the rated apparent power, and the calculation formula is; When the active power reaches the rated value, the reactive power is 0.

Note: phase type can be set: 1 Zero reactive power: reactive power is 0; 2. lagging reactive power: reactive power is negative; 3. leading reactive power: the reactive power is positive.

• Output current calculations

Definition: The basic parameters used and defined in this section of output current calculations are as below:

- U - rated output voltage (RMS of line voltage)
- I - rated output current (RMS of phase current)
- I_p - peak out current when short circuit occurs
- I_k'' - RMS of the initial symmetrical short circuit current value
- I_k - RMS of the short – circuit steady state current
- S - rated apparent power, at 1.1 ~ 1.14 times the rated power
- P - rated active power
- Q - rated reactive power
- $\emptyset$ - power factor angle

Calculation of output power:

- **Apparent power**

*Rated Apparent Power(VA) = √3 * Rated Output Voltage(V)* Rated Output Current (A)*

$$S = \sqrt{3} \times U \times I \qquad \text{----------[1]}$$

- **Active power**

*Rated Active Power(W) =√3 * Rated Output Voltage(V)* Rated Output Current(A)*sin Ø*

$$P = \sqrt{3} \times U \times I \times \cos \emptyset \qquad \text{----------[2]}$$

- **Reactive power**

*Rated Reactive Power(W) =√3 * Rated Output Voltage(V)* Rated Output Current(A)*sin Ø*

$$Q = \sqrt{3} \times U \times I \times \sin \emptyset \qquad \text{----------[3]}$$

Calculation of output currents:

- ### Rated output current

Referring equation [1], rated output current is calculated as:

$$Rated\ Output\ Current\left(A\right)=\frac{Apparent\ Power\left(VA\right)}{\sqrt{3}*Output\ Voltage\left(V\right)}$$

$$I=\frac{S}{\sqrt{3}\times U} \qquad \text{----------[4]}$$

- ### Short circuit current and protection

Overcurrent may occur when grid failures happen during normal operation. The short circuit current includes 3 kinds of protections:

- **Overcurrent protection** is set as 1.7 times of the peak value of the rated current when short circuit occurs.

$$I_p = 1.7 \times \sqrt{2} \times I \qquad \text{----------[5]}$$

- RMS of the **initial symmetrical short – circuit** current value is set as 1.1 – 1.2 times of the rated current which will not last longer than 50ms.

$$I_k'' = 1.1 \sim 1.2 \times I \qquad \text{----------[6]}$$

- RMS of the **short – circuit steady – state** current is set as 1 – 1.13 times of the rated current and will be maintained during entire duration of the voltage drop.

$$I_k = 1 \sim 1.13 \times I \qquad \text{----------[7]}$$

○ Current calculation for REFUsol 350K-8T

Pre-conditions: 352kVA is 1.1 times the rated apparent power, S=320000VA, RMS of output voltage U=800V.

$$I = \frac{S}{\sqrt{3} \times U} = \frac{320000}{\sqrt{3} \times 800} = 230.9A$$

The grid short – circuit overcurrent protection is calculated as:

$$I_p = 1.7 \times \sqrt{2} \times I = 555.2A$$ ---------*lasts for* **55.5 µs**

The initial symmetrical short – circuit current is calculated as:

$$I_k'' = 1.2I = 277.1A$$ ---------*lasts for* **<50 ms**

The steady – state short circuit current is calculated as:

$$I_k = 1.1I = 254.1A$$ ----------(*)

(*) *The duration for steady state short circuit is lesser of undervoltage hold time and the voltage drop time.*

• DC protection functions

The REFUsol 250–350k series inverters are engineered with advanced and comprehensive DC-side protection systems to ensure safe, reliable, and standards-compliant operation of photovoltaic power plants. The key DC protection features are outlined below:

○ Integrated DC protection

The REFUsol 250–350k inverter series integrates internal DC protection devices designed and certified in accordance with IEC 60947-2, ensuring reliable, standardized, and compliant protection for the DC circuitry.

○ String current monitoring

Each PV string input is individually supervised to ensure accurate current monitoring:

- **Strings 1, 2, and 3 are equipped with dedicated current sensors** that provide precise, real-time current measurements.
- **String 4 current is calculated algorithmically** by subtracting the measured currents of Strings 1–3 from the total MPPT input current.
- **Maximum measurable current per string:** 39.9 A
- **Maximum measurable current per MPPT:** 60 A

○ Over-current protection mechanism

When an over-current condition is detected on a PV string, the inverter implements a two-stage protection mechanism:

- **Active Current Regulation:** The inverter first adjusts the MPPT operating point to reduce the affected string's input current to within a safe threshold.
- **Protective Disconnection:** If the over-current condition cannot be resolved through regulation, the inverter automatically opens the associated DC electronic switch. As a result, any additional strings connected to the same switch will also be disconnected.
- **Typical disconnection response time:** 60 ms

○ Ground fault protection

In the event of a ground fault (PV– to ground) occurring within any PV string:

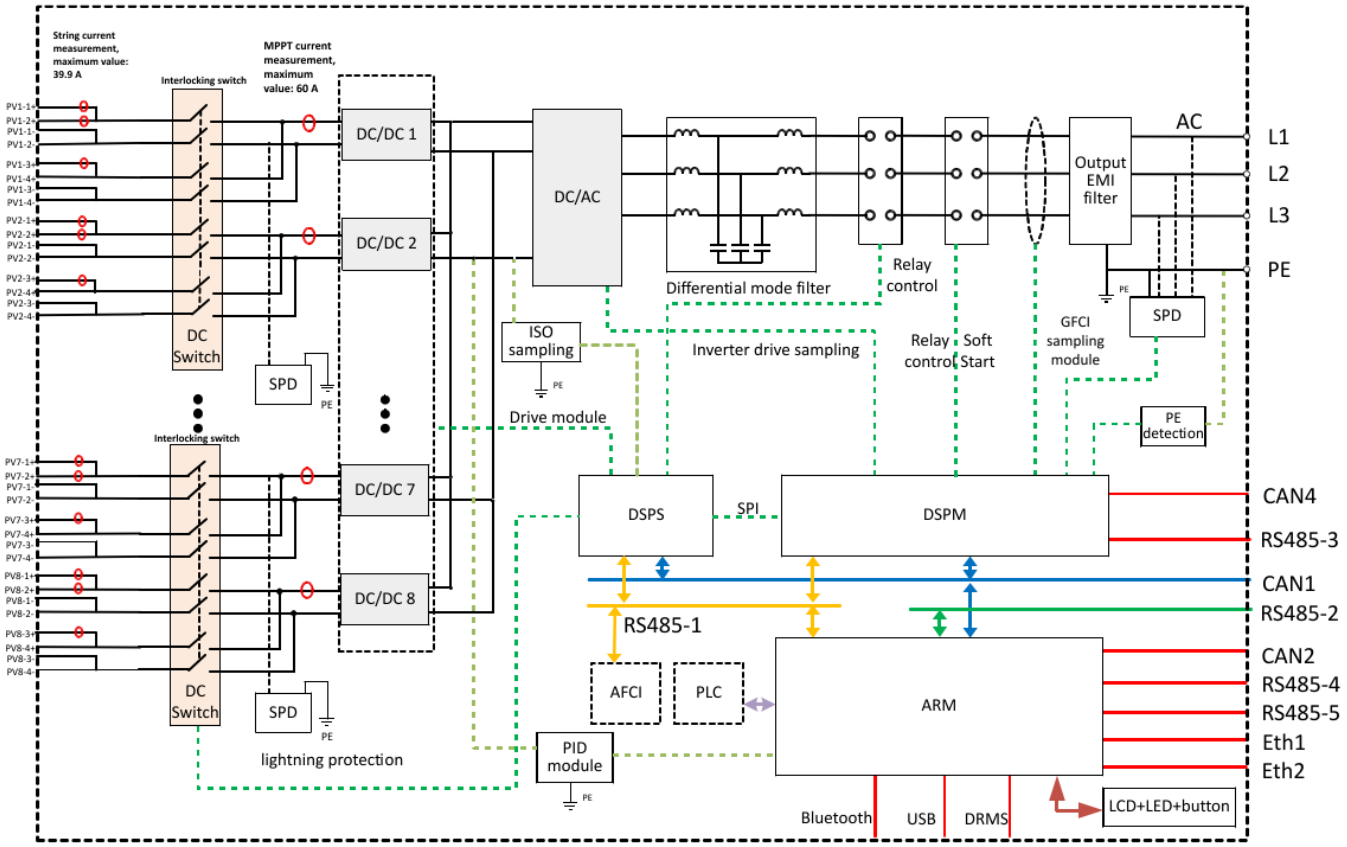
- **Automatic Disconnection:** If a PV–-to-ground short-circuit fault is detected on any input string, the interconnected PV– conductors cause all DC-side switches to disconnect automatically.
- **Fault Notification:** The inverter immediately issues a diagnostic ground-fault alarm.

○ Reverse polarity protection

- **Automatic Disconnection:** If a PV string is connected with reversed polarity, the inverter disconnects the corresponding DC switch, resulting in the disconnection of all strings associated with that switch.
- **Fault Notification:** A diagnostic reverse-polarity fault message is generated immediately.

○ Functional single-line diagram

The following schematic illustrates the DC-side protection architecture and its integration within the inverter system:



• Operational noise level

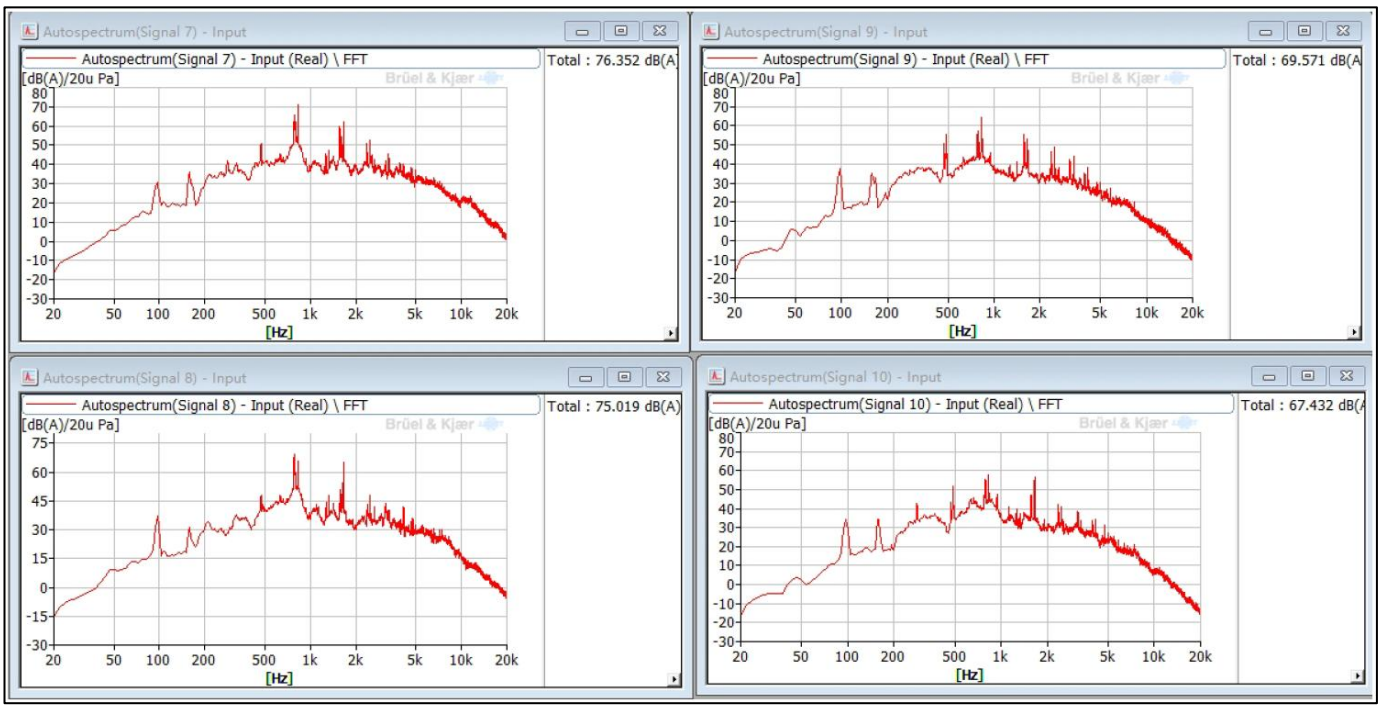
In accordance with **EN / IEC 62109-1**, photovoltaic inverters are required to emit **A-weighted sound pressure levels not exceeding 80 dBA** during normal operation. To verify compliance with this requirement, **acoustic noise testing is conducted** in accordance with the test standard **ISO 7779:2018**.

The **REFUsol 350K-8T inverter family** was subjected to such testing with the objective of measuring the **A-weighted sound pressure level** generated during normal operating conditions across all defined measurement positions. Measurements were performed using **high-sensitivity free-field microphones** in a **controlled acoustic environment**. Sound pressure levels were recorded at multiple positions around the inverter to represent the location of operating personnel.

The test results demonstrate that, **under all test conditions**, the measured **A-weighted sound pressure levels remained below 80 dBA**, thereby confirming **full compliance with the requirements of EN / IEC 62109-1**.

Sample Model	Front (dB)	Rear (dB)	Left (dB)	Right (dB)	Average SPL (dB) (Average of individual measurements)	Overall Average SPL (dB) (Average of three measurements)
REFUsol 350K-8T	76.4	75	69.8	67.5	73.5	73.5
REFUsol 350K-8T	76.4	74.7	69.5	67.4	73.4	
REFUsol 350K-8T	76.4	75	69.6	67.4	73.5	

The graph presented below illustrate the sound pressure levels recorded during the test, validating the inverter's low-noise operational performance.



Disclaimer

This document describes the technical operation and performance of the of REFUsol 350K-8T PV inverter family.

There are many uncertainties in practical applications which may lead to differences between actual use and test data. Therefore, this document information is provided for reference purpose, REFU Elektronik GmbH may change the information at any time without notice.

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