SOLAR PHOTOVOLTAIC SYSTEM

Asmita Parve Mokal[1], Bipin D. Mokal[2]

[1] *Freelancer, M Tech CAD/CAM, Wardha -442001*
[2] *Head of division, Biomedical Engg., DMIMS (DU), Wardha - 442001*

ABSTRACT

A solar PV System is a system which converts solar energy into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the photovoltaic effect. In solar PV system, solar inverter is used to convert the output from direct to alternating current. Solar PV system is very reliable and clean source of electricity which suit a varied range of applications. As the demand for solar electric systems grows, progressive builders are adding solar Photovoltaic (PV) as an option for their customers.

Keyword: - *Solar energy, Photovoltaic, Power generation, On-grid, Off-grid, and Renewable energy*

---

1. Introduction

A Photovoltaic system is a distributed power generation system that produces electrical power by harnessing solar radiation and converting it into electricity. Solar power generation plants come under the category of Renewable Energy sources as they do not involve the use of fossil fuels such as coal or petroleum for power generation. Solar PV plants are classified broadly into two major categories based on their location:

1. Ground-mounted Projects: In this case, the solar panels are mounted on mounting structures that are set up on available land on respective mounting foundations. The entire system including all the components like modules, inverters, cables, evacuation infrastructure are based on ground only.
2. Rooftop Projects: In this case the solar modules are mounted on the roof of an existing building via appropriate mounting structures. The buildings may be of residential, commercial or industrial nature. The roofs may be sloping sheet roofs or flat RCC roofs.

Factors affecting working of Photovoltaic system -

1. Shading – Photovoltaic arrays are adversely affected by shading. A well-designed PV system needs clear and unobstructed access to the sun's rays from about 9 a.m. to 3 p.m., throughout the year. Even small shadows, such as the shadow of a single branch of a leafless tree can significantly reduce the power output of a solar module. Shading from the building itself – due to vents, attic fans, skylights, gables or overhangs – must also be avoided. [1]
2. Orientation – Solar modules produce 95 percent of their full power when within 20 degrees of the sun's direction. Roofs that face east or west may also be acceptable. Optimum orientation can be influenced by typical local weather patterns. [1]
3. Tilt – An increased tilt favors power output in the winter and a decreased tilt favors output in the summer. [1]

PV systems are classified as: Off-grid systems & Grid-connected systems.

a) Off-grid systems: In this case, the system comprises a battery bank that functions as the reference power source as well as a storage mechanism which can supply power at night when the Sun is not available.
b) Grid-connected systems: In this case, the solar power system is coupled with the grid which provides the reference power source and is also an unlimited storage option which can supply electrical power whenever solar radiation is not available. [2]

2. Components of PV system

A brief description of each of the components is presented below:

1. **PV Modules** – The PV modules are the devices that actually convert solar energy to electricity. PV modules are made from PV cells, which are most commonly manufactured using silicon; other materials used include cadmium telluride (CdTe), copper indium gallium selenide/sulfide (CIGS). Good quality PV modules generally have a useful life of 25 to 30 years. It is important to assess the quality of PV modules for use in projects. [2]

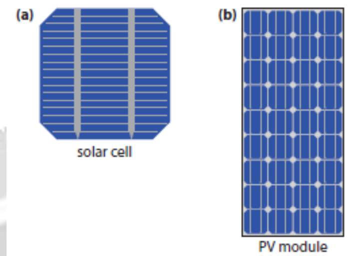

Fig. 2.1: Illustrating (a) a solar cell, (b) a PV module [3]

Types of Solar Panels –
There are three types of solar panels that are widely available for use in photovoltaic systems,
(1) Monocrystalline, (2) polycrystalline, and (3) amorphous thin-film.
Each type of panel has its advantages and disadvantages. The primary differences between these panel types are their cost and efficiency. [6]

Fig. 2.2: Types of solar panels [6]

(1) Monocrystalline Solar Panels - Monocrystalline panels have a uniform crystal structure across the entire panel, and can be made from a variety of materials such as amorphous silicon, gallium arsenide, germanium, cadmium telluride, copper indium gallium selenide, and organic polymers. Monocrystalline solar panels have the highest efficiency ratings and are expensive to manufacture. [6]

(2) Polycrystalline Solar Panels - Polycrystalline silicon solar panels have a unique speckled blue color that varies in shade with different areas of the panel. The silicon used in these panels is not homogenous. As a result, polycrystalline solar panels are less efficient than monocrystalline solar panels, so greater number of panels are required to generate the definite power. They are less expensive than monocrystalline. [6]

(3) Amorphous Thin-Film Solar Panels - Thin-film solar panels are less efficient than monocrystalline or polycrystalline solar panels and have a shorter lifetime. However, their costs are much lower due to the simple manufacturing methods in comparison with crystalline solar panels. Thin-film solar panels can also be made flexible, whereas crystalline solar panels are much more brittle and will crack if they are bent. [6]

2. **Inverter** –The inverter converts the DC power produced by the PV modules into AC power. The AC power is then either injected into the grid or consumed on-site. For grid-connected rooftop solar applications, inverters come in standard sizes ranging from a few hundred watts to hundreds of kilowatts, depending on system size. Selection of an inverter for a project depends on a number of factors such as size, cost, function, usage, etc. Inverters also perform energy monitoring functions. [2]
Inverters take care of four basic tasks of power conditioning:
• Converting the DC power coming from the PV modules or battery bank to AC power

• Ensuring that the frequency of the AC cycles is 60 cycles per second
• Reducing voltage fluctuations
• Ensuring that the shape of the AC wave is appropriate for the application, i.e. a pure sine wave for grid-connected systems. [1]

3. **Module Mounting Structure**– The mounting structure, or racking system, is the support structure that holds the PV panels. PV modules are generally mounted on support structures in order to more efficiently capture solar insolation, increase generation, and have a stable structural support. [2]
4. **Balance of System** – Balance of system consist of cables, switchboards, junction boxes, meters, etc. [2]

3. Design layout of PV system

There are two types of PV system:

1. **Off-grid PV system**- A simple off-grid system, as depicted in Fig. The design presented here is based on very simple assumptions and does not take any weather-dependent performance changes into account. Nonetheless, we will see the major steps that are necessary for designing a system. Such a simple design can be performed in a six step plan:
   a. Determine the total load current and operational time
   b. Add system losses
   c. Determine the solar irradiation in daily equivalent sun hours (ESH)
   d. Determine total solar array current requirements
   e. Determine optimum module arrangement for solar array
   f. Determine battery size for recommended reserve time

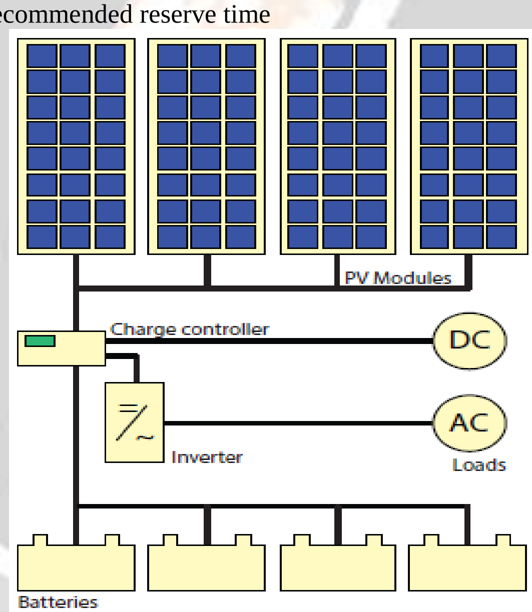

Fig. 3.1: Illustrating a simple off-grid PV system with AC and DC loads [3]

2. **Grid-Connected Rooftop PV System** - In grid connected rooftop or small SPV system, the DC power generated from SPV panel is converted to AC power using power conditioning unit/Inverter and is fed to the grid either of 440/220 Volt three/single phase line or of 33 kV/11 kV three phase lines depending on the capacity of the system installed at residential, institution/commercial establishment and the regulatory framework specified for respective States. These systems generate power during the day time which is utilized by powering captive loads and feed excess power to the grid as long as grid is available. In case, where solar power is not sufficient due to cloud cover etc., the captive loads are served by drawing balance power from the grid.

   A general schematic of the working of a Grid-Connected Rooftop PV System is shown in figure:

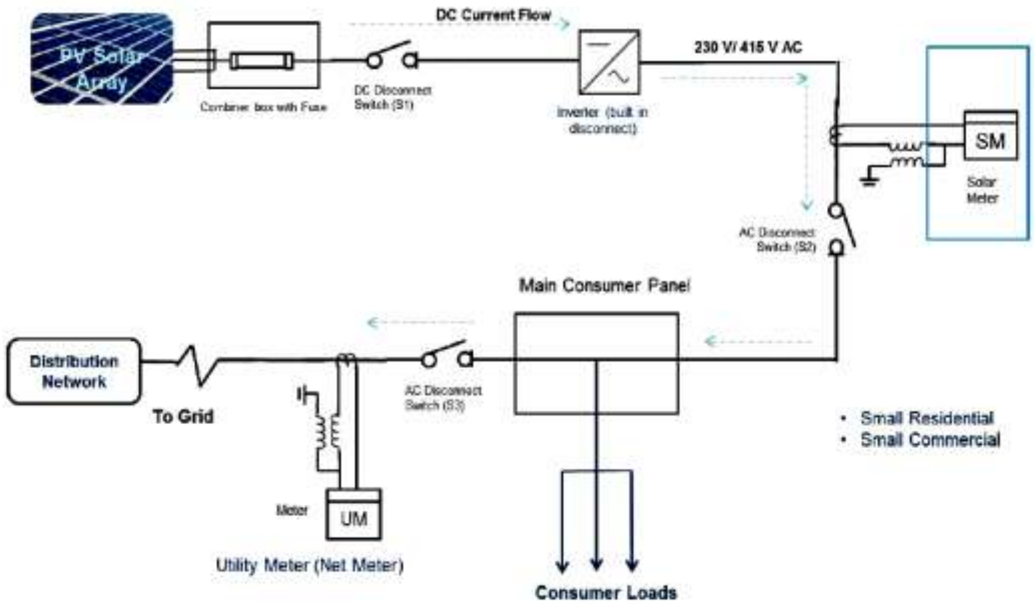

Fig. 3.2: Grid connected Solar PV System diagram [2]

4. PV module mounting structures

The mounting structures are used to support the solar PV modules. Since the solar PV modules are built to last for 25 years, it is very important to choose the solar PV module mounting structure as it has to support the solar PV module for 25 years. Module mounting structures are made of three types of materials:

1. Galvanized iron – In galvanizing zinc coating is applied to iron or steel to prevent it from rusting. There are several methods of galvanizing. The most common method employed in module mounting structure is the hot deep galvanization. [4]

Fig. 4.1: Galvanized Iron Structure [4]

2. Mild Steel is made by melting iron and coal together in a furnace. Once the melting is done, it is moved to another furnace to burn of any impurities. Mild steel has very less carbon. It is very flexible and can be made in to several shapes as it is machinable. [4]

Fig. 4.2: Mild Steel structure [4]

3. Aluminium is a silvery white, soft, flexible material. It is very resistive to corrosion and does not corrode easily. Compared to galvanized iron, this is light weight and cost-effective. [4]

Fig. 4.3: Aluminium structure [4]

5. Solar PV System Sizing

1) Solar Panel Load Sizing –

To determine the power consumption demands, calculate the Total Watt hours per day then Calculate the Total Watt hours per day.

Total Watt hours per day = measuring the average watt hours consumed by different appliances per day.

Total Watt hours per day to be output by the Solar modules = multiply the Total Watt hours per day by 1.3(the energy lost in the system). This gives the Total power that needs to be supplied by the Solar Panels. [5]

2) Solar PV Array sizing –

Different size of PV modules will produce different amount of power.

Sizing a Solar PV module – In the previous step we calculated the Total Watt hours to be output per day by the solar modules. Now calculate the Average daily peak sun hours in your location.

Average daily peak hrs = total Watt hours per day / solar PV system by the daily peak sun hours.

This gives approximate array size in KWh. Divide this value by the efficiency factor of the solar panels to get the power output of the Solar panels.

To calculate the number of panels needed = Divide the Total Watt hours to be produced by the rated power output of the PV modules. This provides the number of PV modules needed. [5]

3) Solar Inverter Sizing –

Solar Inverter converts The DC output from the Solar Panels to usable Ac power. Hence sizing the Solar Inverter is important so that the conversion happens properly. The inverter is rated in Watts. The inverter watt rating should be same or more than the Solar PV systems watt rating.

In case of appliances like motors the Inverter size should be a minimum 3 times the capacity of those appliances. This is to handle the surge current during starting those type of appliances.

For grid tied system, the input rating should be same as PV array rating to allow for safe and efficient operation. [5]

4) Solar Charge Controller Sizing –

The Solar Charge controller is rated with Amps and Volt capacities.
Choose a Solar Charge controller to match the voltage of the PV Array and Batteries. Ensure that the solar charge controller has the capacity to handle the current supplied from the Solar PV system. [5]

5) Battery Sizing –
A battery is not needed in case of Solar On-grid system. It is needed in case of Solar Off-grid system or Hybrid Solar system (a mix of Solar On-grid or Solar Off-grid).
Choose a battery with a capacity equal to or more than that of the Solar panels. Battery capacity is measured in Ampere hours. Find out the Watt hours by multiplying Ampere hours and voltage of the battery.
Ex: For a 40AH, 10V battery the Watt Hours figure is 40(X) x 10(Y) = 400 WH (Z)
This means the battery should supply 400 Watts for 1hr or 200 Watts for 2 hrs i.e. the more energy you take more faster the battery is discharged.
However one cannot take all the power from the battery. This is because once the voltage drops below to that of the equipment it's supplying, it will not be able to power it. [5]

6. PV system efficiency

While wattage can tell us that solar panel is capable of producing under ideal conditions, efficiency tells us how much sunlight solar panel is capable of converting into electricity.
For example, if solar panel has an efficiency rating of 13 percent, that means that 13 percent of the sunlight striking solar panel will be transformed into the power.
Solar panel efficiency can be affected by a few variables itself, which can either subdue or boost it. Within the solar cells themselves, there can be variation in efficiency based on how reflective the cells are. Less reflective cells can collect more sunlight and use it rather than bouncing it back out to space.
The area around rooftop solar panel system can also change efficiency numbers. The most common environmental factors that can subdue efficiency are:

1. Shading from nearby trees or other buildings
2. Excessive cloud coverage
3. Excessive dirt, dust, and pollution
4. Thick layers of snow

Enhance efficiency of system -
There are some things to note about each of these. Shading is generally a fairly obvious efficiency blocker and should be avoided if at all possible. Trimming trees and positioning solar panels to avoid shading from other nearby structures will help.
Cloud coverage does not mean that absolutely no sunlight will make it to your solar panels, but the amount will obviously be reduced.
Dirt, dust, and pollution can degrade solar panel efficiency over time. Rainfall is a natural and aning them off.
While it's true that too much heavy snow can lower efficiency, some snow is actually a good thing because any dust, dirt, and pollution will cling to it and slide off the slick panels when the snow melts. Also, like most electronic equipment, solar panels operate well in cooler conditions. [8]

7. Solar Panel Output

Simple formula for calculating your solar panel's power output as follows:
Solar panel watts x average hours of sunlight x 75% = daily watt-hours
As an example, let's say you have 250-watt solar panels and live in a place where we get 5 hours of sunlight per day. 75 percent is variables which affect overall output.
250 watts x 5 hours x .75 = 937.5 daily watt hours

To translate this into the more familiar kilowatt hours used to seeing on our electricity bill, simply divide by 1000.
937.5 / 1000 = 0.937
To round up and make it pretty, that's 0.94 kilowatt-hours per solar panel. [8]

8. Size of system Examples

8.1 Calculation for Size of system for Total day time energy requirement 40 Kwh

Given			
Total day time energy requirement	40	kwh per day	
Purchase price of consumption from grid	$0.21	per kWh	
Excess energy generated sold to grid	$0.12	per kWh	
While night time requirement may consumed from grid.			
Solution			
Avg. peak sun hours per day	6.5	hrs	Assume
Efficiency factor of the solar panels	0.75		Assume
Total power that needs to be supplied by the Solar Panel =	52	kwh per day	
Approximate array size =	8	KW	
PV array size to fullfill day time energy requirement =	10.67	kw	
Considering PV array size	13	kw	
Then approximate array size =	9.75	kw	
Total power that needs to be supplied by the Solar Panel =	63.375	kwh per day	
Energy produce =	48.75	kwh per day	
Excess energy generated =	8.75	kwh per day	
Total Excess energy generated sold to grid price per day =	$1.05	per day	
Considering night time requirement	3	kw	
Total Purchase price of consumption from grid =	$0.63	per day	

8.2 Calculation for Size of system for Total day time energy requirement 20 kWh

Given			
Total day time energy requirement	20	kwh per day	
Purchase price of consumption from grid	$0.21	per kWh	
Excess energy generated sold to grid	$0.12	per kWh	
While night time requirement may consumed from grid.			
Solution			
Avg. peak sun hours per day	6.5	hrs	Assume
Efficiency factor of the solar panels	0.75		Assume
Total power that needs to be supplied by the Solar Panel =	26	kwh per day	
Approximate array size =	4	KW	
PV array size to fullfill day time energy requirement =	5.33	kw	
Considering PV array size	7	kw	
Then approximate array size =	5.25	kw	
Total power that needs to be supplied by the Solar Panel =	34.125	kwh per day	
Energy produce =	26.25	kwh per day	
Excess energy generated =	6.25	kwh per day	
Total Excess energy generated sold to grid price per day =	$0.75	per day	
Considering night time requirement	3	kw	
Total Purchase price of consumption from grid =	$0.63	per day	

9. Total Cost of 7kW PV system with specifications

There are three type of solar systems - On-Grid, Off-Grid and Hybrid. 7kW Solar System is available in all 3 types. "Generally, 7kW Solar System range with installation as per table including solar panels, solar inverter, solar structure, accessories and batteries in case on Off-Grid and Hybrid Solar Systems".

Off-grid system and On-grid both systems are recommended in 7kW capacity. 10 Solar Batteries of 150 AH are sufficient to store the electricity produced by 7kw Solar Panels. If facing Electricity power cut problem, go for 7kW Off-Grid System. Having a reliable grid, go for 7kW On-Grid Solar System. Or if you want to enjoy the both facilities go for 7kW Hybrid Solar System. [10]

Table 9.1: Costing of PV solar system [10]

Model	Components	Price
On-grid system	Solar panel	$ 8,000.00
	Solar structure	
	Inverter	
	Battery	
	Accessories	
Off-grid system	Solar panel	$ 10,000.00
	Solar structure	
	Inverter	
	Battery	
	Accessories	
Hybrid system	Solar panel	$ 11,500.00
	Solar structure	
	Inverter	
	Battery	
	Accessories	

9.1 Specification of 7kW On-Grid Solar System as follows:

Table 9.2: Specification of 7kW On-Grid Solar System [10]

Particulars	Description
Solar Power Plant	7 Kw
Solar Panel in Watt	335w
Solar Panel Qty.	21 nos.
Solar On Grid Inverter	10 KW 3P
MC4 Connector	10 Pair
DC Cable	100 Mtr
Space required	50 Sqm.
Generation	10,080 kWh (unit) per year
Warranty	5 years for Complete System. 25 years for Solar Panels.
Installation	Yes included in given price

9.2 Specification of 7kW Off-Grid Solar System as follows:

Table 9.3: Specification of 7kW Off-Grid Solar System [10]

Particulars	Description
Solar System	7 kWp
Solar Panel in Watt	335 watts
Solar Panel Qty	21 Nos
Solar Battery	10 x 150 AH
Solar Inverter	7.5kVA (7500VA)
Structure	GI (21 Panels)
DC Wire Meter	100 x 4 SQM
Connectors	6 x Y Connector
Accessories	Fasteners, Cable Tie etc.
Average Generation	10,080 kWh/units per year
Space Required	50 Squire Meter
Warranty	5 years for Complete System. 25 years for Solar Panels.
Installation	Yes included in given price

9.3 Specification of 7kW Hybrid Solar System as follows:

Table 9.4: Specification of 7kW Hybrid Solar System [10]

Particulars	Description
Solar Power Plant	7 KWp
Solar Panel in Watt	335 Watt
Solar Panel Qty	21 nos.
Solar Structure	7 KW
Solar Hybrid Inverter	7 KW
Solar Battery	10 Nos of 150AH each.
Junction Box	1 Nos
DC Cable	100 Mtr
AC Cable	20 Mtr 2C
Space required	40 sqm
Solar Accessories	Fasteners, Cable Tie etc.
Warranty	5 years for Complete System. 25 years for Solar Panels.
Installation	Yes included in given price

10. Costs to Maintain Solar Panels

10.1 Maintenance cost

Solar panel installation is a long-term investment that can serve you well for decades with very minimal maintenance, but that doesn’t mean you can install once and then ignore them. Plan on a yearly inspection and cleaning, and stay cognizant of potential problems such as overhanging trees or storm damage. To ensure that such investments stay in great shape and continue to offer benefits, it is important to have solar panels professionally maintained and cleaned on a regular basis. [11]

Table 10.1: Solar panel maintenance cost [11]

Solar panel maintenance costs	
National average cost	$400
Average range	$300 - $700
Minimum cost	$150
Maximum cost	$1,000

10.2 Solar Panel Cleaning Cost

The average cost to clean and maintain solar panels is $150 to $330. The actual cost of cleaning will depend on a number of factors, including where you live, house height, roof slant, and what type of solar setup you have installed. If you have a 2 kW solar PV system with 10 panels, expect to pay between $150-$330. Cleaning a 20 panel 3kW solar system will cost on average, $500-$750. If you are billed per panel, expect to pay $15-$35 per panel. And some business charge a flat fee. [11]

Benefits of Solar Panel Cleaning -

1. Reduced risk of damaging your solar panels: solar panels are very sensitive and require proper handling when cleaned. A professional solar panel cleaner ensures that minimum risk occurs to the panels during cleaning.
2. Minimal cost: cleaning the system is as important as cleaning and servicing your car, and the price is less in comparison to how much you would spend on replacement or repair if damaged.

3. Information on the condition of your solar panels: while cleaning your solar panels, the professional technician provides you with complete information on the condition of your system. The specialist informs you if anything needs replacing or repairing.
4. No physical stress: climbing onto your rooftop to clean your solar panels can be unsafe and mind-racking. Some risks include electrocution due to live electric wires running over the roof and the threat to your safety due to the inaccessibility of some of the panels mounted on the roof. Only professionals are efficient at climbing onto the roof, cleaning the panels, and climbing back down safely. [11]

10.3 Solar Panel Inspection Cost

The average cost of an annual inspection of your rooftop solar panels is typically $150 to $300. After the inspection, the technician might suggest replacement or repair work if any of the components are broken or not working properly. This could increase the costs up to $750. [11]
A qualified solar maintenance technician inspects your solar panels annually to ensure that your investment is worth it and functions properly. Among other tasks, they focus on:

1. Evaluating overall efficiency and performance using monitoring statistics and onsite records.
2. Carrying out a visual inspection for panel damage, moisture penetration, fractures, and frame corrosion.
3. Inspecting mounting system 1 for fixing points, framework, and module clamps for security and integrity, where accessible.
4. Inspecting cabling for measuring voltage levels and inverters for any damage.
5. Inspecting generation meter to check function and meter display.
6. Inspecting junction 2 boxes for tightness of connections, water accumulation, and integrity of seals.
7. Ensuring correct general operation of inverters, cable connections, and display functionality.
8. Inspecting rigidity and alignment of the framing system. [11]

10.4 Solar Panel Repair Cost

A damaged solar panel system can lead to decreased performance, electricity shorts, and even house fires, so you'll want to have any problems addressed by professionals as soon as possible. These are some of the more common problems found during solar panel inspection, along with the average cost of repair:

Table 10.2: Solar panel average repair cost [11]

Problem	**Average cost**
Broken glass	$20-$400
Obstructing branches	$50-$200
Loose wiring	$100
Cracked panels	$150-$300
Corrosion	$150-$350
Broken inverter	$1,000-$2,000
Damaged tiling	$2,000-$3,000

11. Advantages of Solar PV system

Advantages of solar PV as follows:
1. PV panels provide clean – green energy. During electricity generation with PV panels there is no harmful greenhouse gas emissions thus solar PV is environmentally friendly.
2. Solar energy is energy supplied by nature – it is thus free and abundant!
3. Solar energy can be made available almost anywhere there is sunlight
4. Solar energy is especially appropriate for smart energy networks with distributed power generation – DPG is indeed the next generation power network structure!
5. Solar panels cost is currently on a fast reducing track and is expected to continue reducing for the next years – consequently solar PV panels has indeed a highly promising future both for economic viability and environmental sustainability.

6. Photovoltaic panels, through photoelectric phenomenon, produce electricity in a direct electricity generation way
7. Operating and maintenance costs for PV panels are considered to be low, almost negligible, compared to costs of other renewable energy systems
8. PV panels have no mechanically moving parts, except in cases of sun-tracking mechanical bases; consequently they have far less breakages or require less maintenance than other renewable energy systems (e.g. wind turbines)
9. PV panels are totally silent, producing no noise at all; consequently, they are a perfect solution for urban areas and for residential applications (see solar panels for home)
10. Because solar energy coincides with energy needs for cooling, PV panels can provide an effective solution to energy demand peaks – especially in hot summer months where energy demand is high.
11. Though solar energy panels' prices have seen a drastic reduction in the past years, and are still falling, nonetheless, solar photovoltaic panels are one of major renewable energy systems that are promoted through government subsidy funding (FITs, tax credits etc.); thus financial incentive for PV panels make solar energy panels an attractive investment alternative.
12. Residential solar panels are easy to install on rooftops or on the ground without any interference to residential lifestyle. [12]

Disadvantages of Solar PV system as follows:

1. As in all renewable energy sources, solar energy has intermittency issues; not shining at night but also during daytime there may be cloudy or rainy weather.
2. Consequently, intermittency and unpredictability of solar energy makes solar energy panels less reliable a solution.
3. Solar energy panels require additional equipment (inverters) to convert direct electricity (DC) to alternating electricity (AC) in order to be used on the power network.
4. For a continuous supply of electric power, especially for on-grid connections, Photovoltaic panels require not only Inverters but also storage batteries; thus increasing the investment cost for PV panels considerably
5. In case of land-mounted PV panel installations, they require relatively large areas for deployment; usually the land space is committed for this purpose for a period of 15-20 years – or even longer.
6. Solar panels efficiency levels are relatively low (between 14%-25%) compared to the efficiency levels of other renewable energy systems.
7. Though PV panels have no considerable maintenance or operating costs, they are fragile and can be damaged relatively easily; additional insurance costs are therefore of ultimate importance to safeguard a PV investment. [12]

12. CONCLUSIONS

Grid connected PV system is the simplest option as electrical energy resource from solar energy. It's operating and maintenance cost is low. It also saves on electricity bills up to large extent. To for generation of extra energy additional solar panels causes increase in investment cost. Grid integration of PV system benefits for expensive storage batteries which is recurrent economic burden on other solar systems. As we go on increasing solar panel the electricity bill reduces and at certain number it becomes zero even further this system can be used to earn profits.

13. REFERENCES

[1] Washington State University Extension Energy Program. (Oct 2009). Solar Electric System Design, Operation and Installation.

[2] Central Scientific Instruments Organization. (2015). Solar Rooftop PV System at Central Scientific Instruments Organization (CSIR-CSIO), Chandigarh

[3] Klaus Jäger, Olindo Isabella, Arno H.M. Smets, René A.C.M.M. van Swaaij & Miro Zeman. (2014). Solar Energy - Fundamentals, Technology, and Systems. Delft University of Technology

[4] An introduction to solar PV module mounting structures. (2019). ulaginoli.com. Retrieved from https://www.ulaginoli.com/solar-energy/an-introduction-to-solar-pv-module-mounting-structures/

[5] Are You Buying a Solar Panel for Your Rooftop. (2020). Apollopowersystems.com. Retrieved from https://www.apollopower systems.com/blog/solar-pv-system-sizing/

[6] Components of a Photovoltaic System. (2018). fuelcellstore.com. Retrieved from https://www.fuelcellstore.com/blog-section/components-of-a-photovoltaic-system

[7] How to Design Solar PV System. leonics.com. Retrieved from http://www.leonics.com/support/article2_12j/articles2_12j_en.php

[8] How to measure solar panel output. (2020). vintsolar.com. Retrieved from https://www.vivintsolar.com/learning-center/how-calculate-solar-panel-output

[9] How to calculate the annual solar energy output of a photovoltaic system. photovoltaic-software.com. Retrieved from https://photovoltaic-software.com/principle-ressources/how-calculate-solar-energy-power-pv-systems

[10] 7kW Solar Panel System Price 2019. (2019). pricenmore.com. Retrieved from https://pricenmore .com/in/solar/system/7kw-solar-panel-system-price

[11] Solar Panel Maintenance Cost. (2020). fixr.com. Retrieved from https://www.fixr .com/costs/solar-panel-maintenance

[12] Advantages and disadvantages of Solar Photovoltaic – Quick Pros and Cons of Solar PV. renewableenergyworld.com. Retrieved from https://www.renewableenergyworld.com /2012/12/19/advantages-and-disadvantages-of-solar-photovoltaic-quick-pros-and-cons-of-solar-pv/#gref