BSES

BSES Rajdhani Power Limited

Technical Requirements for Grid Connected Rooftop Solar Photovoltaic Systems

Renewables

Prepared by		Reviewed by		Approved by		Rev	Date
Name	Sign	Name	Sign	Name	Sign		
Bhuvnesh Sharma		Naveen Nagpal		Kiran Kumar Alla		R0	15/09/2017

BSES Rajdhani Power Limited

Revision Record

Rev. No.	Revision Date	Item/ clause no:	Page No.	Nature of Change	Approved by

Contents

List of Tables

1. INTRODUCTION

The purpose of this document is to specify the minimum Technical Requirements for customers connecting the Rooftop Solar PV System (RTSPV) to BRPL's distribution network via grid-tied inverters. This includes all customer RTSPV systems, regardless of whether such systems export electricity into the distribution network or not.

1.1. Context

BRPL presently allows connection to customer generating renewable system electricity to its electricity grid under Net-Metering arrangement as per DERC Net-Metering for renewable energy Regulations, 2014.

1.2. Definitions

Term	Definition
Applicant [1]	a generating company or a person seeking connectivity to the electricity system at voltage level below 33 kV for its distributed generation resource
Connected load or Contract demand or Sanctioned load [2]	meaning as defined in clause (n), (o) and (zn) of Regulation 2 respectively under Delhi Electricity Supply Code and Performance Standards Regulations 2007
Connection agreement [2]	the agreement entered into for connecting Renewable Energy Source to the Distribution system
Distributed Generation Resource[1]	a generating station feeding electricity into the electricity system at voltage level of below 33 kV
Frequency [1]	number of alternating cycles per second expressed in Hertz
Interconnection Point [1]	a point on the electricity system, including a sub-station or a switchyard, where the interconnection is established between the facility of the applicant and the electricity system and where electricity injected into or drawn from the electricity system can be measured unambiguously for the applicant
Inverter [1]	a device that changes direct current power into alternating current power
kWp [2]	kilo watt peak
LHFRT	Low/High Frequency Ride-Through feature ensures that the inverter may remain connected to assist the grid by supplying active power during the transient period, especially on the lower frequency side.
LHVRT	Low/High Voltage Ride-Through function ensures that the inverter does not automatically disconnect for certain temporary faults in the grid, as it may benefit the grid in recovery following the fault. LHVRT does not require the inverter to stay connected if the fault persists beyond a specified

[1] CEA "Technical Standards for Connectivity of the Distributed Generation Resources" Standards 2013
[2] Delhi Electricity Regulatory Commission (Net Metering for Renewable Energy) Regulations, 2014

Term	Definition
	time.
Net meter [2]	an appropriate energy meter capable of recording both import & export of electricity or a pair of meters one each for recording the net import and net export of electricity as the case may be
Protection System [1]	the equipment by which abnormal conditions in the electricity system are detected and fault clearance, actuating signals or indications are initiated without the intervention by the operator
Renewable energy meter [2]	a unidirectional energy meter, installed and used solely to record the renewable energy generation from the Renewable Energy System installed at the consumer's premises
RTSPV	Rooftop Solar Photo Voltaic System
SPD	Surge Protection Device
TDD [3]	Total Demand Distortion
THD [3]	Total Harmonic Distortion
Unintended Island [1]	a part of the electricity system which remains energised by one or more distributed generation resource, when such part of the system has been isolated from the remaining part of the electricity system
User [1]	a generating company whose distributed generation resource is connected to the electricity system

Table 1: Definitions

1.3. Scope

1.3.1. Applicability

This document is applicable to all RTSPV systems connected directly or indirectly to distribution network in BRPL licence area.

1.3.2. Customer Responsibilities

The applicant shall be responsible for the following activities pre and post-installation of RTSPV system in compliance with these technical requirements as well as all other applicable Standards and Regulations

- Planning and design of RTSPV system
- Procurement
- Obtaining permission for Grid connectivity from BRPL under DERC (Net Metering for Renewable Energy) Regulations, 2014
- Installation and Construction
- Operation and Maintenance
- Protection and safety
- Providing solar generation data as and when demanded by BRPL

[3] IEEE 519

1.3.3. Voltage Level for Grid Connectivity

The voltage level for grid connectivity is decided based on the RTSPV system installation size, existing supply voltage at consumer premise, Delhi Supply Code, Delhi Electricity Regulatory Commission (Supply Code and Performance Standards) Regulations, 2017 etc. Based on various system sizes, the voltage levels for grid connectivity are tabulated below:

RTSPV System Size	Voltage level for Grid Connectivity
Upto 10kWp	230V – Single Phase or 400V – Three Phase; depending upon existing supply voltage
Above 10kWp and upto 100kWp	400V – Three Phase
Above 100kWp	11kV or above – Three Phase; depending upon existing supply voltageor Dedicated feeder at suitable voltage level (11kV/33kV/66kV) based on technical feasibility

Table 2: Voltage level for Grid connectivity

1.3.4. System Size Limitations

i. The capacity of RTSPV system to be installed at the Premises of any consumer shall not be less than one kilo watt peak.

ii. The maximum capacity of RTSPV System to be installed at any premises shall be subject to

   a) the feasibility of interconnection with the grid;
   b) the available capacity of the service line connection of the consumers of the premises;
   c) the sanctioned load of the Consumer of the premises;

Subject to 1.3.4 ii. b) and c) above, if a consumer intends to install a RTSPV System of capacity higher than its sanctioned load, and requires to connect it with the BRPL distribution network, then such Consumer of premises shall pay Service Line cum Development (SLD) charges at the time of registration of RTSPV System, equal to the differential amount of SLD charges between the capacity of the RTSPV System and the existing sanctioned load on the lines of enhancement of sanctioned load, as prescribed in the DERC Supply Code & Performance Standards, Regulations 2007 as amended from time to time and relevant orders issued thereof by Hon'ble DERC from time to time.

1.4. Models for grid connected rooftop solar power plants (RTSPV System)

1.4.1. Sales Model (CAPEX)

Under a CAPEX model, the consumer either buys the complete plant and get it installed by an Engineering, Procurement and Construction company (EPC), or buys individual

components (such as modules, inverters, cables, etc.) and provides all to an installer for installation. The consumer pays 100% of the PV system cost upfront.

1.4.2. Renewable Energy Service Company Model (RESCO)

Under a RESCO model, a third party investor comes in to invest into a PV plant on a rooftop and sells solar power to a power consumer. There is no upfront investment required from the consumer. Under this model, the investor and the consumer agree on a tariff (per kWh of solar power) and timeline of a power purchase agreement (typically between 15-25 years). Operations and maintenance of the system is carried out by the RESCO Company instead of the consumer.

In either case, it is to be noted that the Connection Agreement shall be signed with the registered consumer and not with the installer or RESCO Company.

2. TECHNICAL REQUIREMENTS FOR VARIOUS COMPONENTS OF RTSPV SYSTEM

The installation shall meet the requirements of Indian Electricity Rules, CEA, DERC and MNRE Guidelines for grid connectivity. The materials, equipment and methods used in the installation shall conform to the latest edition of IS and IEC standards, and other national and international applicable standards including the following.

CEA – 2007	"Technical Standards for connection to grid" Regulations 2007 and subsequent amendments
CEA – 2013	"Technical Standards for Connectivity of the Distributed Generation Resources" Regulations 2013
CEA – 2010	"Measures Relating to Safety and Electricity Supply" Regulations 2010 and subsequent amendments
CEA – 2006	"Installation and Operation of Meters" Regulations 2006 and subsequent amendments
DERC – 2014	"Net Metering for Renewable Energy" Regulations, 2014 and DERC Guidelines
IEEE 929	2000 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems
IEC 61730 Part 1-2	Requirements for construction & requirements for testing, for safety qualification
IEEE 519	Power Quality Standards
IEEE 1547	Standards for Distributed Energy Resources Interconnection and Interoperability with the Electricity Grid
IEC 61000	Flicker Standard

IEC 61683	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
IEC 62093	Balance-of-system components for photovoltaic systems - Design qualification natural environments
EMC	EN 61000-6-2, EN 61000-6-4, EN 61000-3-11, EN 61000-3-12, EN 50178
IEC 62109-2	Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
IEC 62116	Test procedure of islanding prevention measures for utility interconnected photovoltaic inverters
IEC 60269 / IS-13703	Low voltage fuses
IS 15707	Testing, Evaluation, Installation and Maintenance of ac Electricity Meters - Code of Practice.
IEC 60947	Low Voltage Switchgear and Control gear
IS 1554	PVC Insulated Cable for working voltages up to and including 1100V
IEC 62446 / IS 2551	Signage Requirement
IS 3043	Earthing Standards
IEC 62305	Lightning Protection
IEC 62446	Operation , Maintenance and Documentation
IS 732	Wiring Rules
MNRE Guideline	Best Practices Guide: Implementation of State Level Solar Rooftop Photovoltaic Programs in India by MNRE

Table 3: Codes and Standards

2.1. Grid-tied Inverter

2.1.1. Power Quality Aspect

A. DC Power Injection into AC Grid

DC current injection into low voltage AC grid needs to be controlled as it may cause significant disturbances within distribution and measurement transformers. In addition corrosion risks are also associated with DC currents in the grid. The limits specified are as under:

Parameter	Limits	Reference Standard
DC Injection	0.5% of Full Rated Output at the Interconnection Point	• CEA's (Technical Standard for Connectivity of Distributed Generation Resources) Regulations, 2013. • IEEE 519

Table 4: DC Injection Limit

B. Harmonic Injection

Harmonic voltages and currents in an electric power system are a result of non-linear electric loads and are generated due to conversion of DC to AC power by the inverter. Harmonic currents can cause a voltage drop and result in distortion of supply voltage. Harmonics in power systems result in increased heating in the equipment and conductors, malfunctions, premature failures and reductions in lifetime of electrical components. The allowable voltage distortion limits are as under:

Parameter	Bus Voltage(V) at Interconnection Point	Limits	Reference Standard
Voltage Distortion Limits	V≤ 1kV	Individual Harmonics < 5% Total Harmonic Distortion (THD) <8%	• CEA's (Technical Standard for Connectivity of Distributed Generation Resources) Regulations, 2013. • IEEE 519
	1kV<V≤69kV	Individual Harmonics < 3% Total Harmonic Distortion (THD) <5%	

Table 5: Harmonic Voltage Injection Limit

The allowable current distortion limits for systems rated 120V to 69kV are as under:

Individual Harmonic Order (odd harmonics)[4]							Reference Standard
I_{SC}/I_L[5]	3≤h<11	11≤h<17	17≤h<23	23≤h<35	35≤h≤50	TDD[6]	
<20[7]	4.0	2.0	1.5	0.6	0.3	5.0	IEEE 519
20<50	7.0	3.5	2.5	1.0	0.5	8.0	

[4] Even harmonics are limited to 25 percent of the odd harmonic limits.
[5] Isc = maximum short-circuit current at Interconnection point
I_L = maximum demand load current (fundamental frequency component) at Interconnection point under normal load operating conditions
[6] TDD is based on the average maximum demand current at the fundamental frequency, taken at Interconnection point.
[7] All power generation equipment is limited to these values of current distortion regardless of Isc/I_L

50<100	10.0	4.5	4.0	1.5	0.7	12.0	
100<1000	12.0	5.5	5.0	2.0	1.0	15.5	
>1000	15.0	7.0	6.0	2.5	1.4	20.0	

Table 6: Harmonic Current Injection Limit

C. Flicker

Power-line flicker is a visible change in brightness of a lamp due to rapid fluctuations in the voltage of the power supply. Random or repetitive variations in the root mean square (RMS) voltage between a certain ranges of nominal voltage can be generated by the solar system and produce a phenomenon known as ***flicker***.

Parameter	Scope	Reference Standard
Voltage Fluctuation and Flicker	Inverter ≤ 16A AC Current per Phase	IEC 61000-3-3
	Inverter > 16A and < 75A AC Current per Phase	IEC 61000-3-11
	Inverter ≥ 75A AC Current per Phase	IEC 61000-3-5

Table 7: Flicker Limit

D. Phase Imbalance

Phase imbalance can occur due to varied loads and power injected into different phases of the distribution grid. Phase imbalance can potentially arise from single phase inverters feeding into the distribution grid.

The voltage imbalance should be limited to 3 percent[8] and/or the nominal inverter output rating of multi-phase RTSPV, or systems connected to multi-phase supply connections, should not differ by more than 2.5 kW between phases in compliance with AS/NZS 4777.2.

Inverter sizing for existing three phase connections:

RTSPV System Size	Type of Inverter
Up to 2.5 kW	Single-phase inverter
2.5 kW to 5.0 kW	Two single-phase inverters with no greater than 2.5 kW imbalance between any two phases or one balanced two phase inverter
5 kW to 10 kW	Three single phase inverters with no greater than 2.5 kW imbalance between any two phases or one balanced three phase inverter
Above 10kW	Three Phase Inverter

Table 8: Inverter sizing for existing 3-Ø connections

In case of multiple injections from single-phase RTSPV system connected to the same upstream Distribution Transformer, BRPL shall ensure that they are on alternate phases to prevent undue Voltage imbalance.

[8] Best Practices Guide: Implementation of State Level Solar Rooftop Photovoltaic Programs in India by MNRE

The applicant shall be responsible for measurement of harmonic current injection, Direct Current injection and flicker with calibrated meters before the commissioning of the project and once in a year in presence of the parties concerned and the indicative date for the same shall be mentioned in the connection agreement.

2.1.2. Operational Parameters

A. Voltage Range

As voltage fluctuations can result from the operation of the solar system or a fault in the distribution grid, **the PV system should get disconnected within two seconds if voltage reaches above 110% or below 80%** as per CEA's (Technical Standard for Connectivity of Distributed Generation Resources) Regulations, 2013. Reconnection is allowed only after the voltage reaches within the prescribed limit of 80-110% of the nominal voltage and is stable for at least 60 seconds.

Even though Fault Ride-Through capabilities are not envisaged at present by CEA, it might consider LHVRT once cumulative penetration of PV increases. Accordingly, BRPL mandates that inverters (>5kW) installed in its area of supply should be capable of implementing LHVRT feature.

B. Frequency Range

Frequency, being one of the most important factors in power quality, must remain constant throughout the grid. If less power is taken from the grid than is fed by the generators, the frequency will rise and vice-versa. This fluctuation in frequency can damage the electrical equipment used by the consumers.

CEA's (Technical Standard for Connectivity of Distributed Generation Resources) Regulations, 2013 specifies that the **PV system should cease to energize the grid within 0.2 seconds if the grid frequency reaches beyond the permissible limit of 47.5 – 50.5 Hz**. Reconnection is allowed only after the frequency reaches within the prescribed limit and is stable for at least 60 seconds. After the grid frequency crosses 50.2 Hz, inverters shall reduce their power in steps of 30% per 0.1 Hz until 50.5 Hz, after which inverters are required to shut down.

BRPL mandates that all inverters of capacity greater than 5kW installed in its area of supply should be capable of implementing LHFRT feature.

C. Automatic Synchronisation Device

Inverter shall be equipped with a built-in automatic synchronization device to avoid the need of a separate synchronizing device. Every time the generating station is synchronised to the electricity system, it shall not cause voltage fluctuation greater than ± 5% at the interconnection point.

Paralleling device shall be capable of withstanding 220% of the nominal voltage at the interconnection point.

D. Anti-islanding Protection

Islanding is a condition wherein a RTSPV system keeps on supplying power to a load even though supply from DISCOM grid is no longer present. This can be a dangerous condition for linemen carrying out the repair works / maintenance on grid. Considering the above concern, CEA's (Technical Standard for Connectivity of Distributed Generation Resources) Regulations, 2013 in line with **IEEE 1547** mandates that distributed generation must detect unintentional islanding and stop supplying power if the grid is down.

Inverters shall be equipped with protective functions to sense abnormal conditions on distribution network and get disconnected from distribution network within two seconds of the formation of an unintended island.

Delhi Electricity Regulatory Commission (Net Metering for Renewable Energy) Regulations, 2014 and Central Electricity Authority (Installation and Operation of Meters) Amendment Regulations, 2014 permits the **Intentional islanding** wherein a PV system could disconnect from the grid and continue to supply power to the consumer loads of that particular building using a battery storage system.

However, the inverter shall have

- Separate backup wiring to prevent the battery/ RTSPV system power to flow into the grid in the absence of grid supply
- Manual isolation switch shall also be provided at 24X7 accessible location

E. Reactive Power Support

Reactive power arises due to phase differences between voltage and current in the system. This phase difference is created by electric and magnetic fields in inductive and capacitive loads.

Presently, solar inverters are mandated to be operated at unity power factor; however, BRPL recommends that inverter sizing should be done in such a way that there should be facility to operate the inverters at a non-unity power factor as per below table in a pre-determined auto-response mode for grid support. Inverters shall be able to help the grid either by supplying reactive power under low voltage conditions or by absorbing reactive power under high voltage conditions. The inverters shall be in continuous communication with BRPL's SCADA system for RTSPV system sizes greater than 200kWp.

Inverter Output	Power Factor requirements
Rated output current < 16A per phase	0.95 lagging to 0.95 leading
Rated output current > 16 A per phase	0.90 lagging to 0.90 leading

Table 9 : Reactive Power Support requirements

F. Remote Curtailment

For all RTSPV systems of 200kWp and above size, inverters shall provide the facility to BRPL for remote curtailment / reduction of power injection at Interconnection point in order to overcome the grid voltage issues. The communication system needs to be provided to nearest SCADA system for remote starting or stopping the grid-tied inverter.

In case of higher penetration of RTSPV in any particular Distribution Transformer, the requirement of remote curtailment can also be imposed on RTSPV systems of size less than 200kWp.

2.2. Metering

Installation of Solar Energy meter for recording the total solar generation from RTSPV system and net-meter for recording the import as well as export of energy from/to the grid is not only important from billing purpose, but also for assessing the performance of installed RTSPV system.

- All the meters shall adhere to the standards as specified in CEA (Installation and Operation of meters) Regulations 2006, as amended from time to time, which primarily specifies
  i. IS 13779 is applicable to static watt-hour meters of class 1 and 2.
  ii. IS 14697 provides the standards for static transformer operated watt-hour and VAR-hour meters, of accuracy class 0.2 S and 0.5 S.

- All the meters to be installed for net metering shall be of the same or better Accuracy Class Index than the existing meter installed at consumers' Premises.
- The cost for replacing the previously installed unidirectional meter with bidirectional net-meter shall be borne by the consumer. Depending on technical feasibility, two unidirectional meters can also be installed in place of single unidirectional meter and the cost of these meters shall be borne by the consumer.
- The cost for installation of one solar meter for recording the solar generation shall be borne by BRPL. It is preferred to have single termination point, however, in case there are multiple installations and multiple termination points in a

single consumer premise, the cost of additional solar meter shall be borne by the consumer and the meters shall be provided with AMR.

- All meters, including Solar Energy Meter shall be installed at an accessible location of the Premises to facilitate easy access for meter reading to the BRPL.
- Meters shall be Meter Reading instrument (MRI) compliant or AMR (Automatic Meter Reading) or AMI (Advanced Metering Infrastructure) compliant for recording meter readings.
- The Solar check meters shall be mandatory for rooftop solar installations having capacity of more than 20 KW. For installations size of less than and equal to 20 KW, the solar check meters would be optional.

2.3. Earthing

PV system contains both DC and AC equipment, hence earthing practice needs special consideration. Earthing is required for PV module frames, array structures, power, communication and protective) equipment and enclosures, AC conductors and lightning conductors.

- Although DC and AC systems are considered separate, they should be connected together during earthing to have equipotential system.
- One point of the output circuit of PV system of voltage exceeding 50 V_{dc} shall be provided with a connection to earth, in addition to the normal system earthing, for the purpose of limiting the imposed voltages from outside sources and stabilize the voltage to earth during normal operation. Provided that if there is Ground-Fault Protection (GFP) device in the circuit, the grounding shall only be at that point.
- DC input negative earthing function shall be provided to prevent potential induced degradation (PID).
- The frame of inverter cabinet shall be connected with the earthing bus bar through the earthing terminals using flexible braided copper wire.
- The inverter shall be provided with negative earthing on DC input side, Ground fault detector interruption.
- Protective earthing shall be made inside the inverter cabinet.

IS 3043-1987 (Reaffirmed 2006), "Code of practice for earthing," governs the earthing practices of a PV system.

Following specific practices to be adopted are as under:

Parameter	Practice
Earthing of PV module	• Should be through one continuous earthing cable. • Smaller piece jumper cables to connect frames of consecutive modules are not permitted. • All earthing paths should be created using two parallel earth pits to protect the PV system against failure of one earth pit.

Lightning Arrester	• Separate earthing to be provided along with a separate earth pit.		
Bolting of lugs of earthing cable with the module frame	• Star type washers to be used. • The teeth of the washer cut through surface oxides, paints or other finishes and provide a gas-tight conductive path.		
Earthing Conductor	Rating should be minimum 1.56 times the maximum short circuit current of the PV array. In any case, the minimum cross-section of earthing conductor for PV system is as under:		
Type	Copper	Aluminum	GI wire
PV Equip.	6 mm2	10 mm2	70 mm2
LA	16 mm2	-	70 mm2
Resistance between any point of the PV system and earth	≤ 5Ω		

Table 10: Earthing parameters

2.4. Safety & Protection

Protection devices are needed to prevent damage to the grid, the system and the personnel in the event of voltage fluctuations, frequency fluctuations, unintentional islanding, etc. Typical protection devices in solar systems consist of fuses, surge protective devices, DC and AC isolator switches, lightning protection, etc.

A. DC Overcurrent Protection

The PV system is protected from overcurrent from the PV modules with the help of fuses at the string junction box. As PV modules are connected in series in a string, the short-circuit current of the string is equal to the short circuit current of the PV module.

Each string should have two fuses, one connected to the positive and the other to the negative terminal of the string. The fuse should be rated at 156 percent of short-circuit current and 1,000 V_{DC}; if the exact current rating is not available, the nearest available higher rating should be used.

B. Surge Protection Devices (SPDs)

SPDs are particularly important to protect sensitive electrical equipments like AC/DC Inverter, monitoring devices and PV modules, but also other sensitive equipments powered by the 230 V_{AC} electrical distribution network. This device is connected in parallel on the power supply circuit of the loads that it has to protect.

Reference Standard is IEC 61643-1, "Low Voltage Surge Protective Devices".

Every combiner box shall be provided with suitable Type-1 Surge Protective device with arc extinguishing capability to avoid any risk of fire. The input circuits of

combiner box shall be provided with over current protection. The output circuits of combiner box shall be provided with isolation protection.

As the string inverters used for rooftop PV systems do not allow more than 800 V_{DC}, surge arrestors rated for 1,000 V_{DC} are commonly used. The surge arrestors should be connected to both positive and negative outgoing terminal of the string junction box (if the inverter already does not have an equivalent in-build DC surge arrestor).

C. Lightning Protection

PV systems should have a dedicated lightning protection system including lightning rods, conductor and dedicated earth pits. For this, the existing lightning protection of a building may be used, provided it adequately protects the installation area and is assured of functioning throughout the life of the PV system. In case, existing lightning protection of the building is used, the reassessment of the same is to be carried out before commissioning of the system.

IS 2309 – 1989 (reaffirmed 2010) needs to be adopted for lightning protection related practices of a PV system.

D. Ingress Protection

- The combiner box for outdoor use shall be protected against corrosion, rust and sunlight exposure and a protection class of IP65 or above is required.
- Ingress protection (IP) for PV module and junction box/connectors shall be no less than IP65.
- Although many inverters are rated for operation up to a maximum ambient temperature of 60°C, it is highly recommended to make an additional shading arrangement to avoid exposure to direct sunlight and rain.

E. Fire Protection

RTSPV systems are subject to electrical faults like any other electrical installation such as arc faults, short circuits, ground faults and reverse currents. These faults and other failures of the system, including cable insulation breakdowns, rupture of a module, and faulty connections, can result in hot spots that can ignite combustible material in their vicinity. Wrongly installed or defect DC/ AC inverters have been the reason of several photovoltaic fires as well.

In the worst case, faulty conditions on the photovoltaic system will not only result in a hot spot, but also a DC arc. Solar installations are particularly sensitive because of the continuous DC current and high voltages (300-1000 V) involved. DC arcs do not self extinguish and can reach temperatures as high as 3000°C.

The primary protection against fire is the quality of the components and the installation and the presence of protective devices for the entire electrical system. Few requirements to be followed for prevention of fire are as under:

- Enclosure of combiner box shall be made of fire retardant material with self-extinguishing property and free from Halogen.
- Fire Resistance Low Smoke zero Halogen (FRLSH) cable shall be used.
- Fire detection, alarm and control system shall be provided as per relevant IS.

However, few of the precautions to be taken while extinguishing the fire are as under:

- Use Class "C" Extinguishing Agents - CO_2 or Dry Chemical
- Treat all systems as Energized regardless of Time of Day
- Do not cut into or walk across panels
- Do not break protective glass - all energy in entire system could be released at break point
- Lock & Tag Out Array at Inverter, DC Disconnect and main electrical panel
- Never use water to extinguish lead-acid battery fires, PV array fires

F. Clearance requirements PV modules and switchgear panels

- There shall be a minimum clearance of 500 mm between finished ground level and bottom of any PV modules.
- LT panels facing front to front of each other shall be provided with minimum 1500 mm clearance.
- In case of HT panels facing each other, front clearance shall be 2000 mm and side and rear clearance shall be minimum 1000 mm and 800 mm clearance respectively.
- Clear pathways of minimum 75 cm in width for roof access and emergency exit shall be provided for roof top system.
- RTSPV installations shall be efficiently protected by fencing or other means not less than 1.8 metres in height so as to prevent unauthorised entry.

3. PRE-COMMISSIONING CHECKS

3.1. Labelling

Considering the safety owing to the high DC voltages as well non-familiarity of technicians and laymen with such a system, labelling of all PV equipment is a must. The labelling of a PV system should conform to IEC 62446 standard.

IEC 62446 stipulates that:

- All circuits, protective devices, switches and terminals are suitably labelled.

- All DC junction boxes carry a warning label indicating active parts inside the boxes are fed from a PV array.
- Main AC isolating switch is clearly labelled, dual supply warning labels are fitted at interconnection point and a single line wiring diagram is displayed.
- Inverter protection settings, installer details and emergency shutdown procedures are displayed on site.

3.2. Schematic Diagrams and Drawings

The applicant shall provide the following critical drawings of the rooftop PV system to BRPL:

i. Single Line Diagram (SLD);
ii. Equipment layout diagram; and
iii. Wire and earthing layout diagram.

The same shall also be displayed near the RTSPV system installation. The sample SLD is annexed at Annexure – 1.

3.3. Inspection, Test, Calibration and Maintenance prior to connection

Before physical connection, the applicant shall complete all inspections and tests finalised in consultation with BRPL to which his equipment is getting connected.

The overall inspection activity of the rooftop PV system is divided into two parts: visual inspection and testing.

i. Visual inspection is done to verify:

- Three phases on the AC side and positive & negative conductor on the DC side are marked and identified with different colours.
- Installation, interconnection, workmanship, warranty compliance, ratings of equipment, labelling, etc.
- Safety via over-current/voltage protection devices, residual current devices, surge and lightning protection, disconnectors, earthing and other contingencies.
- Inverter is provided with at least fuse and disconnecting switch at DC input and circuit breaker and emergency stop switch at the AC output.

ii. Testing:

- Performance testing of PV modules, strings, inverter, and overall system output.
- Safety testing for continuity, short circuit and open circuit, polarity, earthing, insulation, islanding, and so on.
- Insulation resistance of Inverters when measured with 2.5 kV DC for 1 minute between input circuit and ground, between output circuit and ground and between input and output circuit shall be at least 2 MΩ.

The applicant shall make available all specifications and test records of the project equipment to BRPL, prior to the connection of its RTSPV system to BRPL network.

3.4. Commissioning Certificate

Each system needs to be inspected and verified before commissioning; however, inspection authority may differ based on the system size.

- For solar plants with capacity above 200 kWp, inspection by Electrical Inspector, appointed by the Delhi Government shall be required to ensure quality, safety, and compliance before commissioning.
- Up to a solar plant capacity of 200 kWp, the consumer shall be responsible for the inspection and verification before commissioning.

However, BRPL shall conduct the inspection and verification of measures related to safety parameters before installation of Net Meters. The standard checklist is annexed at Annexure – 2.

4. RECURRING ACTIVITIES DURING OPERATION

4.1. Cleaning

Solar Modules: With dirt and dust accumulation on solar panel, the power conversion efficiency of solar panels gets reduced. This necessitates for regular cleaning of the panel.

Inverters: Dust in the ventilation system of inverters will increase the operating temperatures and by that lower efficiency and lifetime of the product. The same effect occurs when objects are placed on top of the inverter. The inverter is best operating when it is installed in a cool and weather protected place. The ventilation system should be cleaned from time to time.

4.2. Rusting

Even though non-corrosive materials like Stainless Steel, Aluminum, etc. for module mounting structures are recommended, there should be a regular check for any corrosion, especially for Bolts & Nuts and mounting structures made of galvanised steel.

4.3. Damages / Cracks of Modules

Production errors can lead to the development of hotspots and other damages. Especially the sensitive module backside should be treated carefully to avoid scratches that lower the production. If there are severe damages like glass breaking or burn marks or cracks, the module should get replaced preferably with the modules of same

manufacturer and same rating. Any mismatch in module rating will bring down the efficiency of the RTSPV system.

4.4. Shading

Shading on one module or part of a module brings down the performance of the whole string of modules connected to it significantly. It is recommended to trim the branches of nearby trees regularly if they attribute to shading over module.

4.5. Monitoring

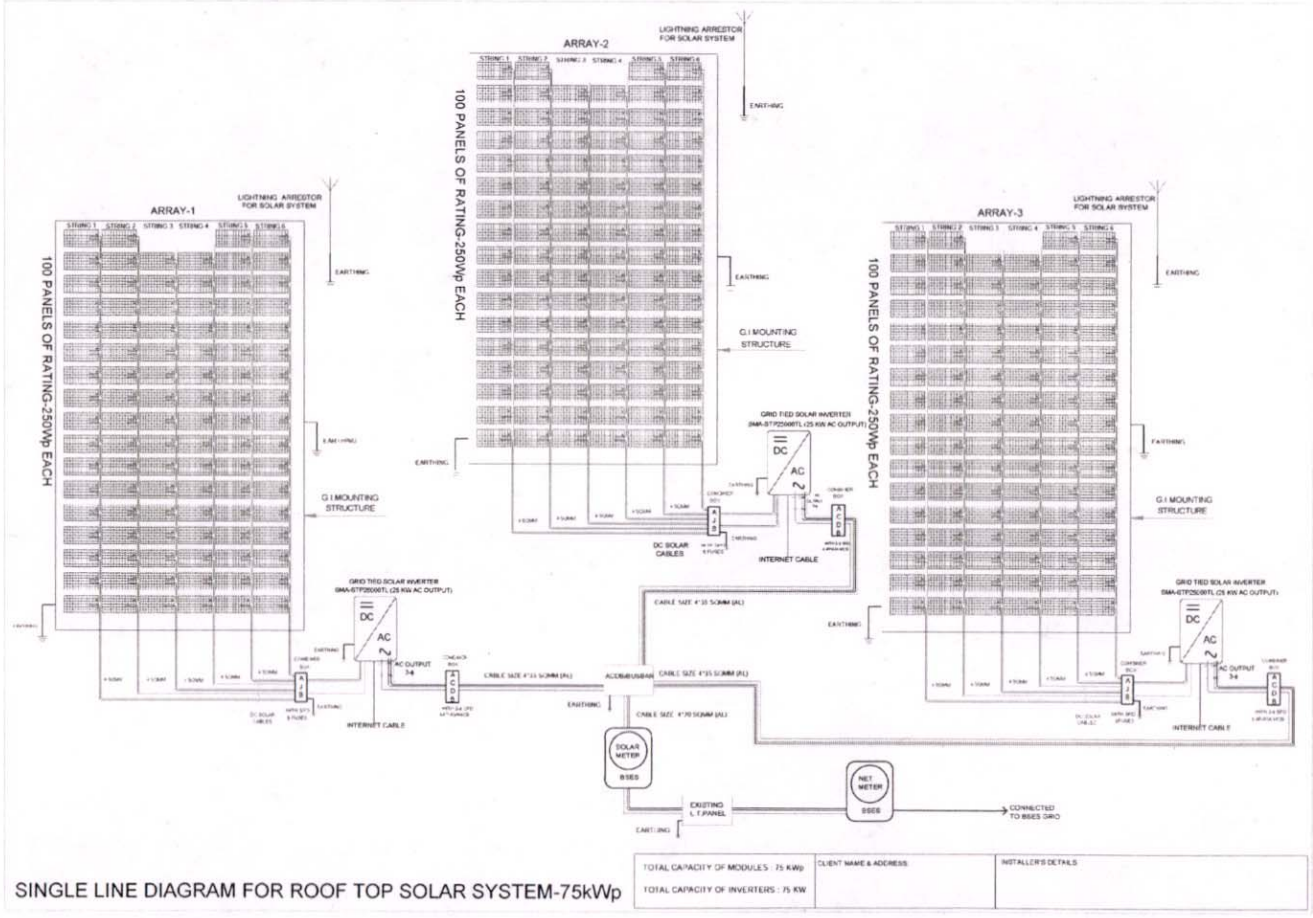
Lower than expected production of a system can have various reasons like damages, inverter shutdown, etc. but gets undiscovered in absence of monitoring. It is recommended to monitor the inverter status and solar generation meter regularly. Most convenient is to install an online distant reading facility. All RTSPV systems users having capacity greater than 10kWp need to mandatorily provide the access to BRPL for remote monitoring of solar generation data.

4.6. Measurement of Power Quality parameters

As conversion of DC power from solar modules into AC power by inverter may bring certain power quality issues, it is mandated to carry out measurement of Harmonics injection, DC injection and Flicker at least once in a year.

5. ANNEXURES

5.1. Annexure – 1: Sample SLD of RTSPV



SINGLE LINE DIAGRAM FOR ROOF TOP SOLAR SYSTEM-75kWp

5.2. Annexure – 2: Checklist for Site Inspection of Grid Connected RTSPV System

Application no. _____				
Checklist for Site Inspection of Grid Connected Solar Photovoltaic System				
Consumer Name			**Inspection Date**	
Address			**Sanctioned load**	
CA Number/Meter Number			**Activity found on site**	
Name of Installer			**Signature of Consumer**	
Applied Solar Capacity (kWp)			**Solar Capacity found on site (kWp)**	
S.No.	**Parameters to be checked**	**Sub-Parameter**	**Details**	**Status**
1	**Solar PV modules**	Make		
		Rating/Qty		
		No. of input strings		
		No. of Modules in one string		
2	**Solar PV inverter**	Make		
		Inverter Model number		
		Rating/Qty		
		Min/Max input DC voltage		
		Output supply type		
		No. of Termination points		
		Cross section of cable		
		Islanding provision		
3	**Earthing Type**	PV Panel		
		PV Inverter		

		Lightning Arrester		
4	**Protection**	A.C Breaker		
		D.C Breaker		
		Lightning Arrester		
5	**Meter Installation**	Space for Net Meter		
		Space for Solar Meter		
		Existing cable size		
		New cable size/length (if required)		
		Required Net meter type		
		Required Solar meter type/Qty		
Notes:				