International Journal of Electronics and Electrical Engineering

Volume 4 | Issue 1 Article 1

February 2022

A Cost-Effective Method for Design Installation and Maintenance of Solar Photovoltaic Power Generation System to Meet the Household Energy Requirement

UDAYA KUMAR SAHOO Mr.
North Eastern Space Application Center, Umiam, Meghalaya, India, uks.nesac@gmail.com

BIJAYANANDA PATNAIK Dr.
IIIT Bhubaneswar, Odisha, India, bijayananda@iiit-bh.ac.in

SRINIVASARAO CHINTAGUNTA Dr.
IIIT Bhubaneswar, Odisha, India, srinivasarao@iiit-bh.ac.in

SHYAM SUNDAR KUNDU Dr.
North Eastern Space Applications Centre, Meghalaya Umiam , India, ssk.nesac@gmail.com

SHIV PRASAD AGGARWAL Dr.
North Eastern Space Applications Centre, Meghalaya, IndiaUmiam,, director@nesac.gov.in

Recommended Citation

SAHOO, UDAYA KUMAR Mr.; PATNAIK, BIJAYANANDA Dr.; CHINTAGUNTA, SRINIVASARAO Dr.; KUNDU, SHYAM SUNDAR Dr.; and AGGARWAL, SHIV PRASAD Dr. (2022) "A Cost-Effective Method for Design Installation and Maintenance of Solar Photovoltaic Power Generation System to Meet the Household Energy Requirement," *International Journal of Electronics and Electical Engineering*: Vol. 4 : Iss. 1 , Article 1.
DOI: 10.47893/IJEEE.2022.1182
Available at: https://www.interscience.in/ijeee/vol4/iss1/1

A Cost-Effective Methof for Design Installation and Maintenance of Solar Photovoltaic Power Generation System to Meet the Household Energy Requirement

Udaya Kumar Sahoo[1], Bijayananda Patnaik[2], Srinivasa Rao Chintagunta[3], Shyam Sundar Kundu[4], Shiv Prasad Aggarwal[5]

[1, 4, 5] **North Eastern Space Applications Centre, Umiam - 793103, Meghalaya, India**

[2, 3] **Department of ETC, IIIT Bhubaneswar Odisha - 751003, India**

Abstract: Solar Photovoltaic (SPV) power generation system is becoming a popular and alternative technology to full fill the requirement of household electric power. The operation and maintenance cost of a typical SPV power generation system is too low at the household level, whereas the initial investment or installation cost of such systems is comparatively too high. Although the SPV power generation system uses free and renewable energy to generate eco-friendly electricity, due to the high initial investment, slow response of service assistance for technical support during the system failure, maintenance, troubleshooting, lack of basic troubleshooting and maintenance knowledge of the end-users are some of the primary reasons for reducing the popularity and faith on SPV power generation technology in the household level. In this paper, an elaborate explanation of design, installation, commissioning, maintenance, and troubleshooting methods have been briefly described to set up an indigenous and cost-effective solar photovoltaic power generation system to meet the electricity demand for basic household requirements with an individual effort.

Keywords: Solar photovoltaic, Rooftop mounting, Design, Installation, Maintenance, troubleshooting, Cost-effective, Power generation system.

I. INTRODUCTION

In its simplest form, electricity is the flow of free charged particles (electrons) through a conducting material in the direction of higher potential to lower potential due to the presence of potential gradient, either naturally or by man-made setups. Since the invention of electricity, it alwayshas had an immense impact on almost all the sectors of civilization. We are so dependent on electricity; the modern civilization can't be imagined for a while without the electricity. Therefore the generation, distribution, and utilization of electricity is crucial for the economic growth of the Nation. From a statistical survey report of the U.S. Energy Information Administration (EIA), India is the third-largest producer and the second-largest consumer of electricity in the world after China and the United States followed by Russia and Japan [1-5]. The electricity production of India has reached 1,252.61 billion units (BU) in the financial year 2020 (FY20) and the average electrical energy per capita of the nation is reached to 935 (kWh per person per year) as of 2019. The country has an installed power capacity of 383.37 Giga Watts (GW) as of May 2021. Out of the total installed power capacity, thermal installed capacity in the country stood at 234.72 GW whereas renewable, hydro, and nuclear energy totaled 94.43 GW, 46.21 GW, and 6.78 GW respectively [6].

Keeping in mind the potential limitations of fossil flue driven power plants, renewable energy is fast emerging as a major source of power in India. As per the World Bank's Ease of Doing Business –"Getting Electricity" rankings, India was ranked fifth in solar power, fifth in wind power, and fourth in other renewable power installed capacity, as of 2019 [7]. A target has been set by the government of India (GOI) to install 227 GW of renewable energy capacity by FY22. The GOI has also planned to double the share of installed electricity generation capacity of renewable energy to 40% by 2030. The country has also raised the solar power generation capacity addition target by five times to 114 GW by 2022. The Government is preparing a 'rent a roof' policy for supporting its target of generating 40 GW of power through solar rooftop projects by 2022 [8, 9]. In the current decade (2020-2029), the Indian electricity sector is likely to witness a major transformation concerning demand growth, energy mix, and market operations.

The aforementioned facts show that the country has great opportunities in the renewable energy sector. The geographical location of India makes the country rich in solar insolation; we receive yearly mean solar irradiation of 6.5 kWh/m2/day [10-12]. Although we are rich in solar insolation and related technologies, the implementation procedures and related policies are critical for a common man to easily afford and maintain an SPV power generation system at the household level; therefore it is becoming a question of affordability, usability, and maintenance in common man level. There are a handful of SPV power generation systems are available in the market like, Off-Grid, ON-Grid, Hybrid-Grid, standalone SPV systems, centralized SPV system micro grid SPV system, rooftop and ground-mounted systems depending upon the technology and types of installation [13, 14]. One can purchase or customize a specific SPV system as per the requirement by investing a onetime initial amount. However, it has been noticed that after the installation and commissioning of a particular SPV plant; the lethargic response and slow technical supports by the vendors or the third parties are degrading the confidence in efficiency, reliability, troubleshooting and maintenance of the system among the end-users. Therefore the generation and application of SPV power are lagging as compared to the demand in our country. Keeping the above facts in view, in this paper we are elaborately describing the design, installation, operation, maintenance, troubleshooting, and various financial aspects to set up an indigenous household-level solar photovoltaic power generation system as per the individual requirements.

This paper has been organized as follows. Section II describes the different design aspects of SPV power generation systems followed by customer's requirement, electrical load assessment, plant site selection, civil and mechanical survey, payback period calculation, and finally feasibility test of the proposed SPV power generation system in the subsequent subsections. Section III describes the installation and commissioning procedures. Section IV describes the maintenance and troubleshooting techniques and section V concludes the discussion.

II. DESIGN ASPECTS

Fig 1.shows the block diagram of a typical SPV power generation system. Along with the other Electromagnetic (EM) radiations, Earth receives visible and Infrared (IR) radiations from the sunlight during the daytime and is basically responsible for photovoltaic power generation. The IR band is usually divided into three sub regions: Near Infrared (NIR) with wavelength 0.78 to about 2.50 micrometers (µm); Middle Infrared (MIR), with wavelengths 2.50 µm to about 50 µm; and Far Infrared (FIR), with wavelengths 50µm to 1,000 µm. All most all SPV panel available in the market converts the incoming radiant solar energy into photoelectric energy (DC Power) by using the upper visible and near IR band of radiation at about 0.45 to 1.3 µm [15-17]. There are different kinds of solar panels are available in the market as like; Monocrystalline silicon (mono-Si), Amorphous silicon (a-Si), Gallium arsenide (GaAs), Cadmiumtelluride(CdTe),MonolithicTandem Cells(GaInP/GaAs/GaInAs), and Copper Indium Selenide (CIS). Among the above, polycrystalline silicon or a-si solar panel is popularly used for commercial and domestic purposes due to its affordability [18-19]. The output of the SPV panel is direct electric current.A single SPV panel consists of numbers of Photovoltaic cells (PV) in a series and shunt manner in order to generate the required DC voltage and current to maintain the specific DC power. For instance, a typical a-Si solar cell generates 0.5 to 0.6 volt and produces a current between 28 to 35 mill amperes (mA) per square centimeter of area. A typical 250 Watt polycrystalline solar panel comes with Power Max (Pm) 250 Watt, Short

Circuit Current (Isc) 8.95 Amp, Max Power Current (Imp) 8.35 Amp, Maximum Voltage (Vmp) 29.95 Volt, Open Circuit Voltage (Voc) 37.25 Volt, System Voltage 1000 Volt, No of Cells in Series 60 Nos. with physical dimension 1.655 × 0.99 × 0.034 meters length, breadth and width respectably and weight approximately 14.2 kg.

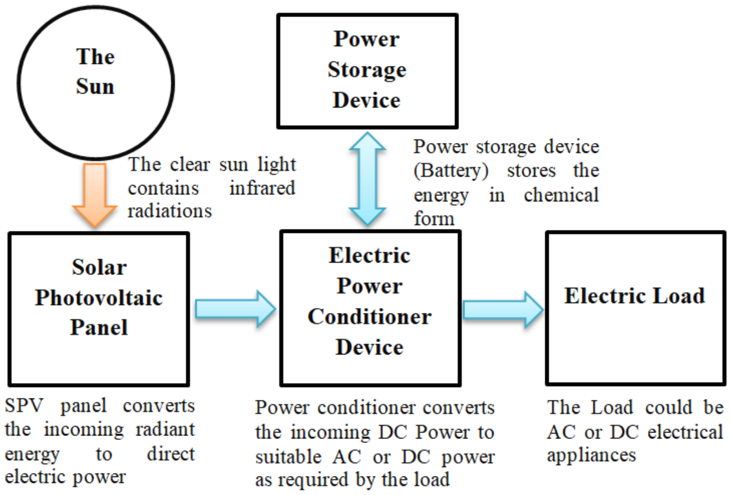

Fig 1. Block Diagram of SPV Power Generation System

The output of solar PV panel(s) is connected to an electric power conditioner device(s). In this stage, the generated DC power is processed to a suitable form to be used either directly in the load or to be stored in the battery for future use or simultaneous application. The basic function of the power conditioner is to eliminate the fluctuation and stabilize the output power of the SPV in order to maximize the output power efficiency. If the nature of the load is AC then a power inverter or a solar retrofit should be used to drive the AC loads and to charge the battery(s) simultaneously. If the nature of the load is DC then a charge controller should be used to drive the DC loads and to charge the battery(s). There are two types of charge controllers are available in the market, Maximum PowerPoint tracker (MPPT) charge controller and Pulse-width Modulation (PWM) charge controller. MPPT charge controllers are popularly used for commercial and domestic purposes as they are more efficient than PWM controllers [20, 21]. A variety of solar inverters, Retrofits, charge controllers are available in the market with a wide range of facilities and costs, and one can select an appropriate device as per the requirement [22]. The battery bank is used as a power storage device to store the generated power during the daytime and to use the same as backup power during night or in the absence of daylight. A variety of batteries are available in the market like lead-Acid, Lithium-ion, and lithium polymer [23]. Maintenance-free lead- acid batteries are popularly used for commercial and domestic purposes. Conventional AC electrical home appliances are normally used as electrical loads, those are generally power hunting devices and could be replaced by advanced power saving DC electrical devices like LED bulbs instead of com- pact fluorescent lamps, Brush Less Direct current (BLDC) fans instead of AC synchronous fan, LED TV instead of picture tube TV, energy-efficient refrigerator, washing machine and other domestic appliances to optimize the use of electric power.

A. Customer Assessment

The customer or the user is an individual who is interested to set up a Home Solar Photovoltaic (HSPV) system for domestic use and a designer is a person or a team of people who will help to set up an HSPV system. A customer can design and set up his HSPV system by himself without the intervention of a third party by following the subsequent steps as discussed below. The first step before going through the design procedures of the HSPV system; is the customer assessment plan. In this stage, the designer collects some useful information as like in Table 1 from the customer to figure out and evaluate the exact requirements of the customer by preparing some preliminary questionnaires

1. Name and address of the customer
2. Electricity Consumer details of the customer
3. Details of sanctioned power from electricity board
4. Details of monthly (yearly) electricity bill
5. Load-shedding information
6. Maximum wind speed information
7. Dimension of HSPV system planned to setup
8. Location details to setup the HSPV system
9. Area availability for panel installation
10. Budget target to setup HSPV system

Table 1: Customer assessment sheet

1	Name and address of the Customer	Mr. X.Y. Sharma
		Plot No. AB/105, Acharyabihar
		Bhubaneswar, Odisha -751022
2	Consumer details of the customer	Vendor Name: CESU
		Customer ID: A503S039T814
		Division: JED Bhubaneswar
		Sub Division: Acharyabihar
		Usage: LT Single Phase
3	Sanctioned power from electricity board	Sanctioned: 02kW domestic
		Monthly Average units: 180
4	Monthly Electricity bill	Monthly Average bill : 419.5
5	Load-shedding Information	Average 05 hr. /day
6	Maximum wind speed information	180 km/hr. during the cyclone
7	Size and type of the HSPV system planned to setup	Size: 02 kW
		Type: Rooftop mounted
		Standalone system
8	Location details to setup the HSPV system	Plot No. AB/105, Acharyabihar
		Bhubaneswar, Odisha -751022
		Latitude: 20.2942
		Longitude: 85.8294
9	Area availability for panel installation to setup HSPA system	Required Area: 14 Sqr. meter
		Available Area: 20 Sqr. Meter
10	Target budget to setup HSPA system	01 Lakh Maximum

B. Home Energy Audit

An energy audit is the second and foremost step from the design point of view. In this step, the designer has to assess and estimate the electrical energy requirement and usage of the customer by conducting a load survey. Load survey is a process to figure out the type of electrical loads and the amount of energy consumption byloads those are either connected previously or need to be connected newly in the HSPV system as well as to determine the energy rating of each load as mentioned in the specification sheet along with the usage period of the individual load. A load survey is also essential to determine the peak power and to estimate the total energy loss during generation, transmission, and conversion, finally to calculate the net and gross energy requirement. One can calculate the amount of energy consumed by a particular load simply by multiplying the power rating with the duration of operation of that load using (1). Table II shows a typical energy audit sheet. For instance, a particular customer has a requirement to use 04 Nos. of 10 W LED bulbs and 04 Nos. of 05 W LED bulbs as light loads to be operated for 08 hrs per day on an average. Similarly, he needs to be operated 04 Nos. of 40 Watt fans on an average of 12 hrs per day and a 100 W LED TV on an average 12 hrs per day. Accordingly, the net electrical energy required to drive loads per day is calculated to 4040 watt-hours (Wh). However, net energy calculation is not sufficient for the design; the designer has to consider the system autonomy, energy loss due to device efficiency, energy loss due to transmission and conversion and depth of discharge of batteries (DoD).

$$\text{Energy (kWh)} = \text{Power (kW)} \times \text{time (hr)} \quad (1)$$

Table II: Energy audit sheet

Sl. No	Load type	Energy rating (Watts)	Qty. (Nos.)	Average operation duration	Energyconsumed Wh / day
1	LED bulb	10	04	08	320
2	LED bulb	05	04	08	120
3	Fan	40	04	15	2400
4	LED TV	100	01	10	1000
Net energy requirement					4040
Energy requirement for half a day autonomous (50%)					2020
Energy requirement to compensate total loss (10%)					404
Energy requirement for battery DOD (25%)					1010
Energy backup for other purpose (15%)					606
Gross energy requirement					8080

The autonomy is the time during which the load can be met with the battery alone, without any solar inputs, starting of course from “fully charged” battery state. Simply, autonomy is one kind of battery backup in the absence of solar input. The autonomy capacity of the system depends on the user requirement and capacity, whereas a minimum of half day autonomy is a good design practice. For instance, the half-a-day autonomy of net energy 4.04 kWh is 2.02 kWh. Again energy production efficiency of solar panels decreases along with time, so to compensate for this loss the designer has to consider 5% of surplus energy produced during the design analysis thus for the above example 5% of 4.04 kWh is becoming 0.202 kWh. Energy loss due to the transmission and conversion can be considered 3% to 5% of net energy, hence another 0.202 kWh needs to be considered by the designer. Any battery shouldn’t discharge to 100% of its capacity during the discharging cycle, so DOD indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery. Recommended DOD for lead-acid batteries are 50% and for lithium-ion, it is varied in between 50% to 30%. On average one can consider 25% of surplus energy conversion to compensate the battery DoD for the smooth operation and longevity of the battery therefore for the above instance 25% of 4.04 kWh is 1.01 kWh has to be added in the net energy. 15% marginal energy should be considered for other domestic applications for system reliability that is 0.606 KWh need to be considered for the above example. Considering the above factors and by adding all the energy requirements as calculated above the gross energy requirement are becoming 8.0 kWh for the instance design scenario. One can follow the aforementioned procedure to estimate the gross energy required to design an HSPV system.

C. Payback Period Calculation and Feasibility Test

After completion of the energy audit, one should estimate the payback period of the project to decide whether the project would be feasible or not. The payback period is the time duration one needs to recover the cost of his investment (2). If the payback period of a system is in between four to six years then the project should be well accepted. If the payback period is beyond eight years one needs to reject or modify the system design. As an instance, a particular customer who is a consumer of the electricity board and is paying 1800.00 INR per month on average including energy charge, meter rent, and other charges for a demand of 02 kW from the board and annually he is paying 21,600 INR. IF he would like to install a 02 kW HSPV system with a payback period of six years, then the investment should be limited to an amount of 1,29,600 INR.

$$\textbf{Payback Period (years)} = \frac{\textbf{Total Investment}}{\textbf{Annual Expenditure}} \quad (2)$$

D. System Design

In this section design of the SPV power generation system has been explained in detail. It could be categorized in two ways, Electrical design and Mechanical design. The electrical design provides the size of the plant, the size of the panel, the size of the inverter/charge controller, size of batteries, size of wires, list of protection devices and switches, and Single Line Diagram (SLD) of the plant. Mechanical design provides the area required for the mount, type of mount (whether rooftop or ground-based), and size/specification of the mount. Electrical design starts from the total size (plant size) determination of the SPV power generation system. The plant size could be determined by simply dividing a factor of 04 with the gross energy requirement (3). The factor of 04 is a standard value for the Indian region. As an instance, in the above, we have determined the gross energy requirement is 08 kWh, so the Plant size of the HSPV system would be 02 kW. After calculating the plant size of the HSPV system, one can find out the Nos. of PV panel required (panel size) to install in the PV array to achieve the energy required. This can be achieved simply by dividing the plant size of the SPV system with the standard PV panel size that is available in the market (4). As an instance, we have calculated the plant size is 02 kW and we preferred a single PV panel with 200 W standard sizes, hence we need 10 Nos. of SPV panels to install in the system.

TableIII:SpecificationofatypicalSPVpanel

Parameters	**Values**
MaximumPower	200W
Tolerance	3%
OpencircuitVoltage	30VDC
Shortcircuitcurrent	8.56Amp
Maximumpowervoltage	24.6VDC
Maximumpowercurrent	8.13Amp
Moduleefficiency	15.30%
Solarcellefficiency	17.20%
Seriesfuserating	15Amp
TerminalBoxtype	IP65
Operatingtemperature	-40to85Degree C
Dimension	1320mm x 992mm x 35mm
TerminalBoxType	IP65
Weight	14.5kg

$$\textbf{Plant Size (kW)} = \frac{\textbf{Gross Energy (kWh)}}{\textbf{04}} \quad (3)$$

$$\textbf{Panel Size (kW)} = \frac{\textbf{Plant Size (kW)}}{\textbf{Standard Size (kW)}} \quad (4)$$

Table III shows the specification sheet of a typical 200 W SPV panel. The output power of the PV array depends on the series and shunt connection of the individual PV panel. Series connection improves the terminal voltage whereas shunt connection improves the terminal current. Depending upon the input voltage and current rating of the solar inverter/charge controller, one can arrange the panels either in series or in shunt or a series-shunt manner in the PV array. PV panels are connected in three different ways in the PV array in order to achieve the required output power, the series connection, the shunt connection, and the series-shunt connection.

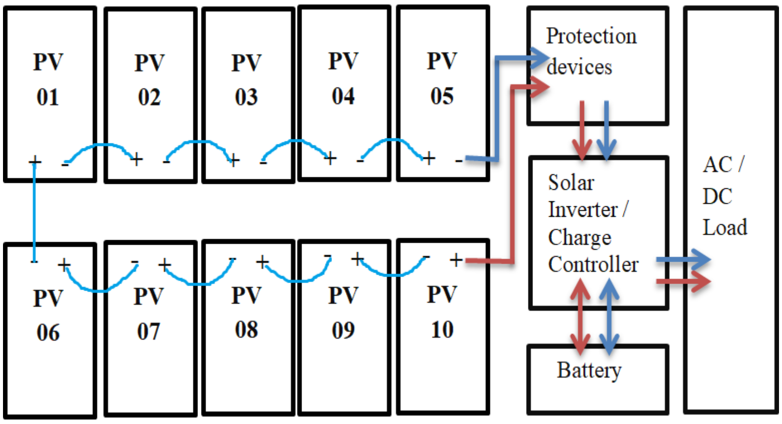

Fig 2. Series connection of PV panels

Fig. 2 shows the block diagram of a typical SPV power generation system with series-connected PV panels. All PV panels are connected in series to maximize the output voltage by adding the individual output voltage of each panel. Then the output voltage of the PV array is fed to the protection devices to secure from the lightning, short circuit, over- voltage, under-voltage, and over-temperature. Then it goes to the solar inverter/charge controller depending on the nature of the load. A battery bank is connected to store the electrical charge and finally the conditioned output power from the inverter/ charge controller feed to the load.

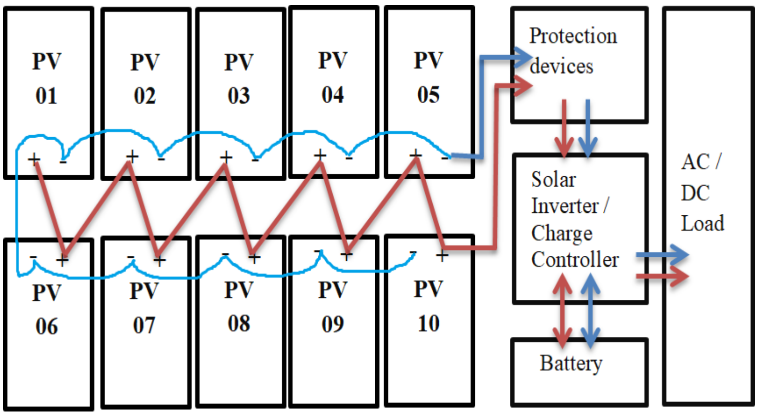

Fig 3. Shunt connection of PV panels

Fig. 3 shows the block diagram of SPV power generation with shunt-connected PV panels. In this design, all panels are connected in shunt to maximize the terminal current. However, for a typical SPV power generation system the terminal voltage of the SPV array shouldn't be less than the input rating of the inverter/charge controller. If all the panels are connected in shunt then the terminal voltage will be equal to the maximum power voltage of a single SPV panel which is 24 to 36 VDC and this will be less than the input rating of the inverter/charge controller. Hence this design is not popular.

Fig. 4 shows the block diagram of the SPV power generation system with series-shunt connected panels. This is an optimum design for the SPV power generation system as it provides the optimum terminal voltage and current. In this design, there should be symmetrical arrays of panels connected to the inverter/charge controller. Asymmetric PV array will generate non-uniform terminal voltage and non-uniform terminal voltages shouldn't be connected in the shunt. This is a popular design to install medium and large size SPV power plants.

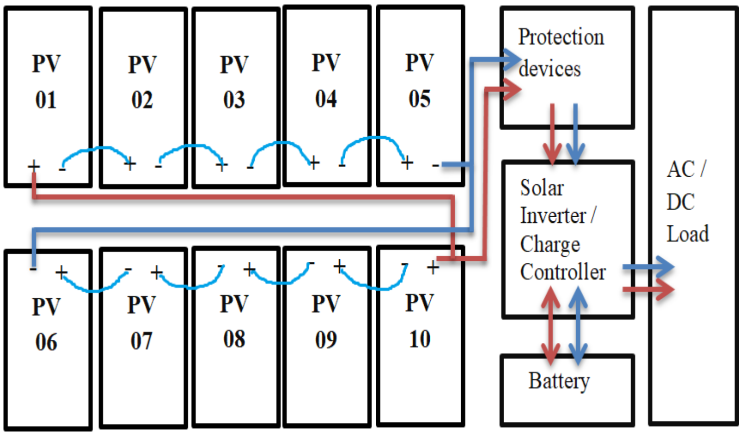

Fig 4. Series-Shunt connection of PV panels

As an instance, suppose the customer is interested to design an HSPV system to drive the AC loads. Then he needs to select a solar inverter instead of a charge controller. Table IV shows the specification of a typical solar inverter. The minimum and maximum input voltage of the inverter is mentioned as 80 VDC and 1000 VDC respectably. As calculated in the above, 10 Nos. of 200 W PV panel each is required to set up a 02 KW SPV power plant. In order to satisfy the inverter input power requirement, we could design 02 PV arrays of 05 PV panels that will provide 120 VDC and 8.13 Amp at the terminal of each PV array.

TableIV:Specificationofatypicalsolarinverter

Parameters	**Value**
Maximuminputvoltage	1000VDC
MPPvoltagerange	210to800VDC
Minimuminputvoltage	80VDC
Maximuminputcurrent	12Amp
Ratedoutputpower	180to270VAC
outputcurrent	17.4Amp
Maximumefficiency	98%
Outputfrequency	60Hz
Operatingtemperature	-40to85Deg.C
Weight	21.5kg

On the other hand, if the customer is interested to design an HSPV system to drive the DC loads. Then he needs to select a solar charge controller instead of an inverter. Table V shows the specification of a typical MPPT solar charge controller. The maximum nominal input voltage and operating current of the charge controller are 48 VDC and 50 Amp respectably. To satisfy the above input power requirement of the charge controller the PV array should be designed in a series-shunt manner where two series-connected SPV panels are linked in five shunt lines to provide 48V DC and 40 Ampere at the terminal of the PV array.

TableV:Specificationofsolarchargecontroller

Parameters	Values
Item type	MPPT Solar charge controller
Maximum Power	02 kW
Nominal input voltage	12/24/48 VDC
Maximum operating current	50 Amp
Maximum charge current	40 Amp
Operating temperature	- 40 to 850C
Weight	2.1 kg

E. Site Survey for SPV Installation

A site survey is crucial from a design point of view; the designer has to select the most suitable place for the installation of the PV panels. During the selection of a site for PV installation, the designer should be concerned about the following points.

1. The installation site should be free from shadow or obstruction of sunlight from 06:00 AM to 6:00 PM for maximum efficiency, as obstruction of the sunlight degrades the PV power production.
2. The installation site should be chosen as a dry and cool place, as the increase in temperature reduces the PV power generation.
3. The designer should avoid a polluted and dusty environment to set up the PV panels, though the dust accumulation over the panel reduces the PV generation efficiency.
4. Distance between solar PV panel and the load should be limited to 100 meters to avoid energy loss due to the long transmission line.
5. For rooftop installation, the designer should be concerned about the area availability and area required for PV panel installation and the mechanical load-bearing capacity of the building roof.
6. For ground installation clay, black and sandy soils are the best choice for mounting the mechanical structure.

A typical rooftop HSPV system is simple and comparatively cost-effective at the household level. As an instance, we will discuss the design, installation, maintenance, and troubleshooting aspects of a 02 kW rooftop HSPV system in the subsequent sections.

III. INSTALATION ASPECTS

A. Mount Installation

Mounting systems are important to hold the PV panels in the array. Basically, there are two types of rooftop mounting; flat roof mounting system and sloped roof mounting system. The flat roof mounting system as shown in Fig. 5 is basically preferred for large-sized systems or for commercial power plants. Sea or river floating solar power plants are basically used flat roof mounting systems. The sloped roof mounting system as shown in Fig. 6 is basically used for residential purposes. It could be either a rail attached system or a fixed mounted system. The rail attached system is a flexible system and in this system, a rail is attached to the roof to support rows of solar panels. Each panel, usually positioned vertically/portrait-style, attaches to two rails with clamps. The rails are secure to the roof by a type of bolt or screw, with flashing installed around/over the hole for a watertight seal. A fixed or rail-less system is a simple and popularly used residential purpose. In fixed rooftop installation, instead of attaching to rails, solar panels attach directly to hardware connected to the bolts/screws going into the roof.

Fig 5. Flat roof mounting systems

Fig 6. Sloped roof mounting systems

As discussed in the design section, for a 02 kW HSPV system, 10 Nos. of 200 W SPV need to be mounted on the rooftop. It depends on the designer and is available for mounting, to mount the SPV in a single row or two different rows. One could find out the effective rooftop mounting area by multiplying the single panel area with the total nos. of the panel needed to install. A typical rooftop mounting is shown in Fig.7.

Fig 7. Rooftop mounting

B. Panel Installation

After mounting the structures on the top of the roof, one needs to install the solar panels upon the mount as shown in Fig. 8. One can install the panel either in series connection or in shunt connection or a series-shunt manner. For HSPV 02 KW system a series-shunt design is suitable as mentioned above. During the panel installation, one should follow the safety precaution by wearing helmet, apron, and hand gloves.

Fig 8. Panel installation

C. Electrical Wirings

Once the installation of the solar panel is done, one needs to connect individual solar panels as per the single line diagram. Every solar panel has two electrical terminals, one termed as positive terminal and indicated as red or marked as +ve; another is the negative terminal and indicated as black or marked as -ve. For the series connection of the panels, one need to connect the +ve terminal of one PV panel with the -ve terminal of the adjacent PV panel. For shunt connection of the panels one need to connect all +ve terminals in one connection and all -ve terminal in other connection. To ensure the terminal voltage of the connections one can use a DC voltmeter or a Multimeter. Once all the PV panels are connected as per the single line diagram, a suitable three-core electrical cable should be connected to the terminal of the PV array to the Protection device and subsequently to the inverter and subsystems. Out of the Three-core one should connect to the +ve terminal another should connect to the -ve terminal and the last core should be used for earthing purposes. For SPV electrical wiring one should be highly concerned about the color code of the electrical cable. The +ve terminal must be connected to the red core, the -ve terminal must be connected to the black core and the earthing terminal must be connected to the green core to avoid the connection and confusion; unlike AC system, DC system always polarity sensitive.

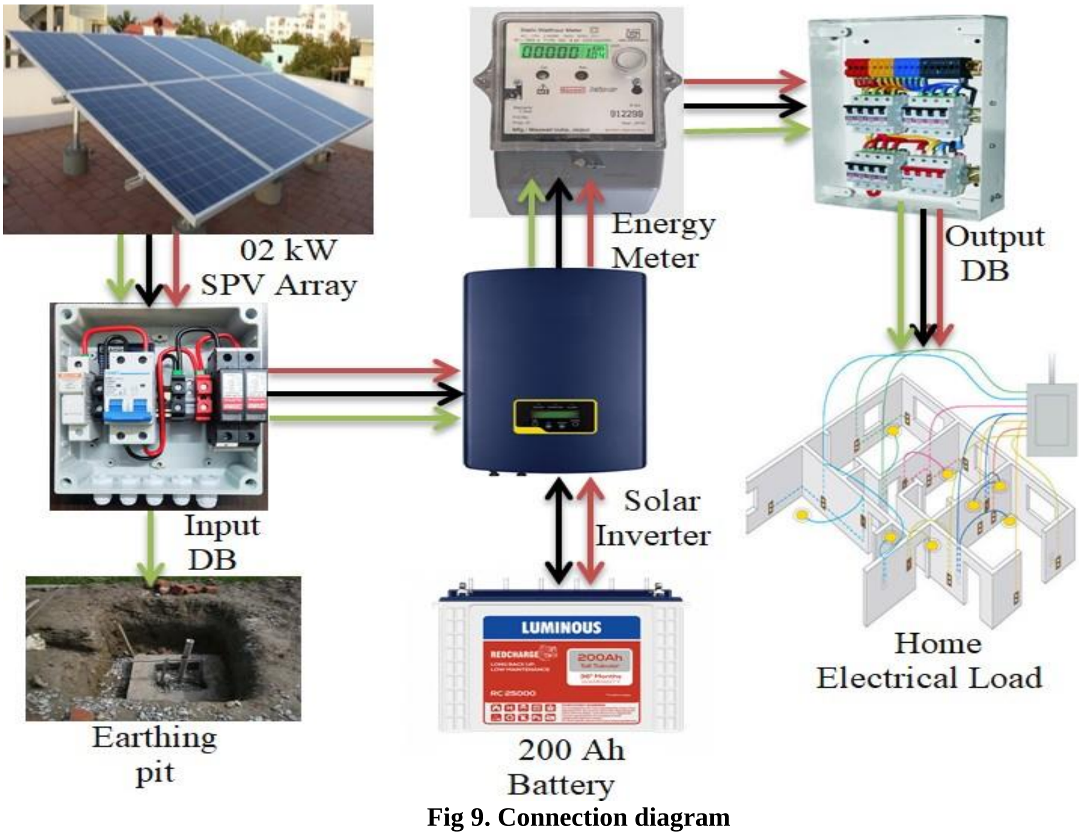

Fig 9. Connection diagram

For the 02 kW HSPV system design, as shown in Fig. 9 the generated DC Power comes from the SPV array to the input Distribution (DB) box through a 100 Amp three-core electric cable. The input DB is consist of two 40 Amp Fuses, two 36 Amp MCBs, one surge protector, and a DC selector switch to isolate the PV array from other connection in case of emergency. An earthing Pit is connected with the connection to protect from surge current during lightning. The DC power from the input DB is connected to a 02 KW solar inverter to generate AC power and simultaneously charge the battery bank. One can use an MPPT charge controller as specified above if the home electrical load is DC in nature. An energy meter is connected in between the inverter output and input DB box to measure the power generated and used. Finally the generated AC power, powered the home electrical load.

IV. MAINTENANCE AND TROUBLE SHOOTING

Virtually solar panels required no maintenance. However, the other equipment and accessories required periodical maintenance for better efficiency. The PV panel needs to wipe at least once a week to ensure the removal of dust accumulation over the panel, only water can be used for cleaning purpose no other cleaning agent is required to clean the PV panel. As a part of preventive maintenance, one should ensure the following at least once a month.

1. Ensure the PV panel should be free from any kind of physical damage or cracks.
2. Ensure there shouldn’t be any dust deposition or any kind of debris falling above the PV array. If so then clean the PV array using plane water.
3. Ensure the tightness of the electrical connections. There shouldn’t be any loose connections, if so then fix the lost connections.
4. If the panels have connected in parallel, the terminal voltage should be nearly 25 Volt DC during peak day- light.
5. If the panels have connected in series, the terminal voltage should be nearly 25 times the nos. of panel connected in the array.
6. Ensure the good health conditions of the fuses, MCBs, surge protectors, and switches in the DB box.
7. Check the input DC voltage through a DC voltmeter in the +ve and -ve terminal connected in the respective MCBs. If the meter shows zero value then check the condition of FUSEs.
8. Ensure the proper earth connection and observe the earth pit condition.
9. Inspecting and cleaning the inverter and making it free from dust. Ensure the operating temperature of the inverter is within the limit.
10. Inspecting and cleaning of battery rack, terminals, and cases trays.
11. Inspecting battery disconnects overcurrent and wiring systems.
12. Measure terminal voltage and specific gravity of batteries if required add distilled water.
13. Inspect auxiliary systems and load capacity of the batteries.

V. CONCLUSION

At the domestic level, a home solar photovoltaic system is useful to provide the round the clock power supply. HSPV system will be helpful to satisfy the power requirements during the load shedding and it also reduces the electricity bill of the consumer. An off-grid standalone HSPV system could able to produce the household power requirement in a remote location independently. An HSPV system could be customized as per the requirement of the user. Anyone can independently design, Procure, install an HSPV system at a nominal cost. The design, installation, maintenance and troubleshooting aspects of a 02 KW standalone cost-effective HSPV system have been discussed. An HSPV system with DC load is more efficient and cost-effective than an HSPV system with AC load. Almost all DC-operated home appliances are available in the market, LED bulbs, LED TV, BLDC fan, home theater, DC-operated refrigerator and grinders, etc. One can convert all the AC- operated home appliances to DC-operated home appliances for efficient use of solar power.

REFERENCES

[1] P. S. Sausen, M. de Campos, A. Sausen, M. Binelo and M. dos Santos,“ProposalforaMethodologyBasedonElectricityConsumptiontoAnalyzeSocialIsolationDuringaCOVID-19Pandemic:CaseStudy,”in IEEE Latin America Transactions, vol. 19, no. 6, pp. 909-916, June2021.

[2] R. Subbiah, A. Pal, E. K. Nordberg, A. Marathe and M. V. Marathe,“Energy Demand Model for Residential Sector: A First Principles Approach,” in IEEE Transactions on Sustainable Energy, vol. 8, no. 3, pp.1215-1224,July2017.

[3] UnitedNations,InternationalRecommendationsforEnergyStatistics(IRES),StatisticalPapers,SeriesM,No.93,2018.Availableathttps://unstats.un.org/unsd/energy/ires/IRES-web.pdf

[4] GovernmentofIndia,ministryofPower,PowerSectorataGlanceALLINDIA,Availableathttps://powermin.gov.in/en/content/power-sector-glance-all-India

[5] Yu,S.,Evans,M.,Page,K.,Vu,L.,Tan,Q.,Gupta,A.,andPatel,“Implementing nationally determined contributions: Building energy policies inIndia’smitigationstrategy,”Environmental ResearchLetters13(3), 2018.

[6] S. K. Behera, J. A. Farooquie and A. P. Dash,“Productivity change ofcoal-firedthermalpowerplantsinIndia:aMalmquistindexapproach,”in IMA Journal of Management Mathematics, vol. 22, no. 4, pp. 387-400,Oct.2011.

[7] India brand equity foundation, Available athttps://www.ibef.org/archives/industry/indian-power-industry-analysis-reports/indian-power-industry-analysis-july-2021

[8] D. Roy, U. K. Rout, S. Jonalagadda and P. Behera, “A brief analysis onsolar status of India”, Proc. Int. Conf. Innov. Mech. Ind. Appl. (ICIMIA),pp.451-456,Feb.2017.

[9] A. Gulagi, P. Choudhary, D. Bogdanov and C. Breyer,“Electricity systembased on 100% renewable energy for india and SAARC”, PLoS ONE,vol.12,no.7,Jul.2017

[10] G. A. Gericke and N. J. Luwes,“Evaluating Real-Time-Location SolarIrradianceDataAgainstSOLARGISGroundStationSolarIrradianceFor The South African Sasol Solar Challenge,” 2019 AEIT InternationalConference of Electrical and Electronic Technologies for Automotive(AEITAUTOMOTIVE),2019,pp.1-6.

[11] A.Habte,M.Sengupta,P.GotseffandC.A.Gueymard,“AnnualSolar Irradiance Anomaly Features Over the USA during 1998–2017Using NSRDB V3,” 2020 47th IEEE Photovoltaic Specialists Conference(PVSC),2020,pp.1947-1951.

[12] A. Burta and R. Szabo,“Solar Irradiance Measurement for a Thermo-Electric Hybrid Solar System,” 2020 5th International Conference onSmartandSustainableTechnologies(SpliTech),2020,pp.1-6.

[13] A. K. Singh, S. Kumar and B. Singh,“Solar PV Energy GenerationSystemInterfacedtoThreePhaseGridWithImprovedPowerQuality,”in IEEE Transactions on Industrial Electronics, vol. 67, no. 5, pp. 3798-3808,May2020.

[14] C.WangandM.H.Nehrir,“Powermanagement ofastand-alonewind/photovoltaic/fuelcellenergysystem”,IEEETrans.EnergyConvers.,vol.23,no.3,

pp.957-967,Sep.2008

[15] M. A. Budiyanto and M. H. Lubis, “Comparison Result of Hourly SolarRadiation Under The Clear Sky Condition Based on of Solar RadiationModel and Measured Data Experiment,” 2020 1st International Confer-ence on Information Technology, Advanced Mechanical and ElectricalEngineering(ICITAMEE),2020,pp. 298-302.

[16] J.K.ParkandJ.H.Park,“Estimationofsolarratio nsdistributionconsidering the topographic conditions at Jeju island”, Journal of theKorean Society of Agricultural Engineers, vol. 55, no. 1, pp. 39-48, Jan.2013.

[17] N.LeiandX.Xiong,“SuomiNPPVIIRSSolarDi ffuserBRDFDegradation Factor at Short-Wave Infrared Band Wavelengths,” in IEEE Transac-tions on Geoscience and Remote Sensing, vol. 54, no. 10, pp. 6212-6216,Oct.2016.

[18] Z.-W.Peng,L.J.KoduvelikulathuandR.Kopecek, “ModelingtheImpactofBulkResistivityonBif acialn-PERTRear-JunctionSolarCells,”inIEEEJournalofPhotov oltaics,vol.11,no.1,pp.3-8,Jan.2021.

[19] Z. -W. Peng, T. Buck, L. J. Koduvelikulathu, V. D. Mihailetchi and R.Kopecek,“Industrial Screen-Printed n-PERT-RJ Solar Cells: EfficienciesBeyond 22% and Open-Circuit Voltages Approaching 700 mV,” in IEEEJournalofPhotovoltaic,vol.9,no.5,pp.11 66-1174,Sept.2019.

[20] B. Subudhi and R. Pradhan,“A comparative study on maximum powerpoint tracking techniques for photovoltaic power systems”, IEEE Trans.Sustain.Energy,vol.4,no.1,pp.89-98,Jan.2013.

[21] S. Jain and V. Agarwal, “Comparison of the performance of maximumpowerpointtrackingschemesapplie dtosingle-stagegrid-connectedphotovoltaicsystems”,IETElect.Po werAppl.,vol.1,no.5,pp.753-762,Sep.2007.

[22] A.Verma,R.KrishanandS.Mishra,“ANovelP VInverterControlfor Maximization of Wind Power Penetration,” in IEEE Transactions onIndustryApplications,vol.54,no.6,pp.6364-6373,Nov.-Dec.2018.

[23] S.DevassyandB.Singh,“PerformanceAnalysi sofSolarPVArrayand Battery Integrated Unified Power Quality Conditioner for MicrogridSystems,” in IEEE Transactions on Industrial Electronics, vol. 68, no. 5,pp.4027-4035,May2021.