MAXIMIZING Solar Power Generation

Making Use of Existing Roofs

In this article, **Satish N Diwakar** outlines various aspects of solar photovoltaic (SPV) systems on rooftops, including evaluation of existing roofs where SPV systems can be safely installed.

The demand for power in India is increasing with the growing population and the aspiration to become a developed nation. Hence, it has become necessary to explore the viability of power generation using renewable energy sources such as solar power since climate change is forcing us to bring down the dependency on fossil fuels.

India has high solar insolation, which provides a favourable condition for generating solar power. A huge potential is available for generating solar power using the unutilized existing and new roof spaces of industrial, commercial, educational, and residential buildings, or any other type of roof spaces available on buildings. Solar power can be used partially to cater to the captive power requirement of the individual facility or building and any excess power can be fed to the grid (on-grid system). So the best suitable long-term solution in India would be to install efficient individual rooftop power-generation systems to minimize the dependency on conventional power.

SOLAR POTENTIAL IN INDIA

Geographically, India falls in the bright sunny region of the world. Most parts of India receive solar radiation of approximately 4.7 kWh/m^2/day with 300–325 sunny days in a year. The Ministry of

New and Renewable Energy (MNRE) has been facilitating different initiatives for harnessing renewable energy in lighting, cooking, and motive power in rural areas, as well as in urban, industrial, and commercial applications. To maximize the use of solar power, the ministry is making all efforts in rural and urban areas to create awareness of the benefits of solar power. However, users might have apprehensions related to power output (yield) viś-a-viś roof area availability, strength of roof, cost of installation (including cost of roof strengthening, if any), payback period, installation and maintenance, and so on.

REQUIREMENTS: ROOFTOP SOLAR

A rooftop SPV installation consists of PV panels assembled in arrays, mounting frames to fix the panels on the roof, wiring, inverters, and other components depending on the type of installation. Battery back-up is an optional feature and can be provided depending on the requirement where grid power supply is expected to be intermittent.

The roof must be able to accommodate and support the components of the SPV system safely. To achieve this, the following minimum requirements should be met to fetch maximum benefit.

- *Desired captive power requirement:* It is necessary to assess the power that would be needed to meet the captive requirement and whether adequate roof area is available to generate such power considering the efficiencies of SPV modules.
- *Accessibility:* The roof must be accessible to carry out installation and maintenance of the panels. It should facilitate lifting and staking of the solar system components onto the roof and personnel to access the work area to install and maintain the system. A walkway between SPV panels needs to be provided for movement during and after the erection of SPV modules.
- *Roof configuration:* The roof plan configuration should be studied to know its location (including longitude and latitude), height, and slope, as well as any facilities already present on the roof. It is also very important to know the possible usage of the roof in the future, such as installation of water tank, water heater, any equipment, or communication antennae for calculating the space available for installation of SPV modules. Since India is in the northern hemisphere, the roof surface facing south or south-east direction is preferred for maximum power generation. Frame-mounted SPV panels facing south or south-east direction may be provided wherever roof slopes face other than south or south-east direction.

- *Solar orientation and shading:* It is preferred to have shade-free roof area for maximum utilization of SPV system. Roof area may get shaded due to the presence of adjoining buildings or trees or any other obstruction, which may lead to lower power output of the SPV system. Although shading changes during the year, observing the roof at different times during a day gives a fairly good idea of the approximate number of sunlight hours and the effective roof area that can be used for power generation. A sun path trajectory analysis for the entire year may also be performed to check shadow envelope.
- *Residual life of the roof:* The design life of an SPV system is estimated to be 25 years. Any existing roof having a residual life of at least 15 years should be considered for SPV installation for reaping maximum benefit as the payback period of SPV installation is generally between 5 and 7 years.
- *Aesthetics:* One needs to check whether SPV modules would affect the overall aesthetics of the building. From the road level, solar modules will be more visible on a sloped roof than on a flat roof. One may adopt a suitable design to camouflage SPV panels on sloping roofs without compromising the overall aesthetics of the building.
- *Maintenance:* Rooftop solar systems require regular maintenance after installation. The maintenance plan typically involves regular cleaning of the solar panels, checking and tightening of connections, servicing electrical accessories in the system, including the inverter, and regularly monitoring the output of the system. The cost of maintenance will be less in the initial period after the installation and will increase with the age of the system due to reduction in panel efficiency. The approximate maintenance cost is 2% per annum of the capital cost of the system installation.

EVALUATION OF AN EXISTING ROOF FOR SPV INSTALLATION

As mentioned earlier, any well-maintained roof having a residual life of at least 15 years can be considered for SPV installation. A structural evaluation should be carried out to assess the strength of the roof and the roof-supporting structure to sustain additional loads (30–50 kg/m^2) of the SPV system. If required, necessary repairs/replacements and strengthening measures should be adopted in order to achieve the required minimum strength and life of the roof.

Generally, in India sloped roofs are designed for live loads as per IS-875. When part of the roof area is occupied by SPV modules, the roof area may not experience the design live load. Since the load due to the SPV system is less than the design live load, it is safe to assume the additional weight of SPV panels as part of the live load on the roof and no additional load is required to be considered due to SPV modules. However, the load-carrying capacity of roof panels should be assessed for concentrated loads due to the SPV panel mounting frames.

Rooftop solar mountings should resist wind pressure acting below the panels during cyclones. This is a critical design consideration if the site is located in a cyclone-prone area. The type of mountings to be selected for supporting panels must be discussed with the SPV system supplier.

If the roof is required to be strengthened, then the project viability and payback period for solar installation should be calculated considering the cost of strengthening the roof and the roof-supporting structure. In the case of extensive rehabilitation cost and longer payback period (more than 7 years), the SPV installation may not be commercially viable. However, the decision to install SPV systems on existing roofs should be taken after proper commercial diligence.

Based on the available drawings and documents, the structural health of a roof should be determined considering the additional loads due to wind acting on the supporting structure of the SPV panel. In situ inspection and non-destructive testing may also be needed in certain cases to ensure structural adequacy.

The structural health analysis report should clearly indicate whether the roof is adequately strong to sustain additional loads throughout its balance life or any structural modifications required to ensure the desired life. If roof space is being leased out to a third party to install solar systems, the owner should appoint an architect or a structural engineer and a legal advisor who would confirm the feasibility of considering the roof for solar installation from structural and statutory aspects, respectively.

SLOPING METAL ROOF

These roofs should also be inspected to see any distress such as excessive deformations, open seams, and presence of water ponding due to sagging of roof sheets. The roof and roof-supporting structure should be inspected to check for any sag and other abnormalities. A sag or depression may indicate a structural deformation that may require further investigation and rehabilitation.

When evaluating the health of an existing roof for PV installation, factors such as the load-carrying capacity of the primary and secondary members, the type of roofing system (standing seam, corrugated, or trapezoidal sheet) and slope, the service life of the roof and the consumed life, and wind and seismic loads should be considered.

One of the primary considerations is whether to install a penetrating type or mechanically fastened system on the existing roof. It is preferred to have a non-penetrating system. In the case of standing seam roofs, the installation of SPV panels would be very fast by adopting a non-penetrating system. With standing seam metal roofs, special clamps are fitted over the seam to install the panel, thereby avoiding penetration of the roofing material and eliminating any possibility of leakages. Also, with the non-penetrating system, the leakage warranty of roofing manufacturers or

pre-engineered building (PEB) vendors is not compromised.

For existing low-slope roofs, it is recommended to use non-penetrating systems to avoid leakage issues during monsoon. If penetration is inevitable, then all the required precautions should be taken while fixing the SPV panels to prevent water leakage.

In the case of non-penetrating systems, the strength of the existing roofing material should be assessed by the sheet manufacturer and clear recommendation on whether the existing roofing material is strong enough to withstand panel loads should be provided. The roof sheeting supported over purlins with centre-to-centre distance of up to 1.5 m is considered reasonably safe to support SPV panels. However, a "no-objection" certificate or a "recommendation" from either the sheet manufacturer or the roofing contractor needs to be obtained.

Existing sloped roofs with metal sheets, tiles, or similar materials should be examined to find whether the primary rafters or trusses can support additional weight as per their residual strength available. This exercise is very important from the point of view that many steel buildings nowadays are PEBs, which are designed to the given loads without considering any margins in the loads. If the roofing installation and performance warranties offered by PEB vendors are still valid, check if installation of a rooftop solar system could nullify the performance warranty of the existing roof. A written confirmation should be obtained from the PEB vendor in this regard before making any decisions.

Prior to SPV installation, all the damaged areas should be repaired appropriately, sheeting replaced, structural member strengthened, and open seams sealed to maintain the structural integrity of the roof.

Some of the typical installations on sloped metal roofs are shown in Figure 1.

FLAT CONCRETE ROOF

Generally, a flat or even low-slope concrete terrace roof will normally have the strength to bear the additional weight of the panels and supporting structures.

In the case of flat concrete roofs, the primary concern is the performance warranty of water proofing provided over the roof. The type of water proofing provided over the roof and its slope needs to be examined and recommendation should be obtained from the waterproofing vendor on the modifications of the existing water-proofing system that are required to be carried out.

For fixing the mounting structure of the SPV module on an existing roof, the water-proofing treatment only in the designated area might have to be dismantled and redone with a similar or better water-proofing system. A well-designed framework of fixing arrangement of PV modules (with or without water-proofing modification) is preferred.

It is often seen that utility equipment such as air-handling units, cooling towers,

» **Figure 1** (a) Typical panel clamping detail; (b) Typical panel installation on steep slope; (c) Panels mounted on frames; (d) Panels mounted on low sloped roof

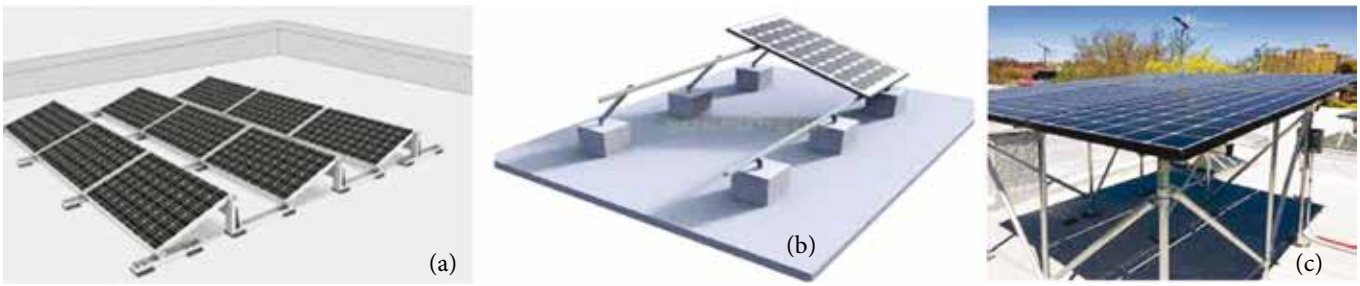

Figure 2 (a) Panels mounted on frames fixed directly on the roof; (b) Panel frames mounted on concrete pedestals; (c) Panels mounted on frames to get a shade-free area for SPV

water heaters, hot water tanks, and pumps are mounted on the roof. In such cases, a proper study of the available area for SPV installation and yield of the SPV system should be carried out. If the required area is not adequate to meet the captive requirement, it may not be viable to install an SPV system.

Some of the typical installations on flat roofs are shown in Figure 2.

CAPITAL COST AND PAYBACK PERIOD

The average shade-free roof area required for a typical 10 kWp SPV power plant is approximately 1000 ft^2 considering 15% panel efficiency. Table 1 gives a fair idea about the area required and desired power for different panel efficiencies.

Table 1: Roof area required for different power outputs

Desired power	1 kW	2 kW	5 kW	10 kW
Panel efficiency	Roof area required in square feet			
12%	125	250	625	1250
13%	115	230	550	1150
14%	107	214	536	1071
15%	100	200	500	1000
16%	94	188	469	938

The estimated cost of an on-grid 1 kWp rooftop SPV plant would be ₹0.9–1.1 lakh (without considering any subsidy and incentive). Similarly, a 1 kWp off-grid system with minimum battery back-up should require ₹1.2–1.7 lakh (without considering any subsidy and incentive) approximately. The above costs would further reduce if subsidies and incentives are considered.

Solar cell efficiencies vary from 6% for amorphous silicon-based solar cells to 44.0% with multiple-junction production cells and 44.4% with multiple dies assembled into a hybrid package. Solar cell efficiencies for commercially available multi-crystalline cells are around 12–16%.

The desired payback period for SPV installation over an existing roof should be between 5 and 7 years considering the efficiency of panels, maintenance cost, various losses in the system, and cost of roof strengthening, if applicable. The financial viability or feasibility of the project is determined through the net present value method.

TRENDS AND DEVELOPMENTS IN SPV SYSTEM AND APPLICATIONS

In the last 5 to 7 years, the solar industry has undergone a sea change in the quality of SPV systems and the type of applications to meet the challenging demands of sustenance. Some of the latest developments in SPV panels include frameless solar panels, clear (glass) solar panels, double-sided solar panels, and so on. The newer constructions in residential and industrial sectors have already commenced installing these SPV systems on the roofs.

In addition to rooftop or ground-mounted solar plants, different solar applications such as floating solar plants, solar installations over water canals, solar trees, and solar roadways are being experimented or piloted, which could transform the solar industry.

CONCLUSION

The Indian government has declared its solar expansion plans of targeting 100 GW of solar capacity, including 40 GW from rooftop solar, by 2022. India has witnessed an exponential growth in the last 5 years. The solar-generation capacity grew from 2650 MW to 12,289 MW during 2014–17. The country added 3.01 GW of solar capacity in 2015/16 and 5.525 GW in 2016/17, the highest of any year.

A rooftop SPV system connected to the grid distribution system and feeding the power in substations or load centres eliminates transmission and distribution losses. Also with grid-connected systems, the cost of batteries for storing power is eliminated. These are the strong reasons for promoting grid-interactive rooftop SPV systems for captive power generation.

Although SPV systems are being installed on the roofs of newer constructions, a large potential is available for generating solar power using unutilized roof spaces. It is now attractive and economical to install SPV systems over existing roofs considering the on-grid system promoted by DISCOMS. While roof is a convenient and suitable place for installing solar panels, a right approach is necessary for ensuring that the serviceability performance of the roof and the warranty offered by contractors for water tightness remain unaffected.

Roof spaces can also be leased out (roof leasing) for generating solar power either for captive requirement or for transmitting back to the grid. AU

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