CAG

Citizen consumer and civic Action Group

ROOFTOP SOLAR INSTALLATION

A PRACTICAL GUIDE

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A SIMPLE PRACTICAL GUIDE

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About CAG

Citizen consumer and civic Action Group (CAG) is a 39-year-old Chennai-based non-profit, non-political and professional organisation that works towards protecting citizens' rights in consumer and environmental issues, and promoting good governance processes including transparency, accountability and participatory decision-making.

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Contact details

Citizen consumer and civic Action Group (CAG)
New #103, First Floor, Eldams Road, Lubdhi Colony, Teynampet, Chennai 600 018
Tamil Nadu, INDIA
www.cag.org.in | +91(44) 2435 4458 | 2435 0387
Email: helpdesk@cag.org.in

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Grid-connected Solar Rooftop

The Government of India has set a target for establishing 500 GW of renewable energy resources by 2030. This includes 100 GW from solar power, 60 GW from wind power, 10 GW from biomass power and 5 GW from small hydropower. Out of 100 GW solar, 40% has to come from consumer categories such as rooftop solar and small scale solar energy systems. Government of Tamil Nadu has taken several measures to promote rooftop solar and introduced the second Solar Policy[1] in February 2019. In continuation to this policy, in October 2021, Tamil Nadu Electricity Regulatory Commission (TNERC) released Grid Interactive Solar PV Energy Generating Systems (GISS) Regulations, 2021[2]. This Regulation introduces a solar net feed-in tariff mechanism where the utility pays consumers for the electricity exported to the grid. In October 2021, TNERC fixed tariff for GISS at Rs. 3.61 per unit[3] up to 10 kW; 3.37 per unit from 11 kW to 150 kW and 3.10 per unit from 151 kW to 999 kW for the exported power. Given the policies, regulations and administrative procedures required for installing grid-connected rooftop solar plants in consumers' residences/premises, it is important that consumers are aware of the same.

[1] http://teda.in/wp-content/uploads/2019/02/SOLARPOLICY2019.pdf
[2] https://www.tnerc.tn.gov.in/Regulation/files/Reg-221020211743Eng.pdf
[3] https://www.tnerc.tn.gov.in/Orders/files/TO-Order%20No%20251020211341.pdf

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Rooftop solar photovoltaic systems are becoming increasingly vital for several reasons. They provide a sustainable way to lower electricity costs and decrease reliance on grid power. Moreover, these systems help protect the environment by minimizing greenhouse gas emissions and reducing fossil fuel dependence. Additionally, installing rooftop solar panels can offer potential income from surplus energy sold back to the grid. Overall, they represent a smart and environmentally friendly investment for the future. Thus, to successfully install a rooftop solar photovoltaic system, consumers need to be familiar with the installation procedures and basic system details. This ensures they can verify all aspects during the installation process. The following guide outlines the step-by-step process for a smooth rooftop solar installation.

1. Enquire with rooftop solar installers

Approach installers to enquire about the details of setting up a rooftop solar - such as capacity, generation etc. Tamil Nadu Electricity Board (TNEB) has provided a list of solar installers enlisted[4] with them. But TNEB does not give assurance for the quality and price of enlisted suppliers/manufacturers/system integrators.

2. Site visit by solar installers

A site visit by the solar installers will entail understanding and calculating the required capacity and available shade free rooftop area for installing the rooftop solar plant. These calculations can also be done by a consumer. Additional requirements to be met for the rooftop solar can also be evaluated during the site visits. A site visit will help the installers understand:

- ***Geographical location***: Location of the premises will help the installers to understand the positioning of the solar panel and requirement of mounting structures;
- ***Mounting structures***: It is important for the installers to inspect the condition of the roof to ensure that it is structurally sound to design the supporting structures for the solar panels.
- ***Placement of the inverter***: It is crucial to allocate a specific area for installing both the DC and AC distribution boxes, as well as the inverter. Placing the DC distribution box on the mounting structures is recommended to minimize resistive losses in the wiring. The inverter should be installed away from direct sunlight and close to the meter board to facilitate easy connections to both the DC wires and the main utility supply.

[4] https://www.tnpdcl.org/static/tnpdcl/assets/files/pmsuryaghar/empanelledvendors.pdf

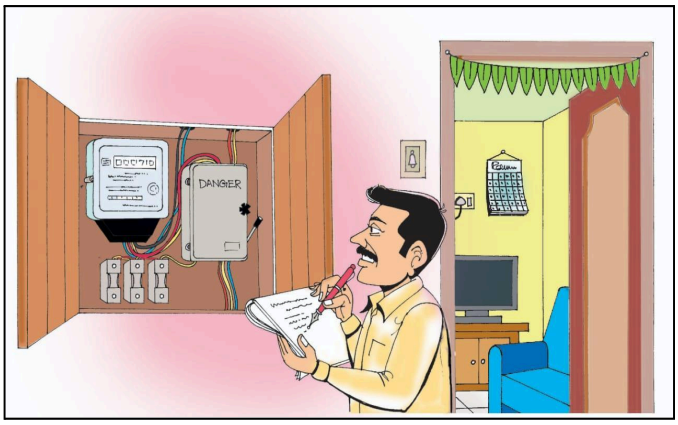

Image 1. Consumption pattern, connected load etc need to be assessed by the installer

- ***Wiring configuration***: If a consumer is having a three-phase connection, he should ensure that the load is distributed equally. This can be done with the help of an installer.
- ***Additional requirements***: It may include electrical wiring, civil works for slanting roof or structurally weak roof and storage space for materials

3. Required capacity to be installed

a) Available shade-free rooftop area:

As per TNPDCL[5], the area required for installing 1 kW solar is about 10 square meters or 108 square feet approximately. The rooftop area should be free from obstacles such as tall buildings, trees, etc to allow maximum sunlight to fall on the solar panel. It should be installed minimum 2 feet away from the parapet wall to ensure there is sufficient space for persons to clean and service panels.

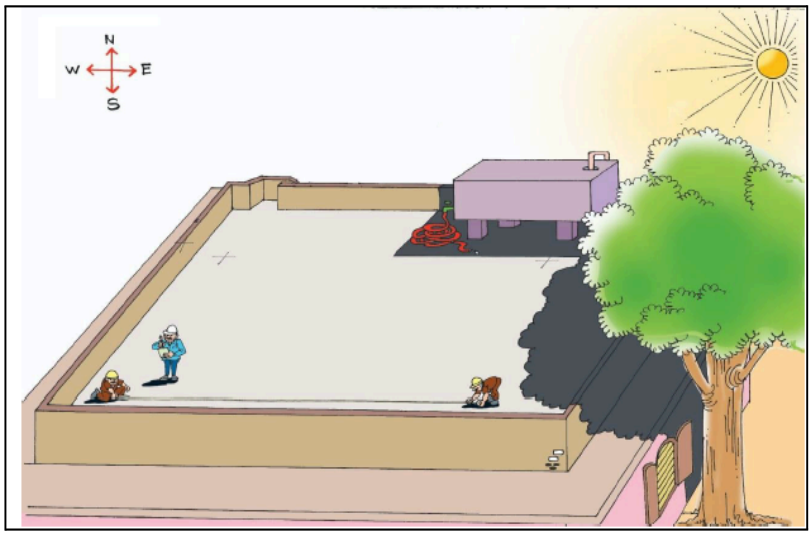

Image 2. Area measurement

[5] https://www.tnebltd.gov.in/usrp/faq.xhtml

b) Electricity consumption:

The capacity of the solar plant can be determined by the electricity consumed on the premises for one year with the help of information available through physical copies of electricity bills or white meter card or through the online consumer portal of TNPDCL.

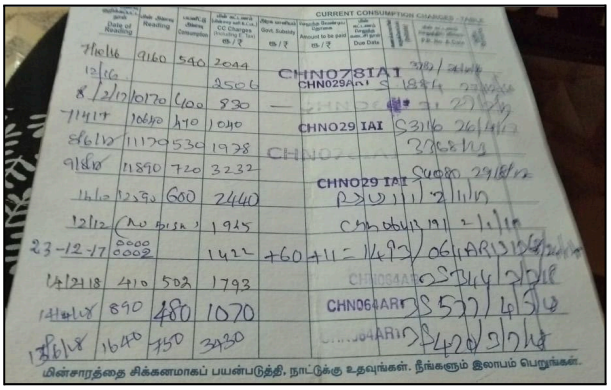

Image 3. A white meter card

It is also necessary to verify the sanctioned load of the premises. According to the order released by TNERC on rooftop solar generation plants[6], a consumer is eligible to install upto 100 % of his or her sanctioned load given by the utility. If the required rooftop solar capacity exceeds the sanctioned load, the consumer must inform the service provider to increase the sanctioned load of the premises.

Assessment Date	Assessment Entry Date	KWH Reading	KVAH reading	Maximum Demand	Power Factor	Consumed Unit
17/04/2019	17/04/2019	17440		7.21		650
16/02/2019	16/02/2019	16790		7.21		550
18/12/2018	18/12/2018	16240		7.21		590
17/10/2018	17/10/2018	15650		7.21		610
17/08/2018	18/08/2018	15040		7.21		580
18/06/2018	18/06/2018	14460		7.21		610

Image 4. Consumer's consumption details as displayed online.

How to calculate required capacity: The required capacity of the solar plant is finalised based on the annual electricity consumption in the premises and the available shade-free rooftop area. In Tamil Nadu, a solar panel of 1 kW capacity will generate an average of 1,500 units in a year.

Example 1 - Let us consider the Image 4 mentioned above as an example and assume that they have a shade free rooftop area of 200 sq ft. It shows that the consumer has consumed a total of 3,590 units from 18/06/2018 to 17/04/2019.

[6] http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf

The capacity of the plant based on annual energy consumption can be ascertained as follows:

a) Annual energy consumption at the premises is 3,590 units.
b) Capacity of the solar plant (3,590 units / 1,500 units) = **2.39 kW**
c) Available Shade free rooftop area = 200 sq ft
d) Capacity of solar plant that can be installed on the rooftop = 200 / 108 = **1.85 kW**

Even though the consumer is in need of 2.39 kW, their rooftop space can support only an installation of 1.85 kW.

Example 2 - Let us consider the image.2 mentioned above as an example and assume that they had a shade free rooftop area of 450 sq ft. The consumer has consumed the same 3590 units.

The capacity of the plant now varies because of an increase in shade-free area:

a) Annual energy consumption at the premises is 3,590 units.
b) Capacity of the solar plant (3,590 units / 1,500 units) = 2.39 kW
c) Available Shade free rooftop area = 450 sq ft
d) Capacity of solar plant can be installed on the rooftop = 450 / 108 = 4.16 kW

In this, the rooftop area of a consumer's premises will support 4.16 kW but their required capacity is 2.39 kW only. So the required capacity of the premises is 2.39 kW.

Note - Shade-free rooftop area requirements are likely to change in the future, as technologies change and advance. . A consumer can discuss requirements with the installer(s) at the time of the site visit.

4. Finalising a solar installer

Consumers should ideally request quotations from different solar installers as this will enable them to compare various items and services offered, in order to finalize a suitable installer.

For comparison, consumers should not only consider the cost but also some additional parameters as given below, as these are equally important for decision-making.

- **Standards:**
  - ❖ Ensure all the components listed in the quotation meet standards set by the Ministry of New and Renewable Energy[7] (MNRE)

- **Solar panels**:
  - ❖ Solar panels are available in different capacities starting from 3 Watts to 350 Watts. Consumers should ensure that the panels given in quotation are for the requested capacity. This is related to the space available in the consumer's premises e.g. a 350-watt panel will be bigger and occupy more space than a 35-watt panel.

[7] https://mnre.gov.in/file-manager/UserFiles/Rooftop-Solar-PV-Quality-Standards_Revised.pdf

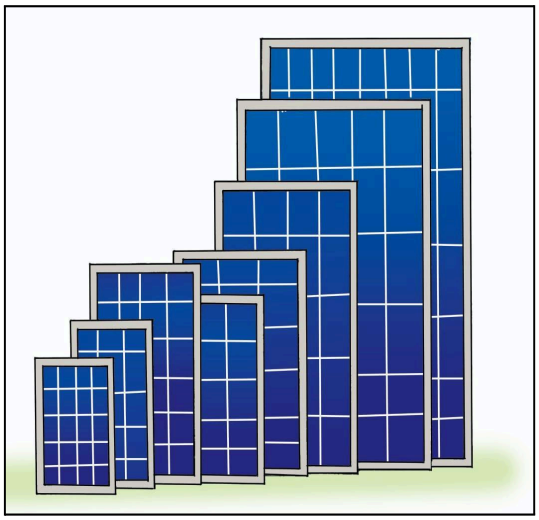

Image 5. Different sizes of solar panels

- Consumers should check whether watt peak (Wp) is mentioned in the quotation. The Wp represents the maximum electric power that can be supplied by one photovoltaic panel in standard temperature and sunshine conditions. Irrespective of size, the panel with higher Wp has high efficiency.
- The consumer should check the make of panel to see if it is a standard manufacturer. This example list[8] can be used for ready reference.
- Ensure that the manufacturer mentions efficiency of the solar panel is greater than 13%.

Types of solar panels[9]

Types of Panels	Efficiency	Highlights
Monocrystalline	17-22%	Highest efficiency, Performs well in low, light conditions and Longer lifespan.
Polycrystalline	15-17%	Lower efficiency, Cost-effective, and Suitable for larger spaces.
Thin film	10-12%	Most affordable, Flexible and lightweight , and Lower efficiency.

[8] https://www.bijlibachao.com/solar/top-ten-best-solar-panel-brands-manufacturers-india.html
[9] https://gserenewables.com/blog/types-of-solar-panels/

- **Solar Inverter:**
  - ❖ The power generated through the solar panel is Direct Current (DC)[10] while household appliances run on Alternating Current (AC)[11]. DC power should be converted to AC power. For this purpose, a solar inverter is used.
  - ❖ Inverter capacity is usually measured in Volt Ampere (VA) or kilo Volt Ampere (kVA)[12] and is related to the capacity of the solar panel required for the premises. Ideally, the inverter capacity must be greater than or equal[13] to the solar panel's capacity. Now, considering the example from Image 4 mentioned above, the required capacity of a solar panel is 2.39 kW, then the corresponding Inverter capacity would be 2.52 kVA.
  - ❖ The make of the inverters should be checked to verify if it is from a recognised manufacturer. Sample list is given here[14] for reference.
  - ❖ The inverter should have a minimum warranty of 5 years.
  - ❖ The efficiency of an inverter indicates how much DC power is converted to AC power. The inverter should have an efficiency of greater than or equal to 95% with the ability to withstand a temperature range[15] of -10 °C to 60 °C. If the temperature increases, the inverter will gradually reduce its power output, by reducing the output AC in order to protect its components. (Consumers can find this information on the label that comes with the respective solar panel.)

Output warranty:

- ❖ Output warranty for a solar panel is referred to as an assured level of power that a solar panel will produce each year. There are two types of warranties a) Linear Performance Warranty b) Standard Performance Warranty.
- ❖ Linear Performance Warranty - In this, the manufacturer will specify that the performance of solar panels may decrease gradually year after year ie., year-1 a 2.5% decrease, and year-2 to year-25 a 0.5% decrease per annum.
- ❖ Standard Performance Warranty - In this, the manufacturer will specify the decrease in performance of solar panels over a period of time ie., the performance of solar panels will not be less than 90% at the end of 10 years[16] and not less than 80% at the end of 25 years.

Thus, over 25 years, panels with linear performance warranty can be expected to generate significantly more power than the panels with standard performance warranty. So while selecting an installer, consumers should opt for manufacturers who provide panels with linear performance warranty. Linear performance warranty will provide a more precise annual decline rate, while a standard performance warranty provides general performance targets over the lifespan. For

[10] https://energyeducation.ca/encyclopedia/Direct_current
[11] https://energyeducation.ca/encyclopedia/Alternating_current
[12] http://www.zelect.in/inverter/inverter-buying-guide
[13] http://www.altenergy.org/renewables/solar/DIY/inverter-sizing.html
[14] https://www.cleanenergyreviews.info/blog/best-grid-connect-solar-inverters-sma-fronius-solaredge-abb
[15] https://www.solarquotes.com.au/blog/how-does-temperature-affect-your-solar-inverter-power/
[16] https://solarrooftop.gov.in/pdf/faq.pdf

example, Case i) In case of linear performance warranty, the manufacturer guarantees that the panel will not lose more than 1% of its efficiency per year. This implies that after 25 years, the panel should still perform at 85% efficiency. Case ii) In case of standard performance warranty, the manufacturer might guarantee that a solar panel will maintain at least 80% of its original efficiency after 25 years, as they will get guaranteed performance of 85% over a period of 25 years.

- **Mounting structures:**
  - ❖ Mounting structures support the solar panels. It should be made of hot-dipped galvanised steel with a minimum galvanisation thickness of 120 microns[17]. Aluminium alloy or anodised aluminium may also be used. Note: It is advisable to use spring washer[18] or locking washer[19] to fix solar panels to ensure that nuts do not loosen over time.
  - ❖ Mounting structures should be able to withstand a wind speed of minimum 150 km per hour[20]. If the premises is near the seashore, anodised aluminium structures will be better.
  - ❖ For a cyclone prone area, mounting structures should be designed in a way to handle the cyclones where wind speeds may reach 200 kph. It has to be discussed with the installer.

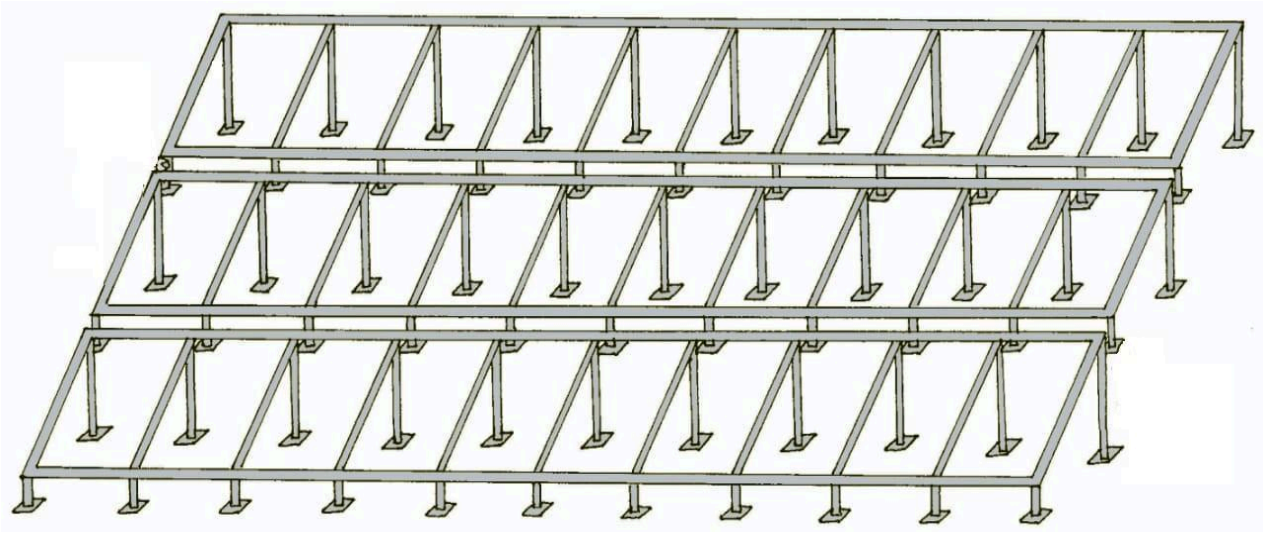

Image 6. Mounting structure

[17] http://www.teda.in/pdf/Specification_Grid_Tie_SPV_plant.pdf
[18] https://www.globalspec.com/learnmore/mechanical_components/springs/washer_springs
[19] https://www.hunker.com/12000174/what-is-the-purpose-of-a-lock-washer
[20] https://manireda.mn.gov.in/wp-content/uploads/2018/05/Guideline-RTS.pdf

- **AC & DC Cables:**
  - ❖ The DC power generated from the solar panel is transmitted through a DC cable to the inverter. DC power gets converted to AC power by the inverter and gets transmitted to the load by AC cables. It is important to check the make of the cables and ensure they adhere to ISI standards.
  - ❖ Copper wires, being a good conductor of electricity, are preferred for wiring.
  - ❖ The minimum size of both DC and AC cables should ideally be 4.0 mm^2 copper.

- **Online monitoring**
  - ❖ Usually, the installer will provide some way to monitor the solar power generation such as a mobile application and/or through web-based monitoring. A consumer should ensure the availability of online monitoring of solar generation data for their benefit. A sample image is given below.
  - ❖ Check the parameters you can monitor online. Basic parameters to look for are the power generation rate, cumulative solar generation (month and year wise), facility to download the generation data, etc.

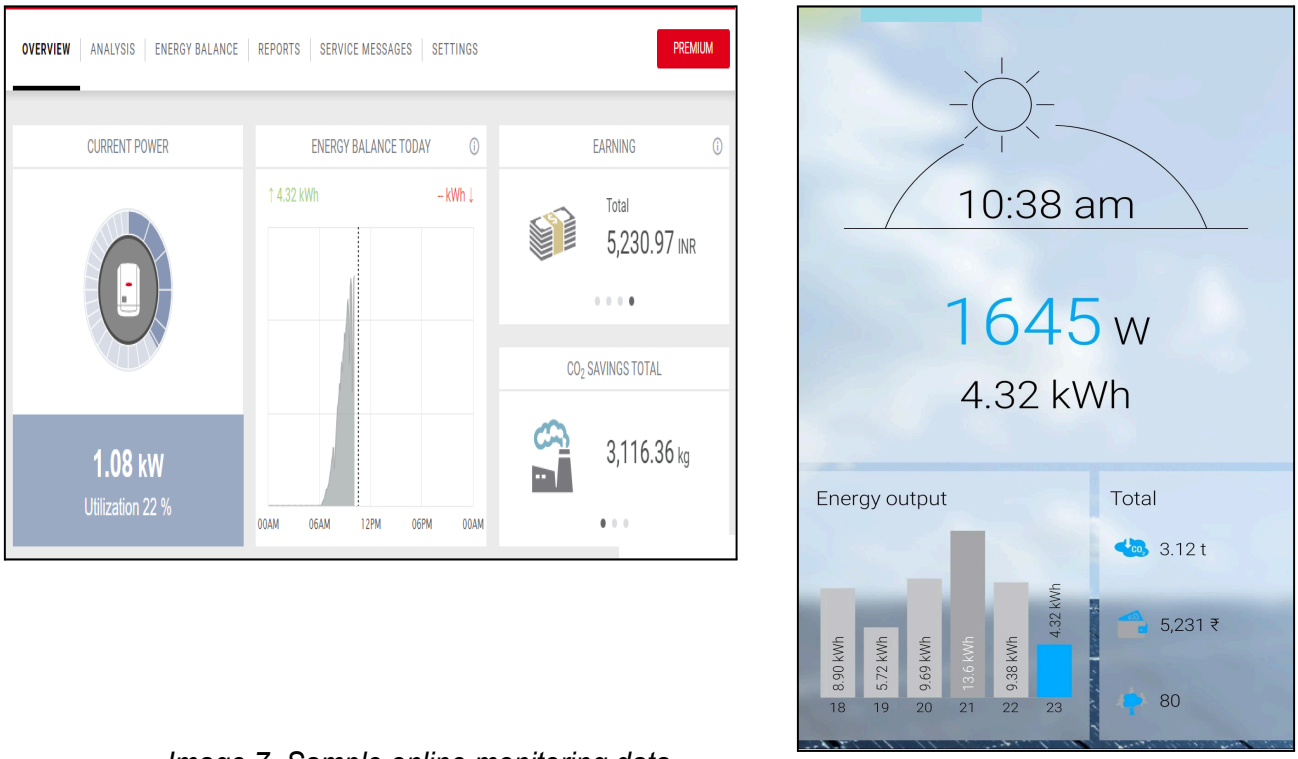

Image 7. Sample online monitoring data

- **Maintenance**
  - ❖ Maintenance includes three major items i.e. servicing of inverters, electrical wiring, and solar panel performance for output.
  - ❖ A consumer has to ensure that annual maintenance is included in the base price. The consumer should also keep a check on what services are covered under or excluded from the Annual Maintenance Contract (AMC).

[Note: For all rooftop solar for which subsidy is availed, annual maintenance for 5 years is already included from the date of installation – consumers should confirm the same. However, for non-subsidised rooftop solar, maintenance is usually covered for the first year, free of cost. Subsequently, a consumer may enter into an AMC with the service provider.]

- ❖ Be sure to check the processes for identifying performance issues, point of contact, and estimated time to inspect and resolve the issue; check whether there will be additional charges.

- **Payment terms and conditions**
  - ❖ Generally, installers demand an advance payment - between 30% and 50% of the total amount. Payment mode will have to be ascertained (i.e., cash, cheque, online).
  - ❖ Consumers will receive an acknowledgement for the payment done.

- **Material dispatch and installation**
  - ❖ Check for the time period for dispatch of materials.
  - ❖ The time period for dispatch is based on the availability of the materials. Certain installers have stock readily available and may deliver in a short span of time. While others may have to get the stock from outside resulting in longer delivery time.
  - ❖ Check the time period required for installation.

5. Assessing the technical feasibility for connecting with TNPDCL distribution network

A consumer interested in installing a rooftop solar PV system should enquire with TNPDCL[21] for connecting rooftop solar PV with the utility's distribution network or grid. TNPDCL officials in the consumer's area will ascertain the technical feasibility of connecting the rooftop solar with the utility grid. TNPDCL officials will ensure that the a) *installed capacity does not exceed 100% of the sanctioned load as per TNERC Order on Rooftop Solar Generation 2019*[22], b) *the total solar PV system connected to the distribution transformer does not exceed 90% of the distribution transformer capacity.* Consumers can avail further guidance from the rooftop solar installers.

How does the rooftop solar, connected to the distribution network or grid of the utilities, work?

Rooftop solar generates DC power and a solar grid inverter will convert the DC power to an AC power. For its functioning,the solar grid inverter synchronises its AC output frequency with the grid frequency (nominally 50Hz) and adjusts its AC voltage output to be slightly higher than the grid voltage so that surplus energy, if any, flows to the grid. The customer is a net exporter of power to the grid when there is surplus generation than consumption and is a net importer of power from the grid when solar generation is less than consumption. Both grid frequency and voltage are needed for the solar grid inverter to function correctly.

[21] https://www.tnebltd.gov.in/usrp/Salientfeatures.pdf
[22] http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf

6. Meeting additional requirements

The installer may recommend additional requirements during the site visits. For example,

- If the requirement of wires between the inverter and building's electrical distribution box is more than 25 metre[23] length then the cost of extra wires may have to be borne by the consumer.
- If the roof is weak or in a slanting position, a concrete block may be required to support the mounting structures of the rooftop solar.

Apart from the above, a consumer may have to provide space for storage of the panels and other components during the period between delivery and installation date.

7. Material purchase

According to the terms and conditions mentioned by the installer in the quotation, a consumer may need to pay a certain percentage of the cost as advance to commence installation of rooftop solar. Once the advance amount is disbursed, the installer should send the materials within the time limit mentioned in the quotation. The consumer should follow up with them for the dispatch of material.

It is important to check the quality of the material after delivery. The quality of solar panels and other components will directly impact the lifetime of the plant and the rate of solar power generation.

a) **Label:** All PV modules should have a label affixed at the rear side of the module displaying the manufacturing details. The label should include information such as maximum power, current and voltage at maximum power, short-circuit current, open-circuit voltage, manufacturer's name, model number, and serial number. The label should be water resistant and heat resistant. If the label is missing or any technical information is omitted, then the module may be counterfeit.

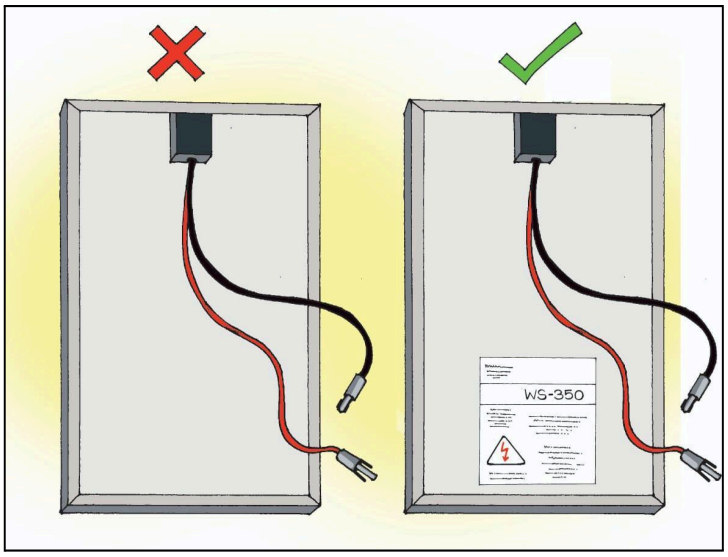

Image 8. Panel with and without the label

[23] http://teda.in/apply/incentive-for-domestic-solar-rooftops-individual/

b) **Cracks and scratches in front glass:** Scratches on the glass cover of the solar panels is a major issue. Water can ingress through the cracks and affect the transmission of light to the underlying cells, leading to output power degradation. Scratches or cracks are also an indicator of poor handling of the module during the manufacturing or transportation process.

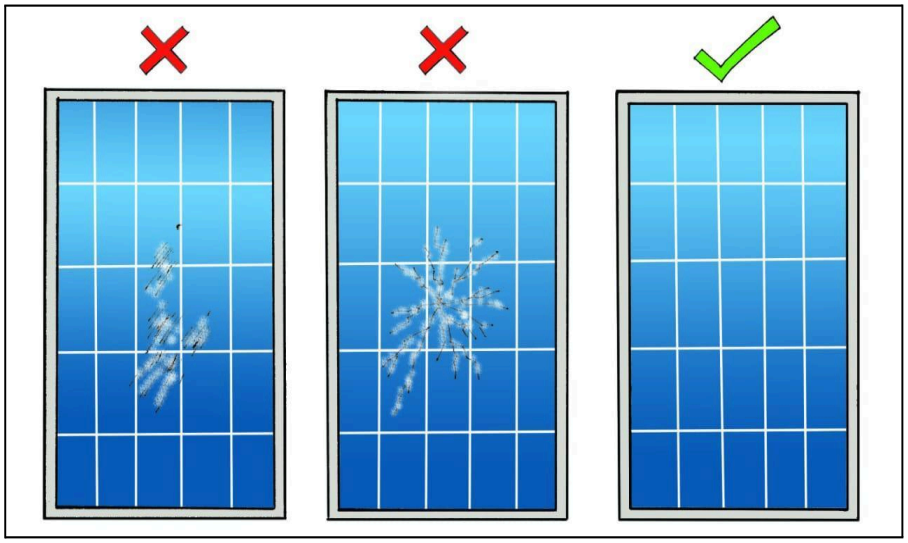

Image 9. Panel with and without defect

8. Installation of the plant :

Following delivery of the material, installation will have to be undertaken by the installers within the time period specified in the quotation. Solar panels are not kept flat but are placed at an angle to capture maximum solar radiation. The angle varies based on the location; in Tamil Nadu, the angle is generally between 11 to 13 degrees. The panels are installed with north-south orientation (ref below image), to avoid shadows falling on the solar panels, and to enhance power generation.

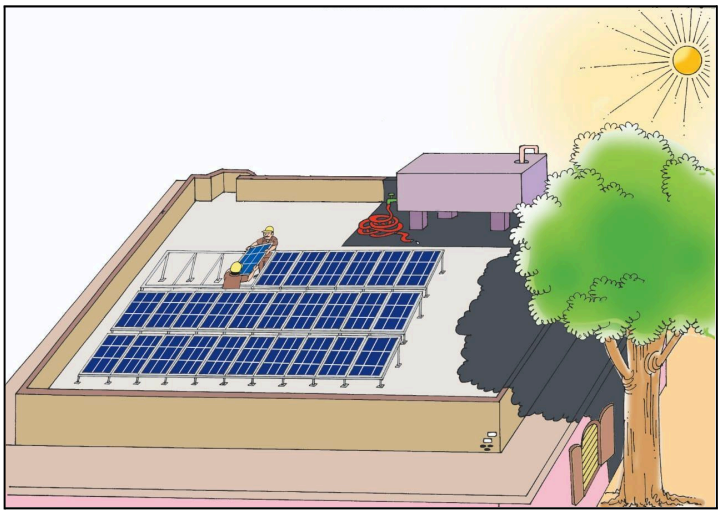

Image 10. Installation of solar panels

It is advisable to mount the panels on a concrete surface so as to increase its resilience against weather conditions such as strong winds.

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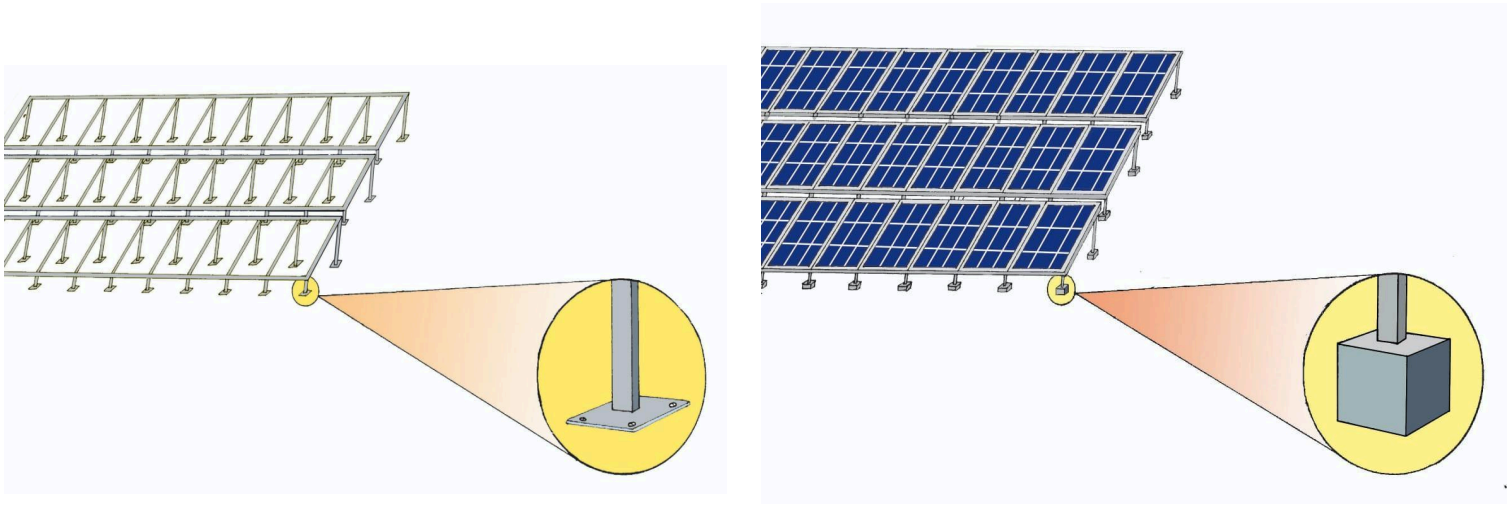


Image 11. *Mounting structure with and without the concrete*

9. Solar PV Models

Roof top solar PV systems generate electricity for onsite usage and for export to the grid. There are two types of grid connected solar PV models widely used:

1. Gross feed model
2. Net metering model

➢ **Gross feed model**

Gross feed[24] based solar rooftop systems consist of grid connected solar rooftop systems, which feed all the energy generated to the grid. Further, the consumer will be paid for sold energy at an applicable feed-in tariff for as per TNERC (i.e ₹3.61 per unit upto 10 kW capacity).

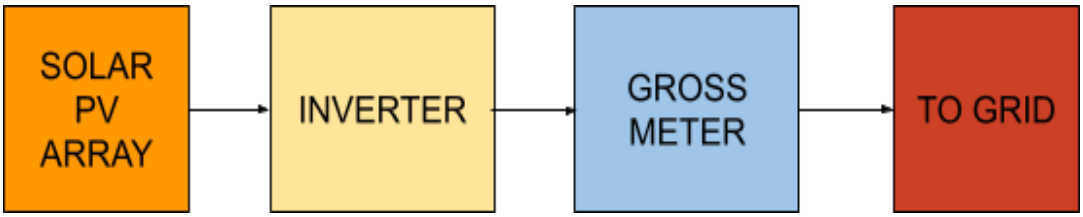


Image 12. Schematic representation of gross feed model

➢ **Net Metering Model**

In this type, a PV system directly connected to the grid, uses grid connected inverters. This type of system is capable of exporting surplus power into the grid. The connectivity to the grid allows the

[24] https://spc.net.in/understanding-net-metering-and-gross-metering-in-solar-power-plants/

consumer to avoid the investment on battery storage. Bi-directional meters[25] are used to quantify the export and import of energy.

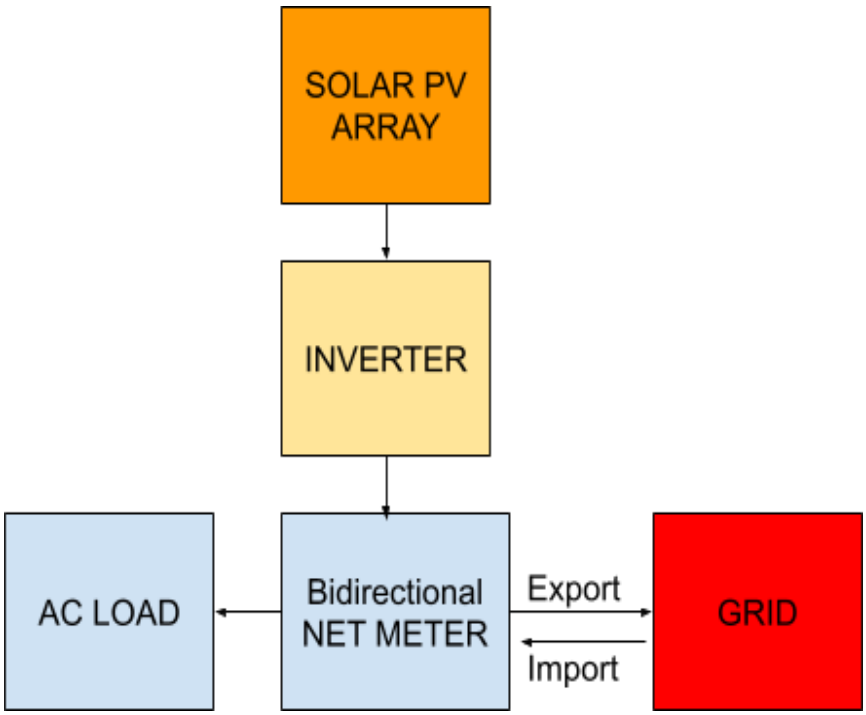


Image 13. Schematic representation of net metering model

10. Energy Meters and Billing Mechanisms

According to the TNERC Order[26] issued in March 2019, consumers wishing to install grid connected rooftop solar have to install two meters namely, solar generation meter and bi-directional meter.

- **Bi-directional meter:** The bi-directional meter is used to measure the amount of power imported from the grid as well as the power exported from the solar panel.
- **Solar generation meter:** The generation meter is used to measure the amount of solar energy generated by the plant.

Normally, the meter installed by TNPDCL is an unidirectional meter which records the power consumed by the consumer from the grid. However it is not programmed to record separately any power produced from solar panels and exported to the grid. This is because the unidirectional meter can account for a unidirectional flow of power rather than a bidirectional flow. Thus, in case of solar generation, an unidirectional meter will record both import and export of power, as consumed. This leads to a higher electricity bill.

To overcome this difficulty, a bidirectional meter is required to be installed as it has the capability to record both import and export of power separately. The bidirectional meters are installed by

[25] https://spc.net.in/understanding-net-metering-and-gross-metering-in-solar-power-plants/
[26] http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf

TNPDCL as per TNERC Order. TNPDCL will buy the meter and also test it before installation. The cost of the bidirectional meter including its testing and installation charges will have to be borne by the consumer.

A. Applicability of Net meter

According to the TNERC Order[27] issued in October 2021, the applicability of net metering is as follows,

- If you registered as a new domestic consumer after 22.10.2021, you can use the net metering system up to the level of sanctioned load/ contracted demand. .
- Domestic consumers who were given the solar net-feed-in facility under TNERC Order No.3 of 2019 can switch to the solar energy net metering system mentioned in this Order to ensure fairness among consumers in the same category.

ACTIVITY	RESPONSIBILITY	TIMELINE
Submission of NEM Application	CONSUMER	Zero Date
Acknowledgment of NEM Application from TNPDCL to Consumer	TNPDCL	1-2 Working Days
Site Verification / Technical Feasibility Leading to Issuance of Letter of Approval (LOA) / Termination[a]	TNPDCL	7-15 Working Days (Varies as per capacity)
Submission of Application of Subsidy	CONSUMER	Zero Date for Subsidy Process (On receipt of LOA from DISCOM)
Acknowledgment of Subsidy Application from State Nodal Agency (SNA) to Consumer	SNA	1-2 Working Days
In-Principle Approval for Subsidy	SNA	10 Working Days
Execution of Net Metering Agreement	TNPDCL & CONSUMER	15 - 20 Working Days
Installation of Rooftop Solar System	CONSUMER	90 - 180 Days (Varies as per capacity – AVERAGE – 100 DAYS)
Meter Procurement Intimation	CONSUMER	15 Days (prior intimating

[27] https://www.tnebltd.gov.in/usrp/Salientfeatures.pdf

		DISCOM on system readiness)
Submit Work Completion Report / Certificate	CONSUMER	As per timeline stipulated in LOA
Inspection by Chief Electrical Inspectorate to government (CEIG)	CEIG	15 -20 Working Days
Issuance of Safety Certificate	CEIG	5 – 10 Working Days Issued by Chief Electrical Inspectorate
Intimation to Install Meter	CONSUMER	7 - 10 Working Days
Inspection by DISCOM Installation of Meter [b] and Commissioning of the System (after receiving Installation Completion and Safety Certificate)	TNPDCL	15 - 20 Working Days (for systems not requiring CEIG approval) And 30 Working Days (for systems requiring CEIG approval)
Inspection for Release of Subsidy[c]	SNA	7 -10 Working Days
Release of Subsidy	SNA	5 -10 Working Days
Billing Process	TNPDCL	1 Month After synchronisation with Grid
Net Metering Adjustment Energy Consumption	TNPDCL	Monthly basis

Table 1: *Procedure[28] for getting Net Energy Meter (NEM)*

Note:

- [a]TNPDCL to communicate deficiencies to consumers and provide an opportunity to resolve them.
- [b]TNPDCL may provide a window of 15 days for consumers to resolve deficiencies found during inspection.
- [c]Joint Inspection by SNA, CEIG and TNPDCL can reduce the timelines substantially. If TNPDCL has no stock of meters, consumers will purchase the same upon intimation by TNPDCL. Inspection dates to be provided within 7 days by SNA, CEIG and TNPDCL from the date of receipt of request for inspection sent by the consumer.

[28] https://solarrooftop.pmsuryaghar.gov.in/knowledge/file-24.pdf

After installation, the installer should give the following documents which are to be uploaded by the consumer on the site https://www.pmsuryaghar.gov.in/consumerLogin, using consumer login credentials.

a) System description: It includes the specifications of solar panel and inverter used in the plant;

b) System single line diagram: It determines the design of the rooftop solar plant. It shows the solar PV array, inverter, combiner boxes, meters and the connections between them in a simple line;

c) Solar PV array layout: Solar array is a group of solar panels arranged in a way to capture more sunlight to generate maximum output. The schematic representation of the array is known as the solar PV array layout;

d) Routing diagram of cables and wires: The schematic representation of connections between the solar panels, inverter combiner boxes and meters;

e) User manuals of solar PV panels and solar grid inverter, and datasheets: Detailed information and instructions about the solar panels and solar grid inverter, and datasheets to monitor daily generation will be provided by the installer;

f) Contact details of the service centre: Name, address, mobile number and email address of the installer / service center (in case the installer is in a different location) to be contacted in case of failure or complaint;

g) Warranty cards: Warranty cards will ensure the performance of rooftop solar panels over the years; and

h) System operation and maintenance register: Based on the quotation, the installer will visit and check the working of rooftop solar periodically. To record this, a maintenance register will be provided to the consumer. To ensure periodical maintenance, consumers should follow up with the installer and get the possible date for the next maintenance.

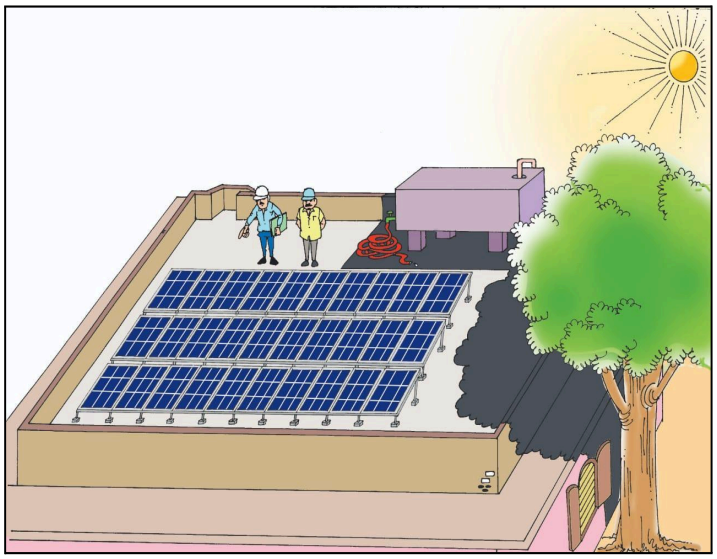


Image 14.Solar panels installed on the premises

B. Applicability of Gross metering

According to the TNERC Order[29] issued in October 2021, the applicability of gross metering is as follows,

- All current and new consumers, except domestic users, along with generators, can use the gross metering system regardless of their tariff. The solar system size for this mechanism must be between 151 kWp and 999 kW.
- LT consumers are not eligible for gross metering.
- New generators who are not existing consumers but want to set up a solar system (GISS) on a site or in an open area and sell all the generated power to the Licensee can use the gross metering system for up to 999 kW. There is no limit on the sanctioned load or contracted demand for these cases.

C. Net feed-in and Billing Arrangement

According to the Tamil Nadu Solar Policy 2019, a net feed-in arrangement[30] has been introduced in Tamil Nadu. Under this arrangement,

a. A consumer has to pay for the units of electricity imported from the TNPDCL grid as per the prevailing tariff[31].
b. TNPDCL will pay for the units of electricity exported by the consumer, through generation from rooftop solar panels, to the grid.
c. The result is that, if the net monetary charges of the exported units are higher than imported units, then the difference in charges will be added as credit and carried over to the next billing period for adjustments against subsequent billing. If it is less, a consumer has to pay the difference in charges within the specified period. Energy settlement will be done on a monthly basis. The electricity generated by the rooftop solar system will be utilised for the self consumption by the consumer. The excess unutilized energy flowing into the grid and recorded in the export register of the meter will be credited into the consumer's account at a tariff fixed by TNERC.

   The energy that is imported from the grid by the consumer will be calculated at the appropriate retail tariff and the monetary value of imported energy debited from the available credit on account of exported energy in the respective billing period. Any credit available in the account of the consumer after debiting the value of imported energy will be carried out to the next billing period. If the amount to be debited is higher than the credit in a billing period, the consumer will have to pay the difference in charges. At the end of the settlement period, the monetary value of surplus generation, if any, will be settled by TNPDCL.

[29] https://www.tnebltd.gov.in/usrp/Salientfeatures.pdf
[30] https://energypedia.info/wiki/Feed-in_Tariffs_(FIT)#Advantages_of_feed-in_tariffs
[31] http://www.tangedco.gov.in/linkpdf/ONE_PAGE_STATEMENT.pdf

Per unit price of surplus solar energy exported to the grid by consumers under solar net feed-in is fixed by TNERC[32]. This price is fixed for each financial year by TNERC and takes the lowest price from among the following:

- 75% of the pooled cost of power notified by the Commission for the respective financial year, or
- 75% of last feed in tariff determined by the Commission, or
- 75% of solar tariff discovered in latest bidding.

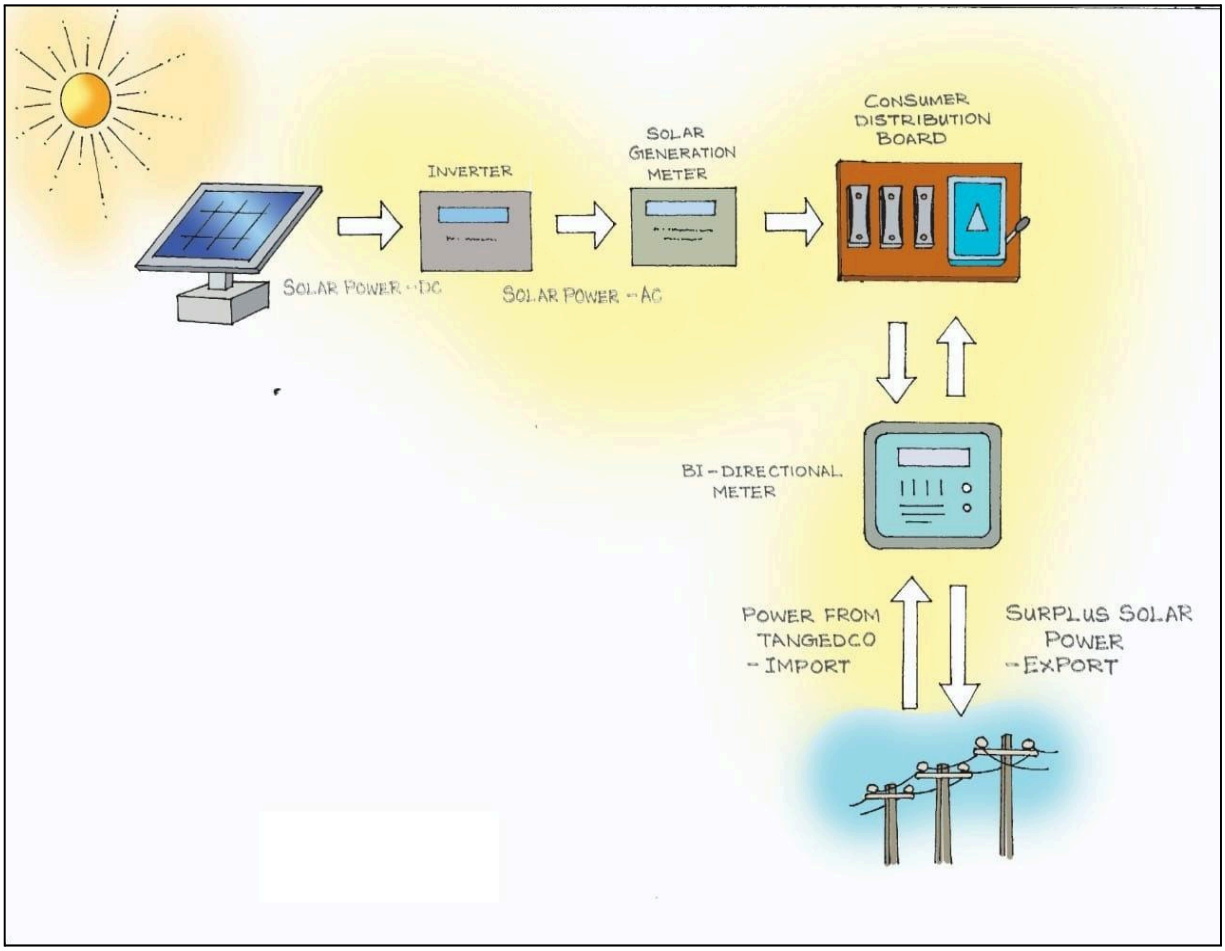


Image 15. Image of a net feed-in solar rooftop system

TNPDCL is currently following the TNERC's Generic Tariff Order for Grid-interactive PV Solar Energy Systems (Order No.8 of 2021, dated 22/10/2021[33]). According to this Order:

- Net-metering is used for domestic consumers.
- Net-feed in is used for all other categories of low tension (L.T) consumers.

[32] http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf
[33] https://www.tnpdcl.org/static/tnpdcl/assets/files/pmsuryaghar/annuxure1.pdf

- For high tension (H.T) consumers, solar capacities from 1 to 999 kW use the net-feeding method.

Net Meter	Net Feed in tariff
• A grid-connected rooftop system operates on a net metering basis. In this system, the consumer pays the utility based on the net meter reading, which is the difference between the imported and exported energy. • If the imported energy exceeds the exported energy, the consumer pays the utility. Conversely, if the exported energy surpasses the imported energy, the utility compensates the consumer for the net energy exported. • All the new domestic consumers registered after 22.10.2021 are eligible for net metering mechanism up to the level of sanctioned load/ contracted demand. • Domestic consumers who have been provided with the solar netfeed-in facility as per TNERC Order No.3 of 2019 shall have the option to migrate to the solar energy net metering mechanism as provided for in this order to avoid discrimination within the same category of consumers.	• Any excess energy generated that is not utilized and flows to the grid at the end of the billing period will be calculated at a tariff set by TNERC and credited to the consumer's account. • The energy imported from the grid by the consumer will be calculated at the appropriate retail tariff, and the monetary value of this imported energy will be debited from the available credit on account of exported energy within the respective billing period. • All electricity consumer categories (except hut and agriculture) irrespective of tariff and voltage levels up to the level of sanctioned load/contracted demand up to a maximum capacity of 999 KW are eligible for solar energy net billing or net feed-in mechanism

Table 2: *Difference between net meter and net feed-in methods*

Based on the above, in October 2021 the rooftop solar tariff for exported power has been fixed at Rs. 3.61 per unit[34] up to 10 kW; 3.37 per unit from 11 kW to 150 kW and 3.10 per unit from 151 kW to 999 kW for the exported power. This solar net feed-in tariff is applicable for the life of the grid-connected solar system.

According to the TNERC Order[35] issued in October 2021, the applicability of net feed-in connection now extends to all electricity consumers (except for hut and agriculture categories). No matter their tariff or voltage levels, consumers can use the solar energy net billing or net feed-in system for up to 999 kW, as long as it is within their allowed or agreed electricity usage limit.

[34] https://www.tnerc.tn.gov.in/Orders/files/TO-Order%20No%20251020211341.pdf
[35] https://www.tnebltd.gov.in/usrp/Salientfeatures.pdf

Application process of net feed-in

The application process for net feed-in is as follows,

- Application for Solar Power connectivity (Annexure 1) to be submitted to the respective Section Officer/Designated Officer of TNPDCL along with a registration fee of Rs. 100. The TNPDCL has to acknowledge receipt of the application (Annexure 2);
- Both the applicant and TNPDCL should sign a net feed-in connection agreement.
- TNPDCL is mandated to install the required energy meters and commission the solar metering facility within three weeks from the date of application by the consumer; and TNPDL should update the billing system with relevant details about net feed in scheme of consumer. Further, the billing data of consumers shall be made online.

D. Billing Procedure:

The total price of exported power will be calculated by multiplying the number of units exported and per unit net feed-in price fixed for the consumer category upto 150 kW capacity. This will be considered as credit.

The total cost for import will be calculated based on the present tariff, as mentioned in the previous section. This will be considered as debit. During every billing cycle (i.e., bi-monthly), the billing will be done as follows:

- If the cost of debit is greater than credit, then the consumer needs to pay the excess debit amount. (i.e., bill amount in INR = debit – credit)

Example 1

Solar net meter	Import (Units)	400
	Export (Units)	350

Debit (for 400 units) = ₹1348 ; Credit (for 350 units) = ₹1180
Bill amount =₹168
Therefore, the consumer would have to pay ₹168 for this billing cycle

- If credit is greater than the debit, then exceeded credit will be added in the consumer's account. It will be adjusted in the next billing cycle, if required. Otherwise, it will be carried forward in the consumers' account.

Example 2

Solar net meter	Import (Units)	400
	Export (Units)	600

Debit (for 400 units) = ₹1348; credit (for 600 units) = ₹2022

The consumer has a credit value of ₹674 and this will be adjusted during the subsequent billing cycle or will be carried forward in the consumer's account. This process will continue until the end of the settlement period, which is 12 months (i.e., 1 April to 31 March).

At the end of the settlement period, the credit i.e., the net units of surplus generation available, if any, shall get lapsed. If the consumption is more than the generation in any given billing cycle, the net consumption units shall be charged under retail tariff fixed by the Commission from time to time.

11. Energy Meters Tariffs

As per Tamil Nadu Electricity Regulatory Commision (TNERC), Grid Interactive Solar PV energy generating System (GISS) Regulation 2021, the eligible feed in tariff for different energy meters is as follows,

Category	Eligibility	Metering Mechanism			Network Charges	Feed in Tariff		
		Net Metering	Net feed in	Gross metering		0-10 kW	11-150 kW	151-999 kW
Domestic LT	Upto sanctioned load	✔	✔	×	20 % of ₹ 1.53 (upto 10kW), 75% of ₹ 1.48 (Above 10kW)			
Other than domestic in LT	Upto sanctioned load	×	✔	×	₹ 1.53 per unit on total generation	₹ 3.61	₹ 3.37	
Consumers of more than 150 kW	151-999 kW	×	✔	✔	₹ 0.96 per unit for net feed in, No charges for gross metering			₹ 3.10
Generator other than consumer	151-999 kW	×	×	✔	Nil			

Table 3: *Energy meter tariffs*

Note: The Network charges towards the Distribution wire business are chargeable to HT prosumers at 83 Paise / kWh and for LT prosumers at Rs.1.27 / kWh. This charge is applicable to all existing

and new prosumers as specified under respective categories until the 'Network. Network charges are not applicable to Gross metering mechanisms.

12. PM Surya Ghar Scheme

An initiative by the central government, the PM Solar Ghar Scheme[36], promotes rooftop solar (RTS) to encourage the use of renewable energy. Reduced electricity costs, increased household access to solar energy, and improved environmental outcomes are the goals of this program. Across India, 1 crore households are anticipated to benefit from this scheme. The government is expected to save Rs. 75,000 crore in electricity costs annually.

Objectives

- ***Promote Renewable Energy***: Support solar energy use as a sustainable and clean energy source.
- ***Reduce Electricity Costs***: By producing their own electricity, households can reduce their electricity costs.
- ***Environmental Benefits***: Make an effort to lessen the reliance on fossil fuels and carbon emissions.
- ***Energy Security***: Improve energy security by adding renewable energy sources to the energy mix.

Eligibilty

- ***Residential Property***: The applicant must own a residential property with a suitable rooftop for solar panel installation.
- ***Grid Connection***: The property should be connected to the local electricity grid.
- ***Compliance***: The installation must comply with the technical and safety standards specified by the government.

Subsidy Structure

1. Subsidy for residential households installing RTS
   Financial incentives provided to the residential households based on the installed RTS capacity is as detailed in table below:

Solar rooftop capacity	Subsidy Support from government
1 kW	₹ 30000/-
2 kW	₹ 60000/-
3 kW and Above	₹ 78000/- Maximum

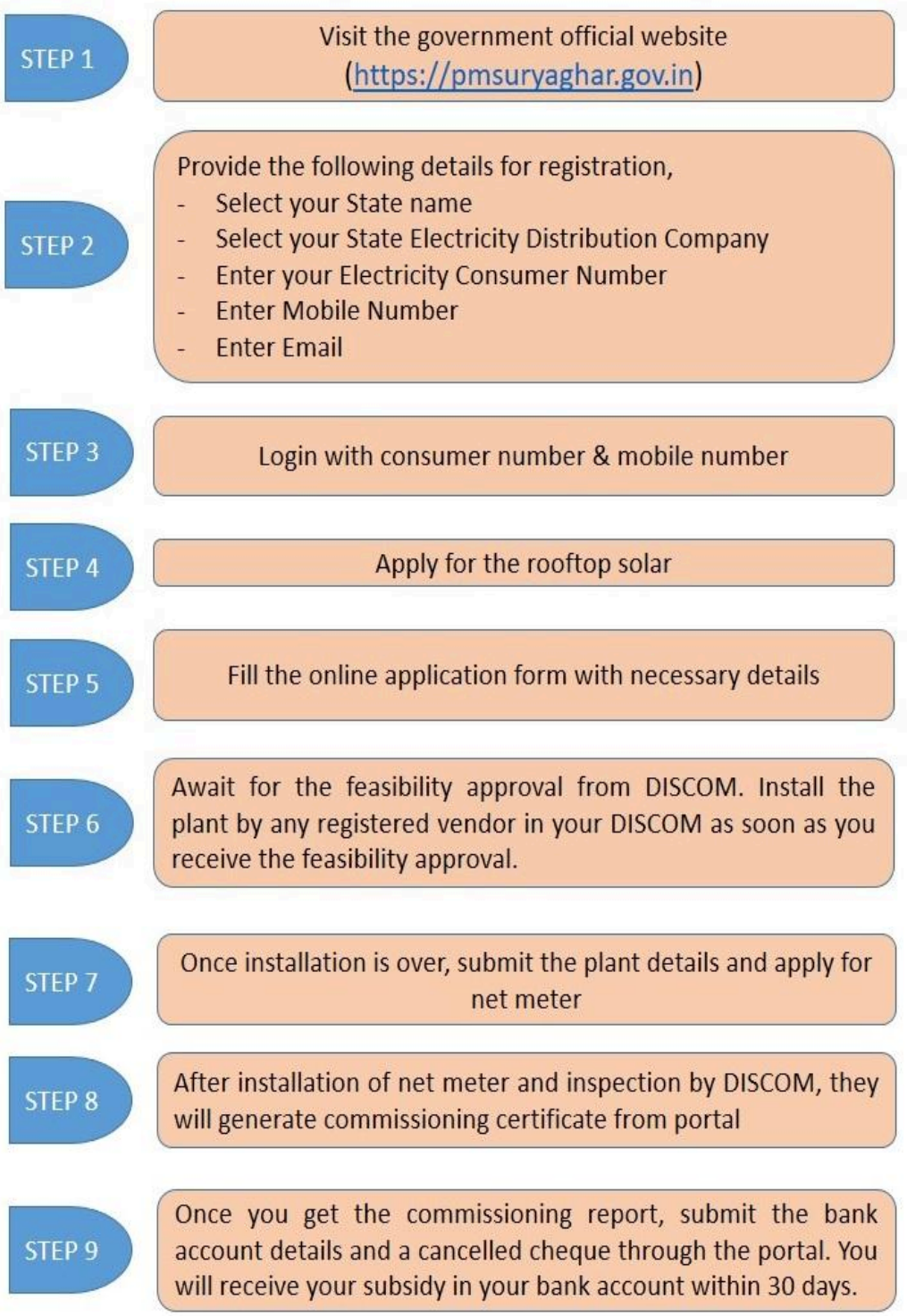
[36] https://www.pmsuryaghar.gov.in/

2. Subsidy for Group Housing Society/ Resident Welfare Association [Eg: Apartments]

   Subsidy available for RTS installation to power common facilities in apartments including EV charging is ₹18000/- per kW, up to the upper limit of 500 kW capacity (inclusive of rooftop plants installed by individual residents (at 3kW per house in the apartment) in the apartment). In addition to the RTS installation for independent residential households, this scheme provides subsidies for group housing societies (i.e: Apartments). For RTS powered Electric Vehicle charging in an apartment block a financial incentive of ₹ 18000/- per kW will be provided. However, the total RTS installed capacity of the apartment block should be more than 500 kW, at the same time RTS installed by individual houses in the Apartment should not be more than 3 kW.

Steps involved in the application process of PM Surya Ghar scheme

The steps involved in the application of rooftop solar under PM Surya Ghar Scheme is illustrated below:



13. Reasons for performance reduction

The performance of solar panels can be affected by a variety of factors, leading to reduced efficiency over time. Accumulation of dust, dirt, and debris on the surface of the panels can obstruct sunlight, limiting energy production. Shade from nearby trees, buildings, or other structures can also block sunlight, further diminishing performance. Lastly, mismatch of panels can cause inefficiencies, further contributing to the reduction in performance. Regular maintenance and optimal installation conditions are essential to mitigate these issues and ensure maximum efficiency.

➢ ***Accumulation of dust particles***

- Reduces the power output.

Trained persons are essential for proper cleaning of PV modules.

Example:

Assume, if cleaned module generates 1000 units for a month

Dust accumulated module may generate 700 units approximately

Thus, units gained by keeping surface clean is 300 Units

Monthly Savings = 300 * 4.8 = 1440/-

➢ ***Shading of Modules.***

- PV modules generate electricity based on solar irradiance.
- If the irradiance is restricted by trees, building structures etc., it will reduce the power output.

Example:

Assume, if unshaded module generates 210 Units for a month

Shaded module may generate 120 Units approximately

Thus, units gained = 90 Units

Monthly Savings = 90 * 4.8 = 432/-

➢ ***Mismatch modules***

Solar panels should be identical in terms of electrical parameters to achieve a high power output. Without this, the resultant current will be limited to a lower rating.

- Mismatch fault may be caused by interconnection mismatch of solar cells and modules.

14. Troubleshooting and fixing rooftop solar photovoltaic systems

Troubleshooting involves identifying and resolving issues that could impact the efficiency or safety of a rooftop solar system. While solar power systems are generally reliable, factors such as environmental conditions, subpar installation, or component deterioration can lead to various issues over time. Here are some common problems with rooftop solar systems and suggested troubleshooting techniques:

(i) Shading: The panels may not be receiving enough sunlight due to the hindrance of trees, nearby building structures, or debris like leaves. This leads to the impact of the overall solar power generation from the solar photovoltaic system. Solar panels are generally connected in series or parallel wiring [37] configurations based on the output constraints. In case of series connection, the current remains constant across all panels, but the voltage adds up. In this case, if any of the connected panels is shaded, it can reduce the output of the entire string of panels. This is because the current passing through the unshaded panels is reduced to the value of the shaded panel.

Image 16. Shading of solar pane | *Source*

In the case of parallel connection, voltage remains constant across all the panels, but the current adds up. If any panel is shaded, it affects only the output of that specific panel, while other panels continue to operate at their maximum capacity. However, the disadvantages are this configuration requires thicker cables, more complex installation and can create lesser power output in early mornings and late afternoons.

For example, consider a solar panel consisting of 36 cells connected in series connection, each cell capable of producing 0.5 V and 5 A

Under full sunshine condition:

Total power output of the panel = 36 x 0.5 x 5 = 90 W

Undershaded condition:

Now, assume 4 cells out of 36 are shaded, reducing their current output to 1 A while the voltage remains at 0.5 V. It is important to note that in series connection current of the entire spring reduces the current of the shaded cell.

Total power output of the panel = 36 x 0.5 x 1 = 18 W

[37] https://blog.santansolar.com/blog-listing/series-vs-parallel-shading

Therefore the power loss = 90 - 18 = 72 W

Thus, the power loss percentage is 80%. It implies that just shading of 4 cells resulted in huge power loss.

***Solutions**:*

Bypass diodes[38] are utilized to bypass the current around the shaded cell and prevent the entire string from being affected. With the inclusion of bypass diodes in the solar photovoltaic system, the loss due to shaded cells will be restricted.

Inclusion of microinverters[39] allow each panel or cell group to operate independently, significantly reducing the impact of shading.

Trees close to the solar PV system installation need to be trimmed on a regular basis to avoid shading.

Impurities such as dust, bird droppings, or other debris can hinder the absorption of sunlight. Use water or a non-abrasive solution to clean the panels.

(ii) Improper Installation: Improper installation of solar panels can lead to underrated power output. Improper installation issues include wrong tilt angle, improper orientation and choosing of poor air circulation zone.

Image 17. Installation of solar panel | Source

For Example, consider the below specification:

Solar panel capacity = 500 W;
Chennai Location: Latitude = 13° N;
Optimal tilt angle for chennai location = 13° south direction facing (Because chennai located north of equator),

[38] https://www.electronics-tutorials.ws/diode/bypass-diodes.html
[39] https://www.energysage.com/solar/microinverters-overview/

Maximum solar irradiance = 1000 W/m^2
Operating efficiency = 18%

If solar panels were installed at 20° south facing instead of optimal 13° south facing, it would cause inadequate sunlight capture (Let's assume 15% drop due to improper tilt angle installation).

If solar panels were installed southeast facing instead of south facing, it would cause inadequate sunlight capture (Let's assume a 10% drop due to improper orientation).

Cumulative efficiency loss =(1 - ((1 - 0.15) x(1 - 0.90))) x 100 = 23.5%
Therefore, Actual power = Panel capacity x (1 - Cumulative efficiency loss)
= 500 x (1 - 0.235) = 382.5 W

Percentage of power loss = [(500 - 382.5) / 500] x 100 = 23.5 %. It implies that due to improper installation the power output of the system is affected significantly. Further, the financial loss from such inefficiencies can be substantial over the lifespan of the panel.

Solutions:

- Usage of instruments (solar pathfinders[40]) to accurately determine the optimal tilt angle and orientation of the solar panel.
- Proper selection of airflow location for the installation.
- Engaging professionals during installation and commissioning.
- Regular inspection to maintain optimal performance.

(iii) Problems with the Inverter[41]: The inverter changes the direct current (DC) from the solar panels into alternating current (AC). Power generation may be impacted if the inverter malfunctions. Examine the inverter for any error codes or lights, and refer to the owner's manual for details on how to fix any problems.

For example, if the inverter is undersized (eg: 2 kW) instead of the required size of 3 kW, then during peak sunshine hours, solar panels may produce above 2 kW. In this the instance inverter clips the excess produced power.

(i) Power output : Inverter without clipping
Energy = Panel capacity x operating Hours x Inverter Efficiency
= 3000 W x 5 hours x 0.95 = 14250 = 14.25 kWh

(ii) Power output : Inverter with clipping
Assume panels produce above 2 kW for 2 hours per day during peak irradiance period
Clipping loss = (Panel capacity - Inverter capacity) x Clipping Duration

[40] https://sinovoltaics.com/learning-center/technologies/solar-pathfinder-what-is-it-and-how-does-it-work/
[41] https://igrowattinverter.com/solar-inverter-problems/

= (3000 - 2000) x 2 = 2000 Wh / day = 2 kWh / day

Actual Energy due improper inverter capacity = 14.25 - 2 = 12.25 kWh / day

Percentage loss = (2000 / 14250) x 100 = 14.035 %.

(iv) Degradation[42]: Over time, solar panels produce less electricity because they wear out naturally, face weather conditions, and have material limitations.

For example, consider an initial panel capacity of 10 kW, with a degradation rate at 0.5% per year, lifespan of 25 years, and annual solar irradiance = 1500 kWh per kW panel.

Initial energy output (In First Year)

Energy output = Capacity x Solar Irradiance = 10 x 1500 = 15000 kWh per year

Energy output (In Twenty fifth Year)

Degraded capacity = Capacity x [(1- Degradation percentage)^n] ; where n - year

= 10 x [(1 - 0.005)^25] = 8.82 kW

Therefore energy output at twenty fifth year, = 8.82 x 1500 = 13230 kWh per year

Total Loss due to degradation of panel = (15000 - 13230) x 25 = 44250 kWh

***Solution*:**

1. Install a monitoring system to track daily and annual output.
2. Compare the present performance with rated values.
3. Inspect the areas with heat concentration, often caused by microcracks or dirt.
4. Use thermal imaging cameras to monitor hot spots and replace damaged panels.
5. Check the manufacturer's performance warranty. File claims if the degradation exceeds warranty limits.

(v) No generation of electricity during sunshine hours

If the system does not generate enough electricity during the sunshine hours, possible reasons and solutions are listed below,

- **Disconnected or Damaged Cables**: Check wiring connections (loose or damaged cables), particularly those that run between the inverter and the panels. .
- **Blown Fuse or Tripped Breaker**: Check the breaker panel or fuse box for any blown fuses or tripped breakers. As necessary, change or reset them.
- **Damage to Panels**: Examine the panels for any obvious damage, such as discolouration or cracks. It might be necessary to replace damaged panels.

[42] https://waaree.com/blog/solar-panels-degradation

(vi) Reasons for inverter not operating

- **Inadequate Voltage**: The inverter in rooftop systems needs a specific voltage to operate. The system might not turn on if it is not producing the necessary voltage. This can be the result of inadequate sunlight or shadows.
- **Inverter Temperature**: Installing inverters in poorly ventilated areas can cause them to overheat. Make sure there is enough ventilation and shade for the inverter. It might be necessary to replace the fans in some inverters.
- **Component Failure**: Especially in older inverters, capacitors and other internal parts may deteriorate over time. Get in touch with an expert for replacement or repairs.

(vii) Electrical fault

- **Electrical Short Circuit**: When an electrical current leaks to the ground, it can result in a ground fault and be hazardous. When this happens, built-in safety features in solar systems—such as ground fault protection devices—switch the system off. Check for loose connections or broken wires, and have a qualified technician make necessary repairs.

(viii) Ambient temperature

- Moderate temperatures are ideal for solar panel performance. Their effectiveness may be lowered by excessive heat. Make sure there is enough ventilation for cooling beneath the panels. If the overheating doesn't go away, you might want to buy panels that are made to handle high temperatures better.

(ix) Regular Monitoring of system performance

- **Bugs in software**: Updates or resets may be required for the monitoring platform. To find out about updates or troubleshooting procedures, contact the software provider.
- **Network Connection Issues**: Data transmission may be impacted by connectivity issues if the monitoring system uses Wi-Fi or another network. Change the router's settings or re-connect the device to the network.

Annexure 1

ROOF TOP Solar Net feed-in Connection Application.

Photo of applicant

To
The Executive Engineer,
O & M / _ _ _ _ _ _ _

I / we herewith apply for a Roof top solar energy net feed - in connection at the service connection and for the solar PV plant of which details are given below:

1. Name of applicant
2. Address of applicant
3. Service connection number
4. Service connection tariff
5. Telephone number(s)
6. Email ID
7. Solar PV plant capacity (Watts)
8. Solar grid inverter make and type
9. Solar grid inverter has automatic isolation protection (Y/N)?
10. Has a Solar Generation Meter been installed (Y/N)?.
11. Expected date of commissioning of solar PV system.

Name:
Signature

Date:

Annexure 2

Net feed-in connection Application Acknowledgement

Received an application for a Roof top solar energy net feed-in connection from,

(To be filled by the applicant)

Name.

Date:

Service Connection number:

Solar Plant Capacity:

Your application for setting up of solar grid interactive roof-top and small SPV power plant under policy on Rooftop Solar Net feed-in connection in accordance with TNERC Order No.03/2019 dt.25.03.2019 has been received along with registration fee.

(To be filled in office).

The details of payment are as below:

Application registration no.:

Signature:

Name of Officer:

Checklist for choosing an installer

1	Ensure that the solar panel and its components mentioned in the quotation comply with MNRE standards	
2	Ensure that the performance warranty for the panels have been mentioned.	
3	Quotation should mention that solar panels have an efficiency greater than 17%	
4	Mounting structures should: ● Withstand the wind speed of 150 km per hour; ● Be made of hot dipped galvanised steel with a minimum galvanisation thickness of 120 microns or aluminium alloy; and ● Be made of anodised aluminium, if the premises is located near the seashore.	
5	Inverter should have: ● Minimum warranty of 5 years; ● Working efficiency greater than or equal to 95%; and ● Withstand the temperature range of -10°C to +60°C	
6	Additional requirements (if any) mentioned by the installer should include: ● Civil structures ● Electrical works	
7	Advance amount to be paid should be mentioned in payment terms and conditions.	
8	Provision for online monitoring of solar generation data	
9	Annual Maintenance Contract (AMC) including the base price and services covered under or excluded	
10	Confirmation of post installation service ● Point of contact for issues ● Identification of performance issues ● Timeline for attending to the issue ● Additional charges, if any.	

CAG
Citizen consumer and civic Action Group
No.103 (First Floor), Eldams Road, Teynampet, Chennai 600 018
T: +91(44) 2435 4458 | 2435 0387
helpdesk@cag.org.in
www.cag.org.in
@CAGChennai