

# Model Specifications of Voltage Regulation and Harmonics management

Noida Smart Distribution Project

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# 1. Introduction and General information

## 1.1 Introduction

As we are moving towards integration of clean technologies (Solar and Wind) and distributed energy resources (Solar Rooftops, EVs, Batteries, Prosumers) the power systems are increasingly facing several challenges. A key challenge with renewable energy technologies is their intermittent and variable power output. These sources can disrupt voltage profiles and cause phase imbalances. In addition, bidirectional power flows put pressure on existing voltage control systems and cause overvoltage due to the unpredictable power output from these sources. This demands more advanced voltage control systems to ensure that the voltage remains within the desired limits, a critical objective for electric utilities. Some of the interventions/ options for voltage regulations are as follows:

1. **Installation of Power Quality meters:** PQMs are ideal for continuous monitoring of a three-phase system, providing metering for current, voltage, real and reactive power, energy use, harmonics, power factor, and frequency. The installation and strategic placement of power quality meters emerge as critical endeavors. To guarantee the efficacy of these meters in monitoring and analyzing the electrical environment, a comprehensive survey is imperative. This survey, facilitated by handheld equipment, serves as the linchpin for identifying optimal locations. By meticulously assessing electrical parameters, potential disturbances, and load variations, this approach ensures the precise deployment of power quality meters, fortifying the resilience and reliability of the power system. The judicious use of handheld equipment in this survey underscores the commitment to accurate data acquisition, thereby empowering organizations to proactively address and mitigate power quality issues.
2. **On-Load Tap Changer for Voltage Control:** This involves adjusting the amplitude of the in-phase voltage. The On-Load Tap Changer (OLTC) offers a wide voltage regulation range and operates without power interruption during the regulation process, playing a vital role in enhancing power quality and ensuring the economic operation of the power system. By running DMS, utilities can dynamically manage and optimize OLTC settings, ensuring efficient voltage control, minimizing losses, and enhancing overall grid stability. This coordination allows for real-time adjustments based on system conditions, contributing to the reliability and performance of the power distribution network.
3. **Smart Inverters (Voltage-Reactive Power (Volt-Var) Mode):** Solar smart inverters play a crucial role in enhancing voltage regulation and reactive power management within solar power systems. Equipped with advanced control capabilities, these inverters actively monitor grid voltage variations, adjusting their output to maintain stability and prevent voltage fluctuations. Additionally, smart inverters contribute to efficient grid operation by managing reactive power, optimizing the power factor, and providing or absorbing reactive power as needed. Their ability to seamlessly integrate with the grid, communicate in real-time, and respond to dynamic grid conditions makes them instrumental in ensuring the reliability and optimal performance of solar energy systems within the broader electrical infrastructure.

In-addition, distortions in the electricity grid's waveform, known as Harmonics, are typically caused by non-linear loads such as industrial devices, LEDs, air conditioners, electric vehicles etc. These distortions result in problems including network overloads, equipment overheating, reduced power efficiency, and voltage instability. They can also interfere with communication systems and affect the performance of electrical devices. Thus, controlling these harmonic levels is essential for maintaining

the integrity of equipment and ensuring the quality of the power supply. Harmonics management addresses distortions in electrical systems as follows:

- Harmonics measurement up to DT LT bush: To measure harmonics at a Distribution Transformer's (DT) Low-Tension (LT) bushing, a Total Harmonic Distortion (THD) meter/ power analyzer is employed for monitoring voltage and current waveforms safely. This approach enables data collection and analysis to identify levels and source of individual harmonics and Total Harmonic Distortion, crucial for maintaining power quality and equipment efficiency.
- Harmonics and Reactive power correction system (harmonic filter): Improves power quality by reducing harmonic distortion with harmonic filters and correcting reactive power imbalance using capacitors or inductors. This dual approach enhances efficiency, stabilizes voltage, and extends equipment lifespan, especially in heavy-load electrical environments.
- Installation of Automatic Power Factor Correction (APFC) unit at Sub-stations: Installing APFC panels at substations for harmonics management leads to improved power quality and energy efficiency, reduction of harmonic distortion, and lower reactive power consumption.

These improvements result in a prolonged equipment lifespan, enhanced voltage stability, and decreased operational costs.

## **1.2 Objectives**

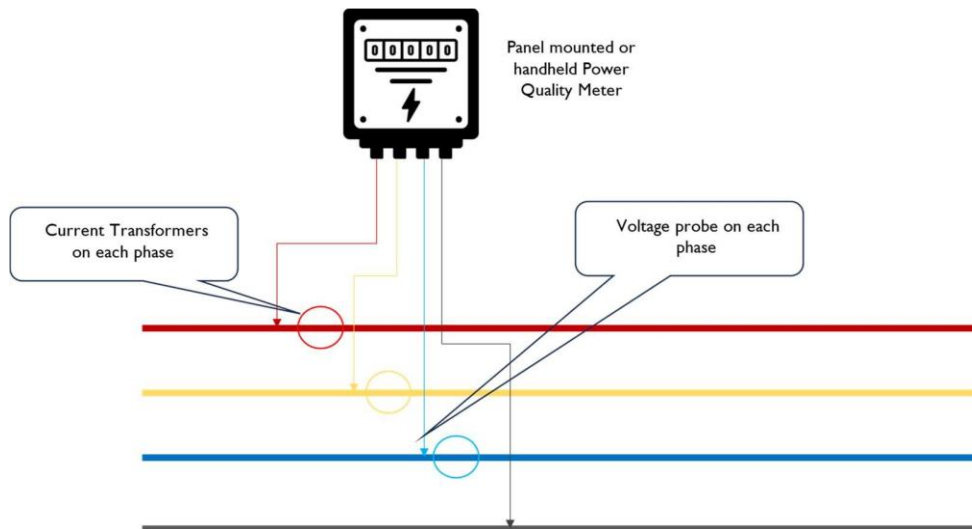
PVVNL grapples with pronounced harmonic challenges, as a consequence of the escalating deployment of power electronics, electric vehicles (EVs), and solar rooftop systems within its distribution network. This surge in electronic devices has exacerbated harmonic distortions, necessitating a robust response. The increasing complexity of voltage regulation and management poses a substantial challenge, even with the utilization of capacitor banks and on-load tap changers (OLTC) that, presently, prove insufficient to address the issue adequately. In light of this, PVVNL is undertaking a comprehensive assessment to quantify harmonic orders and strategically recommend the installation of filters. The objective is to enhance the effectiveness of voltage regulation and mitigate the adverse effects of harmonics on the power distribution infrastructure. Notably, PVVNL is considering the deployment of 30 filters, underscoring the scale of its commitment to systematically address these technical challenges.

In view of this, PVVNL aims to install smart devices on pilot basis, for voltage and harmonic correction and measurement, namely Power Quality Meters, Harmonic Filters and Smart Inverters for solar rooftop systems on government buildings. Installation of smart inverters for solar rooftop systems will be done in close coordination with UPNEDA.

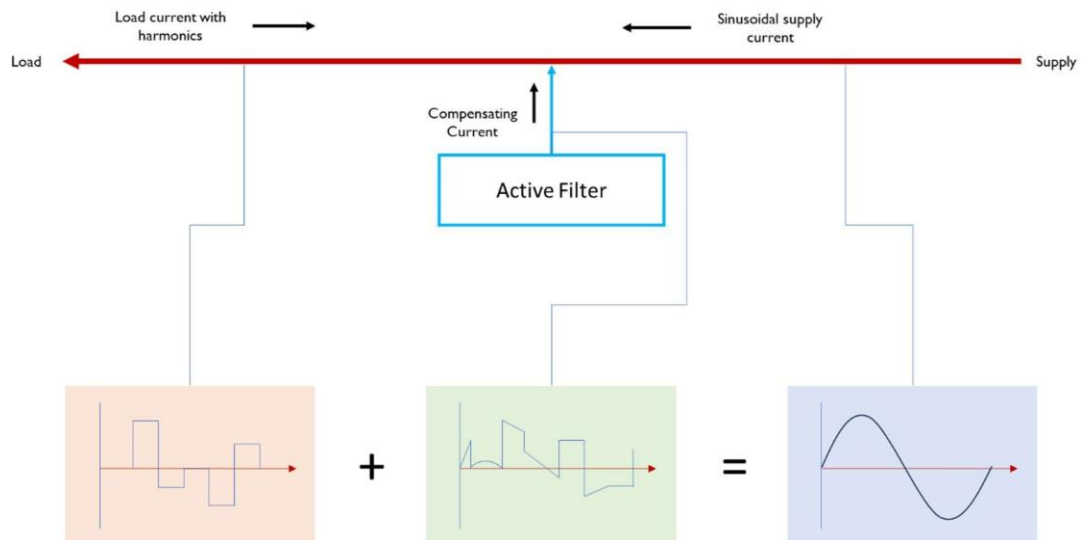
The following benefits are envisaged for PVVNL:

- Reduced number of equipment failure (network assets and Behind the Meter)
- Reduced number of consumer complaints
- Improved power quality
- Reduced instances of under / over voltage

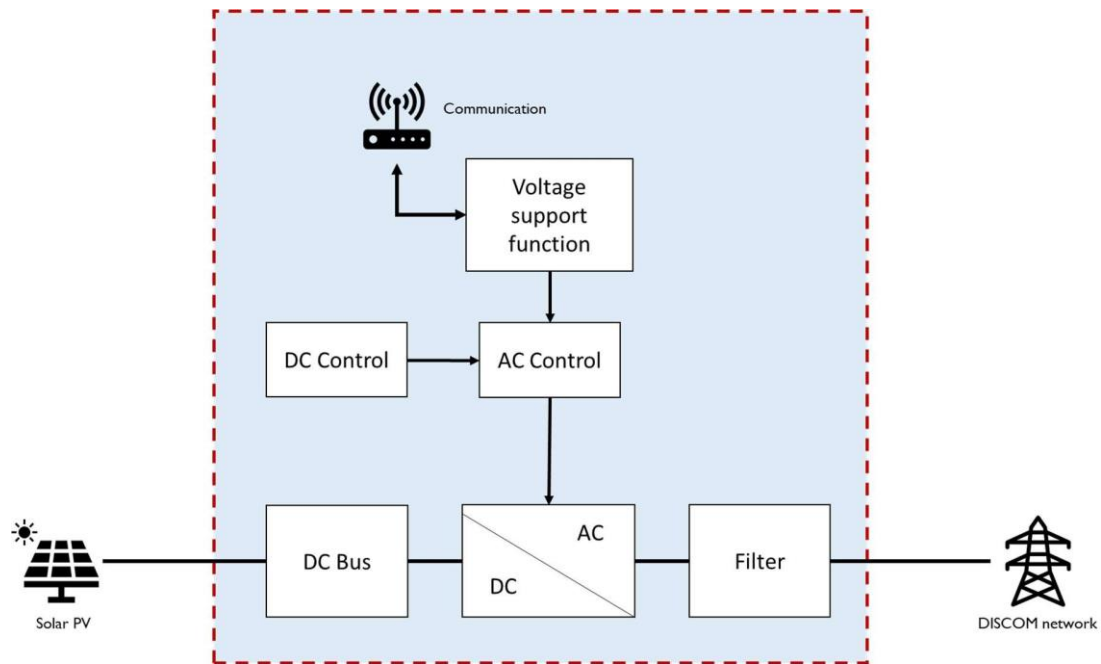
### 1.3 Schematic diagram of power quality meter



### 1.4 Block diagram of Active Harmonic Filter



### 1.5 Block diagram of Smart inverter



## 2. Scope of work

### 2.1 Unpriced BoQ

The bidder is required to provide an unpriced Bill of Quantity (BoQ) for supply of the following:

- a) Power Quality Meters (shall include option of panel mounted as well as mobile kit)
- b) Active harmonic filter
- c) Smart inverter

This unpriced BoQ must state all the line items influencing the supply of the items as defined in this scope of work.

### 2.2 Selection of voltage regulation and harmonic filter equipment

The selected bidder shall assist PVVNL in selection of the voltage regulation and harmonic filter equipment as per the suggested specifications in this document.

The following sections provide the suggested specifications for each equipment.

## 3. Specifications of Power Quality meters

This specification covers the design, engineering, supply and installation of Three Phase Power Quality Analyzer of class A certified for AC balanced / unbalanced loads of HT Consumers. The analyzer should be suitable for connection to 3 phase 4 wire system. Power Quality Analyzer shall monitor, record and analyze harmonics generated in the PVVNL network. The Harmonics and other electrical parameters should be made available at the utility server for further analysis in real time & analysis of harmonics should be as per IEEE 519 standard.

Power Quality Analyzer shall conform in all respects to high standards of engineering, design and workmanship and shall be capable of performing in continuous commercial operation, in a manner

acceptable to purchaser, who will interpret the meaning of drawings and specification and shall have the power to reject any work or material which, in his judgment is not in accordance therewith. The offered material shall be complete with all components necessary for their effective and troublefree operation.

### 3.1 Service Conditions

The Power Quality Analyzer must perform satisfactorily under non-air-conditioned environment. Analyzer to be supplied against this specification shall be suitable for satisfactory continuous operation under the following tropical conditions.

Environmental conditions of the place of use (Noida) are given below:

Sl. No.	Parameter	Value
1	Maximum ambient temperature	55°C
2	Maximum ambient temperature in shade	50°C
3	Minimum temperature of air in shade	5°C
4	Maximum daily average temperature	40°C
5	Maximum yearly weighted average temperature	32°C
6	Relative Humidity	10 to 95 %
7	Maximum Annual rainfall	1450 mm
8	Maximum wind pressure	150 Kg/m <sup>2</sup>
9	Maximum altitude above mean sea level	1000 mtrs
10	Isoceraunic level	50 days/ year
11	Seismic level (Horizontal acceleration)	0.3 g
12	Climate is Moderately hot and humid tropical climate conducive to rust and fungus growth	

### 3.2 Applicable standards

The Power Quality Analyzer shall conform in all respects including performance and testing thereof to the latest relevant and applicable Indian / International Standards to be read with up to date and latest amendments / revisions thereof:

Standard	Applicability
IEC 61000-4-1	Electromagnetic compatibility (EMC)-Part-4-1:Testing and measurement techniques-Overview of IEC 61000-4 series
IEC 61000-4-7	Electromagnetic compatibility (EMC)-Part-4-7:Testing and measurement techniques-General guide on harmonics and inter-harmonics and instrumentation
IEC 61000-4-30	Electromagnetic compatibility (EMC)-Part-4-30:Testing and measurement techniques-Power quality measurements methods
IEC 61010-1	Safety Requirement
En 50160	Voltage Characteristics in Public distribution system

Furthermore, the power quality meter's surge withstand shall conform to IEEE C37.90.1 and ANSI C62.41 (6 kV)

### 3.3 General technical requirements

Sl. No.	Parameter	Value
1	Type of installation	Indoor/Outdoor
2	Type	Power quality analyzer for 3-phase, 4 wire balanced / unbalanced loads
3	Frequency	50 Hz $\pm$ 5%
4	Accuracy Class	Class A Certified
5	Rated Voltage	0-600 V AC L-N

### 3.4 Design and Construction

1. The Analyzer shall accurately measure voltage (V), current (A), power factor, active energy (kWh), apparent energy (kVAh), reactive energy (kVAh lag and kVAh lead separately) along with voltage and current harmonics in the system.
2. The analyzer shall use 10A Clamp / Split-Core CT and the combined accuracy of all electrical measurements shall be of accuracy class 0.5.
3. It shall be user programmable for voltage range to any CT or PT ratio.
4. The power quality meter shall compensate for errors in current transformers and potential transformers. Errors shall include voltage, multipoint current, multiphase angle, and better than .01% resolution.
5. The unit shall utilize five different current compensation points per phase, wherein the points shall be concentrated at the lower end of the dynamic range
6. The power quality meter shall have a voltage burden of not more than 0.072 VA per phase Max at 600 volts, and 0.003 VA per phase Max at 120 volts.
7. It shall have a current inputs burden of not more than 0.008 VA per phase max at 20 A.
8. The power quality meter shall accept a voltage input range of (5 to 347) VAC Line to Neutral, and a range of (10 to 600) VAC Line to Line.
9. It shall accept a current reading of up to 20 A continuous. Start-up current for a 5 A input shall be no greater than 0.005 A.
10. The power quality meter shall have a frequency range of (45 to 69.9) Hz
11. The analyzer body shall be type tested for IP51 degree of protection as per IS: 12063 against ingress of dust, moisture & vermin. The type test certificate shall be submitted along with the offer
12. The analyzer shall measure True RMS phase to phase as well as phase to neutral voltage with minimum and maximum values.
13. The analyzer shall measure True RMS phase to phase as well as phase to neutral current with minimum and maximum values and phase displacement.
14. The analyzer shall indicate angle displacement between voltage and current as well as three phase voltage sequence.
15. The analyzer shall measure active, reactive and apparent power per each phase and also total values for three phases.
16. The analyzer shall measure voltage and current harmonics minimum up to 50<sup>th</sup> order for each phase expressed as a percentage of fundamental.



17. The analyzer shall display waveforms of the measurements of voltage, current, power factor and harmonics.
18. The analyzer shall have facility to compute flickers in accordance with IEC-61000-4-15.
19. The analyzer shall measure the following:

Sl. No.	Parameter
1	Apparent power (min/max, total)
2	Active power and reactive power (min/max, total)
3	Current (min/max, average)
4	Voltage (min/max, average)
5	Frequency (min/max, average)
6	Total current harmonic distortion THD (I) (per phase)
7	Total voltage harmonic distortion THD (V) (per phase)
8	Power factor (min/max, average)
9	Apparent energy (total)
10	Active power and reactive energy (total)
11	Harmonics (voltage, current, power, voltage-current phase difference) min. up to 50 <sup>th</sup> order
12	Inter harmonic (voltage/ current): 0.5th to 49.5th order
13	Inrush current
14	Dip, Swell, Interruption
15	Flicker measurement

20. The analyzer shall have minimum 5.0 inch color LCD TFT display.
21. The analyzer shall have RS-485 Modbus Slave, serial interface for data transfer server.
22. One set of three CTs of 0.5 accuracy class shall be supplied with each analyzer.

### 3.5 Display

1. The power quality meter shall include an integrated 5.7-inch touch screen TFT LCD color display with multiple display modes.
2. Display shall support 4 groups of screens: Real Time, Trending, Alarms, and Power Quality modes. Groups of screens shall include:
  - a. Real Time viewing of voltage, current, power, demand.
  - b. Accumulated Energy and Time of Use readings.
  - c. Flicker readings in Instantaneous, Short Term (PST), and Long Term (PLT).
  - d. Alarm conditions.
  - e. Phasor analysis.
  - f. Harmonic spectrum analysis and waveform scopes for both voltage and current.
  - g. Real Time trending.
  - h. Log status.
  - i. Configuration settings.
  - j. Time of Use.
  - k. Test Mode.

3. The Display shall be constructed of bright TFT glass with a high temperature and long-life LED backlight. CCFL backlight shall not be acceptable.
4. The meter shall have two LED accuracy test pulses on the meter front.
5. The display shall support screen rotation to enable vertical meter mounting.

### **3.6 Communication**

The Harmonic Analyzer shall have provision to transfer the data to a Web server of the PVVNL using GPRS communication mode. It should have RTC & on-chip data storage facility of minimum 4GB.

The power quality meter shall provide multiple digital communication ports and support multiple open protocols:

1. The meter shall include an ANSI Optical port that supports speeds of up to 57,600 bps, for communication to external devices.
2. The meter shall have one standard 10/100BaseT Ethernet port. With Software Option B or C upgrade packs, this Ethernet port shall offer IEC 61850 protocol in addition to Modbus TCP/IP and DNP 3.0. The IEC 61850 protocol Ethernet network server shall provide the following features:
  - a. Integrates into any IEC 61850 network
  - b. Provides support for Modbus TCP/IP, DNP 3.0 and IEC 61850 protocols simultaneously
  - c. Configurable for multiple logical nodes
  - d. Provides buffered and unbuffered reporting
  - e. Provides configurable .ICD and .CID files
  - f. Provides GOOSE messaging
  - g. Provides alarms and waveform capture in response to GOOSE messages
3. The meter shall have two optional RS485 ports through the Dual Pulse Output/RS485 card. The card shall have 4 user-programmable KYZ pulse outputs. Each RS485 port shall be user configurable with regard to speed, protocol, address, and other communications parameters.
4. All ports shall support a communication speed of up to 115200 baud simultaneously and be assignable for Modbus or DNP 3.0 communication.
5. The meter shall have a high-speed USB port mounted on the front panel.
6. The meter shall communicate simultaneously using Modbus RTU, Modbus ASCII, DNP 3.0, Modbus TCP/IP, DNP over Ethernet, and, with Software Option B or C upgrade packs, IEC 61850 protocols as standard configurations. All instantaneous data, logged data, event data, power quality analysis and waveform information shall be available using both Modbus TCP/IP and FTP file transfer format. The meter shall also provide means for custom Modbus mapping.

### **3.7 Software**

1. The analyzer shall have software for data collection, analysis, representation and verification.

2. The software shall be in house developed by the Bidder
3. The Licensed real time monitoring software will be hosted on PVVNL server
4. It should be capable to communicate with on field hardware at programmable logging interval of 1 min, 5 min, 15 min etc.
5. Software license will be handed over to PVVNL at the time of handover
6. Software should be capable of tracking, monitoring & analysis the various electrical parameters like voltage, current, KW, KVA, Power Factor, KVAR, KWH, KVAH, Voltage & current harmonics
7. Software shall have ability to store historical data.
8. Software database & server will be provided by PVVNL
9. It should generate the reports in compliance to IEEE 519 standard
10. It should generate the customized reports as per PVVNL requirement
11. It should have provision to generate SMS & automatic emailing facility

### **3.8 Markings**

The analyzer shall be marked legibly with the following information:

- a) Name or trademark of manufacturer
- b) Year and month of manufacture
- c) Country of origin
- d) Type / model and serial number

### **3.9 Calibration certificates**

The Power Quality Analyzer shall be supplied along with the valid calibration certificate as per relevant standards.

### **3.10 Packing**

The analyzer shall be suitably packed in corrugated boxes in order to avoid damage during transit or handling.

### **3.11 Quality Control**

The purchaser shall send a team of experienced engineers for assessing the capability of the firm for manufacturing of meters as per this specification. The team should be given all assistance and cooperation for inspection and testing at the bidder's works. 3 tender samples should be kept ready for assessing and testing. The tenderer has to give all facilities for carrying out the testing of these samples

### 3.12 Training

The successful bidder shall depute their representative to train PVVNL's Engineers at their works of familiarization of design, application, operation & maintenance of the instrument of purchaser as and when they will be called for at no extra cost.

### 3.13 Accessories

- a) Power cables
- b) Voltage cables
- c) Carrying case
- d) Standard warranty certificate and installation manual

### 3.14 Guarantee

The Instrument shall be guaranteed for a period of 2 years from the date of commissioning or two and half years from the date of receipt whichever is earlier. The instrument found defective within above guarantee period shall be replaced / repaired / rectified by the supplier free of cost, within one month of receipt of intimation. After the replacement / repairs / rectification, the accuracy shall not be

## 4. Specifications of Active harmonic filter

These specifications describe requirements for Industrial grade floor mountable AHF panel. The AHF will be connected to the PCC bus (415V) through ACB/ SFU, however, necessary isolation along with protection trip to be considered in the AHF panel side. The AHF Panel shall be suitable for installation and satisfactory operation in a substation with restricted natural air ventilation and in a tropical, humid and corrosive refinery atmosphere. All the equipment described in this specification is intended for continuous duty under the specified ambient conditions unless indicated otherwise. AHF shall have Digital Fast Fourier Transform with Hysteresis current control principle to perform in challenging industrial power conditions like transient, dips, spikes etc.

Vendor has to ensure the supplied active harmonic filter should mitigate harmonics from the 2<sup>nd</sup> to 50<sup>th</sup> order and limit harmonic distortion at the point of connection to the limit, as prescribe by IEEE 519 standard-2022 or latest version. Harmonic/ THD report of the PCC section attached as Annex 1 for reference.

### 4.1 Principle of operation

AHF should measure level of harmonics in supply line and eliminate it by generating the counter harmonics. It should employ a Digital signal processor which determines the harmonic current amplitude to be injected in the opposite phase angle of each harmonic order. The active filter shall not only provide harmonic mitigation, but also should have feature like power factor correction and load balancing. Harmonic correction, PF correction and Unbalance correction should be able to set with priority and filter should work to employ the priority as per the user settings.

### 4.2 General technical requirements

The Active harmonic filter shall conform to the following technical requirements:

Sl. No.	Parameter	Value
1	Active Harmonic Filter Current Rating	300 A
2	Input power source	415 VAC (-15 % & + 10 %), 3 Ph, 3-

Sl. No.	Parameter	Value
		Wire, 50 Hz (+/- 5 %)
3	IGBT	7th Generation IGBT or Latest technology. (PCB mounted IGBT based modular technology not acceptable).
4	Design ambient Temperature	45 Degree C
5	Temperature compensation facility Available	Required
6	Design Efficiency	> 97 % at rated current
7	Harmonic Attenuation Ratio	Better than 97 % at rated current
8	Harmonic Order Filtration Capability	up to 50th orders (non-Zero Sequence)
9	Heat Loss	< 3 %
10	Switching Frequency	15 kHz or more
11	Transient Response Time	Less than one power cycle
12	PF Improvement Capability	+0.6 lag to -0.6 lead with separate current limit
13	Load Balancing Capability	Available with separate current limit.
14	Overload Capacity	120% overload for 1 minutes
15	Potential Free Contacts	Min 3-Programmable relays, 1-NO, 1-NC (for fault)
16	Enclosure IP	IP 31
17	Type of cooling	Forced Air Cooling
18	Protective Functions	Short Circuit, Phase Loss, Over Current, DC Bus Over Voltage, DC Bus Under Voltage, Over Temperature, Ground Fault, External Fault, Processor/ DSP Fault/ error, CT Detection Fault
19	Reference Standards Compliance	IEEE 5192014, IEC 61000-3-2, IEC 61000-3-4
20	LCD/ TFT display	Graphical LCD/ TFT with Real Time Clock display shall have provision to display the following load side & supply side parameters: 1.Voltage 2. Current 3. Power factor 4.Temperature 5. Voltage and currentHarmonic spectrum 6. Active Power 7. Reactive Power 8. Apparent Power 9. Frequency etc.
21	Panel Color	RAL7035/ equivalent
22	Software	Monitoring software (if any) shall be provided by the bidder free of cost along with communication cable

Vendor has to supply required CT (1500/1 or as designed) of rectangular split core type, for mounting on PCC Incomer bus bar.

Vendor has to provide onsite supervision support for smooth installation, commissioning of the equipment (Installation activity is not in the scope of vendor) & Training on the supplied product.

## 5. Specifications of Smart inverters

### 5.1 Applicable standards

The Smart inverters (grid-interactive) shall conform in all respects including performance and testing thereof to the latest relevant and applicable Indian / International Standards to be read with up to date and latest amendments / revisions thereof:

Standard	Applicability
IS 16221 (Part-1), IS 16221 (Part-2) : 2015	Requirements for the design, construction, and testing of power converters used in photovoltaic systems.
IS 17980 : 2022 IEC 62891 : 2020	Maximum Power Point Tracking Efficiency of Grid Connected Photovoltaic Inverters
IS 12834 : 2013	Solar Photovoltaic Energy systems - Terms, definitions, and symbols

### 5.2 Technical features

Technical features of the inverter to be as follows:

Parameter	Value
Switching devices	IGBT / MOSFET
Control	Microprocessor / DSP
Nominal AC output voltage	415V, 3 Phase
Output Frequency	50 Hz
Grid Frequency Synchronization range	+ 3 Hz or more
Ambient Temperature	-20o C to 50o C
Humidity	95 % Non-condensing
Protection of Enclosure	IP-20(Minimum) for indoor. IP-65(Minimum) for outdoor.
Grid Frequency Tolerance range	+ 3 or more
No-load losses	Less than 1% of rated power
Inverter Efficiency(minimum)	>93% (In case of 10 kW or above with in-built galvanic isolation) >97% (In case of 10 KW or above without in-built galvanic isolation) > 90% (In case of less than 10 kW)
Total Harmonic Distortion	< 3%
Power Factor	> 0.9
Waveform	Sine wave
Ripple	DC voltage ripple content shall be not more than 1%.
Efficiency	> 95%
Losses	Maximum losses in sleep mode: 2W per 5 kW Maximum losses in stand-by mode: 10 W
Casing Protection Levels	Min. IP-21 for internal and IP 65 for outdoor units
Communication Interface	RS485 / RS 232

### 5.3 General requirements

1. The inverter shall be capable of complete automatic operation including wake-up, synchronization & shutdown.
2. Inverter shall have internal protection arrangement against any sustainable fault in feeder line and against the lightning on feeder.
3. It shall have anti islanding protection in conformity to IEEE 1547/UL 1741/ IEC 62116 or equivalent BIS standard.
4. The inverter shall be tested from the MNRE approved test centers/ NABL/ BIS/ IEC accredited testing- calibration laboratories. In case of imported power conditioning units, these shall be approved by international test houses.

## 5. Documentation requirements

The successful bidder shall be required to maintain and produce the following documents -

- Detailed specifications and schematics of the equipment
- User manuals / installation manuals
- Warranty / Guarantee cards
- Testing / calibration certificates
- Documentation and training materials for field technicians and maintenance personnel.
- Any other records / documents in consultation with nodal officer of PVVNL