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Design of Solar Power Plant for Dr. Babasaheb Ambedkar Technological University, Lonere

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Abstract - *The concern related to global energy crisis and climate change threats from conventional sources of energy leads to look for alternate sources of energy. Solar energy is seen as a potential alternate source of energy as it is available globally in abundant. Solar Photovoltaic (PV) energy conversion system has drawn the tremendous attention of researchers in the past recent years. This paper deals with Solar Photovoltaic based electric power source for University Complex which is situated at place in the ranges of Western Ghats of Maharashtra in India. University campus is surrounded with huge open space and shade free solar radiation which is suitable for solar power generation. This paper include study of total load calculation, area available for placing solar panel, total solar radiation available on daily, monthly and yearly basis, designing of suitable model, designing of efficient storage system, cost analysis including life cycle cost and payback period.*

Key Words: Solar PV System, Cost Estimation, Payback Period, Battery, Inverter.

1. INTRODUCTION

Global energy crisis and threat of environment disorder has become a common concern worldwide. The demand of electrical energy is growing constantly. The conventional sources of energy like thermal etc are having serious issue of having limited reservoirs which may end in the next few decades. The carbon emissions from the power plants using conventional sources are adding serious threat to the environment. Also other source of energy i.e. nuclear is possessing serious threat to the safety of human being. Solar PV cells have nonlinear characteristics. Its efficiency is very low and the DC power output varies with solar irradiation and ambient temperature. In order to get the maximum power from solar PV in different ambient conditions it is necessary to fix the operating point at the maximum power of the PV curve.

In order to arrest the climate change and in view of the depleting conventional energy sources, India is taking firm steps towards development of renewable energy. India has significant potential of electricity generation from Renewable Energy Sources. The Renewable Energy (RE) potential in India is estimated as 896,602 MW comprising of 748,990 MW of Solar Power, 102,772 MW of Wind Power, 19,749 MW of Small Hydro Power and 25,090 MW of Bio-Energy. The Government of India, in pursuit of energy security and for minimizing impact on environment, has been prioritizing the development of RE sector through its policies and programmes. Wind, Solar and small Hydro are three emerging renewable energy sources [2]. It has been observed that, solar as viable alternative for power generation among the available clean energy sources, has the highest global warming mitigation potential. India is one of the best recipients of solar energy due to its favorable location in the solar belt.

Photovoltaic (PV) Technology is a process of generating electrical energy from the energy of solar radiation. The principle of conversion of solar energy into electrical energy is based on the effect called photovoltaic effect. The smallest part of the device that converts solar energy into electrical energy is called solar cell. Solar cells are in fact large area semiconductor diodes, which are made by combining silicon material with different impurities. The sand, a base material for semiconductor, is the most abundantly available raw material in the world. The ordinary sand (SiO_2) is the raw form of silicone. The solar energy can be considered as a bunch of light particles called photons. At incidence of photon stream onto solar cell the electrons are released and become free. The newly freed electrons with higher energy level become source of electrical energy. Once these electrons pass through the load, they release the additional energy gained during collision and fall into their original atomic position ready for next cycle of electricity generation. This process of releasing free electrons (generation) and then falling into original atomic position (recombination) is a continuous process as long as there is the stream of photons (solar energy) falling onto the solar cell surface [3].

Section 2, 3 describes about solar photovoltaic system and its configuration. The system requirement and design is discussed in section 4.

2. SOLAR PV SYSTEM

The basic element of solar PV system is solar cell. These basic cells are connected to form solar PV nodules. Further expansion of solar PV is done by connecting solar PV modules to form solar PV array as shown in Fig.1. and are done as per the power requirement.

Solar Cell Solar PV Module Solar PV Array

Fig-1: Solar PV Connection

Photovoltaic systems are generally categorized into three distinct market segments: residential rooftop, commercial rooftop, and ground-mount utility-scale systems. Their capacities range from a few kilowatts to hundreds of megawatts. A typical residential system is around 10 kilowatts and mounted on a sloped roof, while commercial systems may reach a megawatt-scale and are generally installed on low-slope or even flat roofs. Although rooftop mounted systems are small and display a higher than large utility-scale installations, they account for the largest share in the market. There is, however, a growing trend towards bigger utility-scale power plants, especially in the "sunbelt" region of the planet.

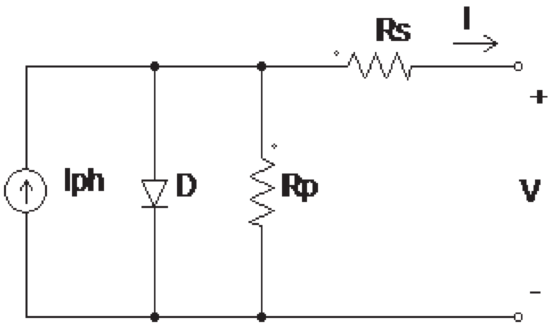

Fig-2: Equivalent Model of PV module.

In recent PV installations crystalline silicon PV modules are most commonly used. However thin film technology is growing in application where its lower cost compensates its lower efficiency. Different solar panel manufacturers are presented for both crystalline silicon and commercial thin film modules. The data has been extracted from the datasheet. The power extracted from crystalline silicon is less that 350W with MPP voltage varies between 20 and 55V. The thin film panel PV has MPP voltage from 50 to 100V with a low power generation of up to 150W. This diode D, which emulates the PN junction of a PV cell; a comparison is useful for researchers to decide the type of PV panel to be chosen.

Table -1: Conversion efficiencies of various PV module technologies

TECHNOLOGY	MODULE EFFICIENCY
Mono-crystalline Silicon	12.5-15%
Poly-crystalline Silicon	11-14%
Copper Indium Gallium Selenide (CIGS)	10-13%
Cadmium Telluride (CdTe)	9-12%
Amorphous Silicon (a-Si)	5-7%

3. SOLAR PV SYSTEM CONFIGURATION

If a solar PV system is designed to meet only a fraction of the electricity load, the system will need to be interconnected with the power grid to meet the demands of the consumer's needs for electricity. If a solar PV system needs to be grid-connected, interconnection is key to the safety of both consumers and electrical workers, and to the protection of equipment.

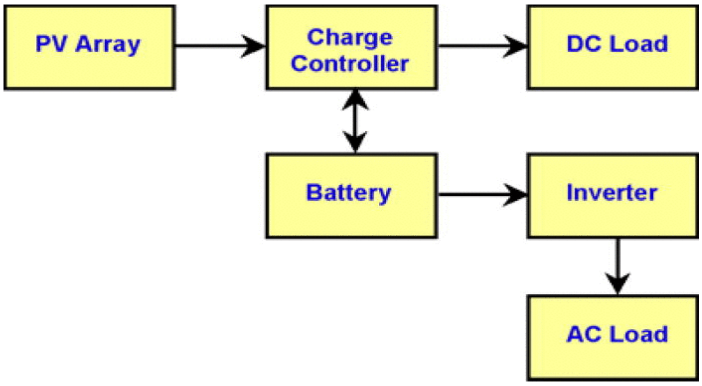

Fig-3: Block diagram of PV System

4. SYSTEM DESIGN

A solar PV system design can be done in four steps:

1. Load Calculation.
2. Estimation of number of PV panels.
3. Estimation of battery bank and inverter.
4. Cost estimation of the system.
5. Payback Period Calculation

They are discussed one by one as follows

4.1 Load Calculation

Considering the average connected load of 100 KW. The total Consumption in the entire day when the whole connected load is switched on is given by,

Total consumption = 100 KW × 10 hrs = 1000 KWh.

4.2 Estimation of number of PV panels

Considering a module of 310 Wp. The watt-peak ratings are generally designed for the solar radiation of 1000 W/m² but the university campus is getting around 850 W/m^2 on an average every day. So the actual output will be lesser than the expected output.

Actual power output of a PV panel = peak power rating × operating factor = 310 × 0.75 = 232.5 = 233 Watts.

Power available at the end use is less due to lower combined efficiency of the system = 233 × 0.81 = 189 Watts.

Table-2: Datasheet of Solar Module

Module Type	Asp-7-310 (Multi Crystalline)
Peak Power (W)	310
Maximum Power Voltage (V)	35.61
Maximum Power Current (A)	8.71
Open Circuit Voltage (V)	44.98
Short Circuit Current (A)	9.14
Module Efficiency (%)	15.81%
Size Of The Panel (L×B×H) (mm)	1976×992×35/40

Energy produced by one 310 Wp panel in a day

= Actual power output × $\frac{7\ hrs}{day}$ = 1631 Wh/day.

So, number of panels required to satisfy given estimated

Load= $\frac{total\ Watt - hr\ rating}{daily\ energy\ produced\ by\ panel}$ = 1000× $\frac{1000}{1631}$ = 615 panels.

4.3 Estimation of Battery Bank and Inverter:

Battery system sizing and selection criteria involve many decisions and trade-offs. Choosing the right battery for a particular PV application depends upon many factors. While no specific battery is appropriate for all PV applications some common sense and a careful review of the battery literature with respect to the particular application requirements will help the system designer to greatly narrow down his choice. Once a particular type /make of battery has been selected, the designer should consider the battery subsystem, i.e., the number of batteries in series and parallel, selection of proper type and size of wires, over-current and disconnect requirements.

Series Connection of Battery: Batteries connected in series have only one path for the current to flow and the total voltage is the sum of the individual battery voltages.

Parallel Connection of Batteries: Batteries connected in parallel have more than one path for the current to flow and the voltage across the entire circuit is the same voltage as across the individual parallel branch.

The size of battery can be calculated as follows:

Battery Capacity (Ah) = Total Watt-hr consumption per day ×

$$\frac{Days\ of\ autonomy}{efficiency \times aging\ factor \times nominal\ battery\ voltage}$$

$$= \frac{1000 \times 1000 \times \frac{1}{24}}{0.9 \times 0.8 \times 24} = 2420A - hr$$

Considering a 120 A-hr battery; Number of batteries required= $\frac{2420}{120}$ = 21 Nos.

Inverter Calculation:

Total load = 100×1000=100000 Watts = 125000 VA; considering 0.8 pf.

Considering a 5500 VA rating of a inverter, No of required Inverters= $\frac{125000}{5500}$=23 Nos.

Table-3: Technical Specification Of The system

Model	Specification
Number of days of autonomy	1
System Output Voltage	230(V), 50(Hz)
Module Type	Multi-crystalline
Array Wattage	310(Wp)
Battery Type	Lithium Ion
Battery Capacity	24(V), 120(A-hr)
Inverter nominal power	5500(VA)
Input voltage	24(V) DC
Output voltage	230(V) AC
Frequency	50(Hz)

4.4 Cost Estimation of the System

a) Cost of the solar panel

= 100×90×615= 55,35,000 Rs.

b) Cost of the Battery

= 8000×21=168000 Rs.

But life of battery is on average 5-6 years. So including the replacement charges for battery, Total cost of battery system will be= 840000 Rs.

c) Cost of battery charge controller.

= cost per kWh × KWh loading = 1500 × 1000 = 1500000 Rs.

d) Cost of Inverter.

= inverter cost per 5500 VA × number of inverter required = 15000 × 23 = 345000 Rs.

Table-4: Total Cost Estimated for System

Component	Approximate cost (Rs.)
Solar Panel	5535000.00
Battery	840000.00
Battery Charge Controller	1500000.00
Inverter	345000.00
Total Cost	8220000.00

4.5 Payback Period Calculation

The solar PV system installed will generate around 1000 KWh. So the annual generation of electric power will be around 1000 × 250 = 250000 Units annually.

Life of solar panel in normal atmospheric condition can be 30-32 years when maintained properly.

The payback period of the proposed system will be around 19-20 years, and the rest of the years will be beneficial to the University.

5. CONCLUSION

Efficiency of plant can be improved by above proposed techniques about 15 to 30 percentage. Thus the college campus can look forward towards full independency from MSEB supply. While implementing the improvement techniques capital cost increases but return period is significantly decreases which is indirectly beneficial. Although it good earning potential to college by giving extra energy to grid through net metering by increasing current energy generation. The results showed promise for solar development in the future. While the area studied may not have the best solar suitability on the west coast, it should be strongly considered for solar power plant development as solar technology advances and alternative energy as a whole becomes more affordable relative to fossil fuels. This study encourages small, locally-funded power plants for the small towns in this region that can remove themselves from the larger grid by embracing the solar resources around them. Most likely, any solar plants built in the region will be much smaller than the thermal power plants in the southwest, and they will use photovoltaic means instead of thermal means to produce power.

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