A BRIEF STUDY OF AN INSTALLATION OF A ROOFTOP SOLAR PV SYSTEM IN INDIA

Karthik Sivaraman[1], Aniket Rawool[2]
Design team
Periurja energy pvt. Ltd.

abstract
Solar rooftop photovoltaic installation is one of the most popular setups used in the country of India, being economical and apt for the space available in the country. This paper focuses on the key aspects of the design involved in the setup of the system, regarding not just the engineering design for a PV system, but also other key components such as installation site evaluation of a given rooftop to the final cost analysis. Hence, the discussion in the paper will give the average understanding of how a rooftop photovoltaic system is processed through in this country from an engineer's point of view.
Keywords – solar; rooftop Photovoltaic; PV system design

Introduction

Solar energy is one of the most popular harnessed form of renewable energy in the globe; Considering its availability in the major section of the globe, outrunning other sources such as availability of wind, water resources as well as natural heat producing elements.
Solar energy as such is a form of energy that can be utilized in the form of either a natural heat source; like the usage in concentrated solar power systems, and the other form being conversion of the light of the sun into electricity, better known as photovoltaics[1]. This paper focuses on the latter, as it is more suitable in a commercial building setup where it would be beneficial to tap in the renewable sources, mostly to save the electricity bill, while doing it greener. The solar photovoltaics has a major advantage compared to other forms of renewable power[6], i.e, once it is setup and installed, it produces no pollution during its operation and on top of it releases no harmful green gas emissions.
The usage of photovoltaics has evolved tremendously over the past decades from a niche of small scale applications such as running a basic calculator or a torch light to a fully emerged mainstream source of electricity. The electricity is the result of a converted light energy using a solar cell, the terminology being photoelectric effect.
The evolution of the solar cell roots back to 1880s, introduced to the planet by Charles Fritts[7]. The technology then evolved further when Dr Bruno Lange, a German engineer developed a photo cell by laying out silver selenide, replacing copper oxide in the year 1931. This technology was not well received as it produced an efficiency of about 1 %, but this marks a landmark in the field of solar cells, and as a result of this, in the current era the efficiency has reached to about 40% in certain controlled conditions[2].
The solar PV systems has had its advancement in technology over the years that has made it cost effective and efficient usage of it in grid connected as well as stand-alone systems began in operation right from 1990s. German based Eurosolar organization were pioneers in mass production of solar PV in 2000.
The Indian scenario is not lagging behind in the utilization of Solar PV system. The installed capacity as of 2018 has reached 26GW, which is 8 times of what it had in 2014, which was approximately 2650 MW. The mainland of India has a mean of 300 sunny days in a year and this had led to a potential of generating 5000 trillion kilowatt hours per year[3]. This means

that there is a possibility of solar PV system to surpass the output of all the fossil fuel energy reserves.

The major cons of this technology in India is the scarcity of available land. The estimated land required for every 40 to 60 MW generation Is approximately 1 km^2[4]. Hence the emergence of solar rooftop systems, which not only generates the required electricity for a building, but also efficiently utilizes the barren area that is of a little productivity[5].

The best suited system for the Indian scenario would be the rooftop photovoltaic power generation system connected via the local grid, which would be the primary focus of this paper.

In this paper, there will be a detailed discussion about the process involved in a typical rooftop solar installation in an Indian scenario, involving the steps such as installation site evaluation, preliminary design, required load calculation, precise design, installation and cost estimation.

PV system design

The step by step design for a PV rooftop setup can be categorized in the following order:

1. SITE EVALUATION

The site evaluation is the primary step to be followed, that enables a PV designer to roughly estimate the required amount of electricity for a whole building as it would give us the carpet area of the rooftop, allowing the designer to calculate the rough number of solar panels (having a pre-determined dimension) required on the building. The next step of the site evaluation is to determine the dimensions of other structures such as water tanks, structures providing aesthetics to the building etc., so that a design can be estimated to prevent shadow falling on the panel from those structures so as to prevent shading and maintain a reasonable efficiency in the power generation of the panel. The third part of the site evaluation is to determine the optimum spot for placement of a solar inverter and the distribution boxes, so that the DC run is not too long. The longer the DC cables, the larger the losses. Hence, an optimum design should be such that the DC cables carrying the output from the panels should not travel long towards a distribution box, but to be short in length and provide a scope for minimal losses. Next step involves the location of the meter room for local grid, so as it provides a suitable spot to attach a net meter, and also allows the designer to compute the AC run from the inverter. Normally a grid meter is placed at the ground level of a building structure, hence the site evaluation must incorporate the structure height also, in order to determine the length of cables required to travel from the rooftop to the meter room.

2. PRELIMINARY DESIGN

After the site value details, a designer makes a structure in a design tool (AutoCAD inventor, Google Sketch up etc.) to virtually simulate the building and provide a rough placement of the predetermined solar panel, keeping in mind the shadows and other constraints. These constraints are mostly the solar irradiance available, the albedo factor and some solar angular values obtained for the coordinate of the rooftop. This provides the approximate number of panels that can be mounted on the rooftop, hereby allowing the designer to quote the maximum power output that can be extracted from the panels that would be mounted.

3.LOAD CALCUALTION

This process involves the calculation of the amount of actual load utilized in the building and extracting the precise kWh value that is essential for the building. This is carried out by a simple calculation, that involves summing up of all the AC loads utilized in a day, determining peak hours of utilization and duration of utilization of the equipment. The normal estimation of the typical load is achieved using the already arriving electricity bills for the building, but for the reader's convenience, the methodology is straight forward. The estimation is done by considering the output wattage of an equipment, multiplying it with the duration it runs per day, thus allowing us to receive a Watt Hour or unit and further to take it to the standard kilowatt hour, we simple divide the result by a 1000 so that we can refer it to as a unit of electricity for a household. For example, in India, an air conditioner utilizes 1500 W of power and say it runs for a given duration of 6 hours a day, the unit would be [(1500 x 6)/1000] kWh which is 9 kWh or 9 units. Similarly, the same calculation is to be estimated for all the building electrical such as the lift usage, lights etc.

The next step is to run a simulation in a tool that enables us to determine the given characteristics that provides a rough estimate on the number of panels, strings required, as well as the cost estimate. There are many tools available for this process, namely PVSyst, helioscope, system advisor model etc.

Let us consider running a test model for 100kWp in PVSyst. Here, let us consider for the city of Mumbai, India. Here we consider a polycrystalline module of 300 W, along with an inverter of 100kW. The panel is inclined at an angle of 20^{o} and is facing the south. Some of the simulation screenshot are as follows.

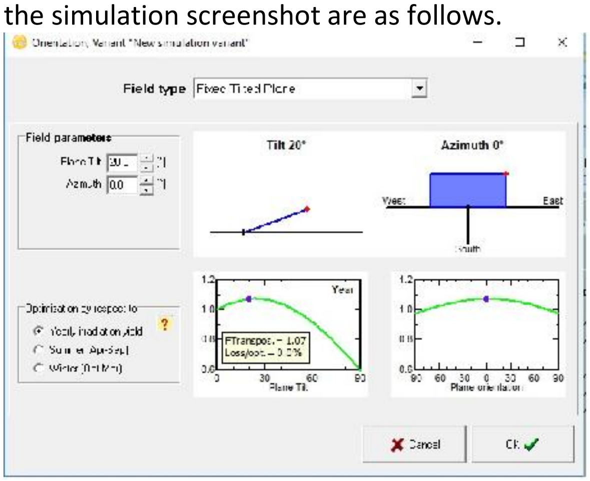

fig 1. defining the angle of tilt

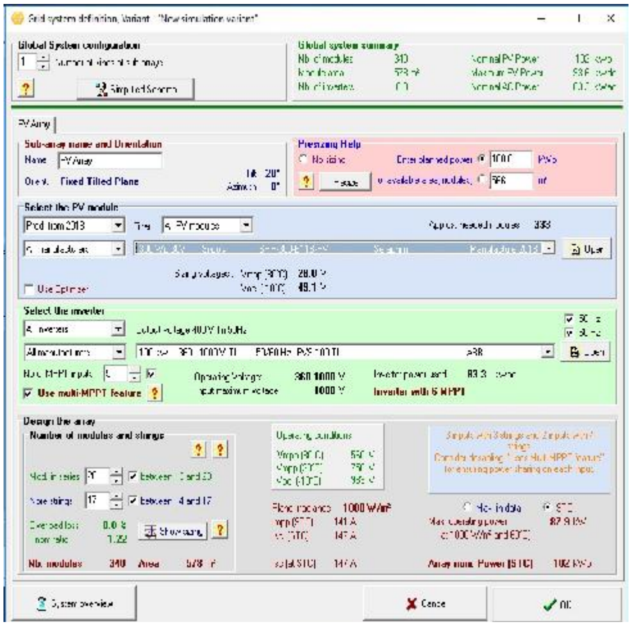

fig 2. system parameters definition in the software

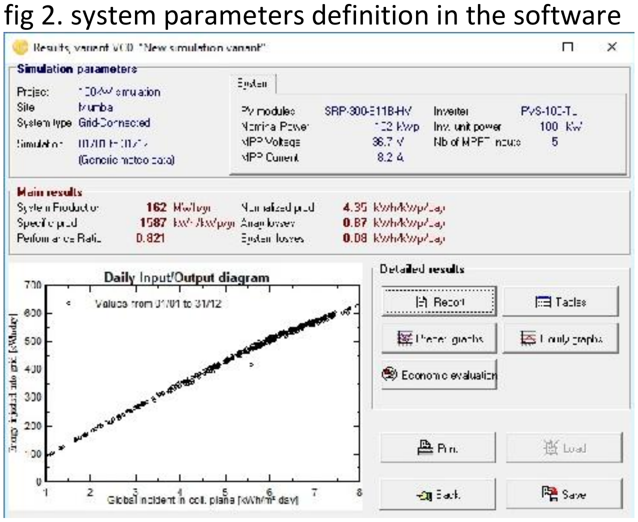

fig 3. software generated report

4. DESIGN

This is the main step where a designer actually designs for the setup. The process includes a drawing with actual dimensions, optimum placement of panels keeping in mind the shadows and space available, calculation of the number of strings in an array, determination of the accurate size of the inverter, optimum placement of the inverter along with the solar meter and the distribution boxes, cable size determination, AC and DC run and then finally the net metering process.

The first step as mentioned before is the optimum setup. This forms the basic layout diagram of the building, providing the rooftop geometry and the accurate measurements of the panel placed, all dimensions to scale.

Next step involves the determination of the strings. This is done with the help of data sheets of the panel as well as the inverter. The calculation is simple. For example, if we design a system for 10 kW, having a panel of 330 W, we would require 31 panels to be installed. We now segregate the optimum values for the size of the string say 15 and 16, which together constitute to 31. Based on the data sheet we have the maximum voltage range say from 300 to 1000V for the selected inverter and the module and the maximum voltage of the panel is say 38V. Hence, 16 x 38 is 608V and 15 x 38 is 570V, both falling in the range of the inverter, thereby allowing a string setup. Henceforth, for a 100kWp setup, However, note that the string is calculated not just in these terms but also the feasibility, reduction of DC run and various parameters also, but this being the general idea to determine the same. Next step is the inverter size. Normally we can simply use a 10KW for a 10kW system, however, we can split-up the required number of inverters depending on the site geometry, or depending upon the cost of installation. Now this inverter is placed at the optimum position along with the DC and the AC distribution boxes to allow the economic stability of the installing person. The next important step is to determine the cable size for carrying the DC and AC loads. The most essential electrical calculation for cable sizing states that cable sizing based on a current rating will produce better understanding as current flowing through the resistive losses in the conductors and dielectric losses via the insulation, all causes the cable to generate heat. So larger the cross sectional area, lower the resistive losses. This is explained by a simple formula $I_c = I_b \times K_d$, where I_c is the installed current rating in amperes, I_b is the base current rating and K_d are the product of all derating factors. An example, say for a base current of 50A, and overall derating factors be 0.5, the installed rating would be 50 x 0.5 = 25A. Now based on the material of the cable, the length of the cable and the installed rating, we may refer a chart that specifies the optimum cross section necessary for our installation. The DC and the AC run is a simple calculation. The DC run can be computed simply by determining the distance of all the modules to the DC distribution box and the AC run is the cable distance required from the AC distribution box to the meter connected to the grid. Net metering, finally is a simple process that allows profit to the consumer, who generate excess electricity from solar and send it to grid. By definition, it is the difference between the solar electricity production and the electricity consumed by the consumer over the monthly billing period.

5. INSTALLATION

The approval of the design allows the site engineer to supervise the structure to be mounted on rooftops with least possible errors and provide an efficient promised system to the consumer.

6. COST ESTIMATION

For any energy producing organization, each of them have their own cost per unit of electricity, keeping in mind for the profit of the organization. Here, however, I shall provide the most basic idea on which a unit rate can be determined, without considering the debit, equity and the taxes. Let us consider, for a 100kW system, having a panel wattage of 330W, the breakup of the capital cost could be as follows:

Panel cost = Rs.19830

Inverter cost = Rs. 25000

Mounting structure = Rs. 6000

Miscellaneous(cables and distribution boxes) = Rs. 6000

Installation = Rs. 5000.

Therefore, the total cost would be Rs.61830.

The approximate value, that a solar system would generate can be described as follows:

Years 1-5 – 1,400, total of 7,000 units (100% rated capacity)
Years 6-10 – 1,300, total of 6,500 units (92% rated capacity)
Years 11-15 – 1,200, total of 6,000 units (85% rated capacity)
Years 16-20 – 1,100, total of 5,500 units (78% rated capacity)
Years 21-25 – 1,000, total of 5,000 units (71% rated capacity)
Total number of units generated over 25 years:30,000. considering the generation for 25 years, cost per unit of electricity generated would be = Rs. 61830 / 30000 = Rs. 2.061.

Conclusion

As observed from the cost analysis as well as the cleanliness of the PV system, it is by no objection, one of the best methods of power generation systems to exist in this era. The cost of Rs 2.061 is to be further added along the Taxes and the other components apart from the basic calculation, approximately Rs.3 more per unit[8]. This cost is still cheaper than the per unit cost of a non-renewable source of energy supplied in our grid[9][10]. The usage of solar photovoltaics is being promoted to a high extent by the Ministry of new and renewable energy, providing subsidy for solar[11][12]. This way, the solar PV system is slowly becoming popular in this country, especially rooftop PV system, mostly in Metropolitan cities. Hence, as an energy consumer, it is very important of us to be familiarized to this technology so that we can leap forward to a greener world.

References

1."Technology Roadmap: Solar Photovoltaic Energy, 2014", International EnergyAgency (IEA), Available: ▯http://www.iea.org/publications/freepublications/publication/technology-roadmap-solar-photovoltaic-energy—2014-edition. html▯ .

2. Siva Reddy V, Kaushik SC, Panwar NL. Review on power generation scenario of India. Renew Sustain Energy Rev 2013;18:43–8 Feburary.

3. Ummadisingu Amita, Soni MS. Concentrating solar power –technology, potential and policy in India. Renew Sustain Energy Rev 2011;15(9):5169–75 December.

4. Kapoor Karan, Pandey Krishan K, Jain AK, Nandan Ashish. Evolution of solar energy in India: a review. Renew Sustain Energy Rev 2014;40:475–87 December.

5. Sharma Naveen Kumar, Tiwari Prashant Kumar, Sood Yog Raj. Solar energy in India: strategies, policies, perspectives and future potential. Renew Sustain Energy Rev 2012;16(1):933–41 January.

6. Energy Efficiency and Renewable Energy, Available: ▯ http://apps1.eere.energ gov/news/news_detail.cfm/news_id¼21282▯ .

7. Clean Technica –Solar Power, Available: ▯ http://cleantechnica.com/sola - power/▯ .

8. Ministry of New and Renewable Energy Source India, Government of India. Available: ▯ http://mnre.gov.in/mission-and-vision-2/achievements/▯ .

9. Central Electricity Regulatory Commission. Terms and conditions for tariff determination from renewable energy sources, regulations, 2012. Avail-

able: ▯ http://www.cercind.gov.in/2012/orders/RE_35_2012.pdf▯ .
10.Ministry of New and Renewable Energy Source, Policy support for grid interactive renewable power. Available: ▯ http://www.mne ▯ .
11. Solar Energy Corporation of India (SECI), Available: ohttp://mnre.gov.in/centers/seci/4
12. Solar Industry in India, Bridge to India, IIT Kanpur Database. Available: ▯ http www.iitk.ac.i/solarlighting/files/Indian_Solar_Industry.pdf▯ .