A Case Study on Implementation of Grid Connected Photovoltaic System for an Institutional Campus, Wardha

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Abstract *- A photovoltaic system also called solar PV power system is a system designed to supply usable solar power by means of photovoltaic* cell. *This paper presents a detailed study of Grid-connected photovoltaic system for power supply of institutional building in rural area. The process of acquiring power from PV panels involves a proper selection, design and determination with specifications of various components that are used in the system for confirming the load estimation. The completion of this process depends on different factors such as geographical location of institution, weather condition and solar irradiance at location along with load consumption at the institute. This paper gives complete procedure for specifying each components of the Grid-connected PV system and an institution in Wardha, India is selected for case study. Complete cost analysis which also includes installation and maintenance cost of a solar photovoltaic system has been carried out. It has been observed from the analysis that capital investment is high but payback period is less and after that it will gain consequential profit.*

***Key Words*: Case study, PV Panel, Solar Irradiation**

1. INTRODUCTION

Energy is the primary and most universal measure of all kinds of work by human being and nature. The degree of development and civilization of a country is determined by the amount of energy utilized by human beings. Electrical energy need is increasing day by day due to increase in population and their standardization, urbanization and industrialization. As we know fossil fuel is the main fuel for thermal power, there is a fear that they will get exhausted eventually in the next century. Therefore other generating plant system based on non-conventional and renewable sources are being tried by various countries from last decades. These are solar energy, wind energy, sea, geothermal and biomass are clean, inexhaustible and environment- friendly resources.

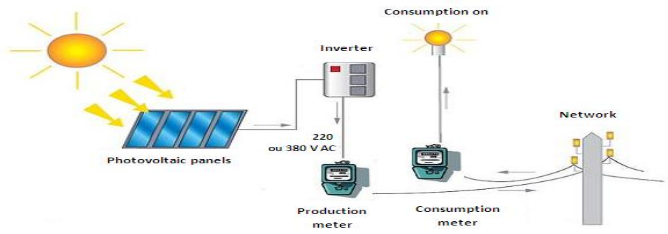
Solar energy has the more ability of all the sources of renewable energy and if only a small amount of this form of energy could be used, it will be one of the most important supplies of energy especially when other sources in country have depleted day by day. The sun gives us 1000 constant rate, due to clouds, winds, haze, etc. but there are limited applications of this generation sources in the electric power. Sun is available at day time only; hence we require the off- time extra energy storage device to meet the demand. In this paper, grid connected solar power system is now being contemplated.

Different places on the globe experience different climatic condition. Variation of total solar irradiance that reaches the surface of earth depends on time of day, season, location and weather condition. Therefore, design of grid connected solar system cannot have only one standard. Location is a major angle that will affect photovoltaic (PV) power system design and it varies from place to place. India is blessed with enough sun shine which can meet our energy demand without any compromise and it is also pollution free. Grid connected PV system is a popular concept in rural areas of India where national electricity grid connection is easily available but solar power is not as common practice to use. There is a general impression that grid energy from conventional source is much less costly compared to solar and other alternate energy source.

In this connection to think on above consideration, equipment specifications given are based on availability of the best components in market. In addition to design considerations, we did a detailed cost analysis of the system in this paper. As expected initial cost of solar power plant installation has been found to be very high and so, the cost of solar energy consumption unit is much more than conventional energy supply system. However, more interestingly, our estimation of the long term cost and area requirement of a grid connected SPV power plant installation establishes our other objective that, contrary to general perception, it is very much economical and cost effective system [1].One of the objective of this paper is to calculate the potential of solar PV power system in rural area. For this purpose, Datta Meghe Institute of Engineering, Technology and Research (DMIETR) building located in Wardha is taken up for designing and developing a PV system based on its daily load requirement. Before presenting the results and analysis of this case study, we have given introduction of different components of a grid connected PV system and their functions in the below section.

2. GRID CONNECTED PHOTOVOLTAIC SYSTEM

A grid-connected PV power system is connected to the utility grid. The components of such a systems are: 1) Solar PV array, 2) Charge controller, 3) Inverters 4) Cables and 5) Protection devices. Depending upon load requirement and radiation intensity at the location, the components of the system will have to be specified. Figure 1 gives a schematic diagram of interconnection of components of a typical grid connected PV power system.



In following subsections we give a brief review of functions of the components.

2.1 Solar Photovoltaic Panel

The solar panel or module is consisting of solar cells that are responsible of collecting solar radiation from sun and convert it into electrical energy in direct current. The solar panel arrays are connected in combination of series (to increase voltage) and/or parallel (to increase current) so as to provide the required energy for the load. The electrical current supplied by an array of solar panels depends on the solar radiation, which is the primary component in a PV system. Voltage and Current generated depends on the area of the cell. A single solar cell can generate voltage of about current density of 30-35mA/cm and 0.55-0.6 Volt.

2.2 Inverter

Inverter is the plays vital role in PV system. A device which converts electrical power from DC to alternating current (AC) is known as inverter which allows some loss of energy.

2.3. Load

A load refers to a component or a part of a circuit that consumes electric power. This is opposed to a power source, such as a battery or generator. In electric power circuits, load such as electrical appliances, light, machines are power consumption devices. Power consumption units are load for a PV system to be planned. Proper load estimation is necessary for designing a grid connected PV system. In PV system design, there is a broad classification of electrical loads such as resistive load and inductive load. Resistive load does not require any significant surge current when energized for example Light bulb, electric heater but inductive load requires a large amount of surges current when the first energized which is about three times the normal energy requirement. Examples of inductive load are fan, electric motor, air conditioner etc. Depending on the load estimation of a building a proper design can be implemented.

2.4 Balance of the system components

Components such as protective device, blocking and bypass diodes, lightning-protection system, fuses, bus bar and cable wiring consist what is known as balance of system components. These components are required to protect the system in an efficient way. Cable size should be chosen to minimize voltage drop or cable loss.

3. PROBLEM STATEMENT

1) In recent years, non renewable sources are used mainly thermal power plants make pollution in environment.
2) DMIETR campus currently depends on state electricity board.
3) Chances of supply failure or load sharing problem
4) Energy demand of College campus is increasing.
5) Pay cost to MSEDCL for use of electricity.

4. METHODOLOGY FOR PV SYSTEM DESIGN

In PV system design, we determine the power, voltage and current of each component of a grid connected PV power system to meet the load requirement. The designing is done with following steps:[2]

Step 1: Site inspection and radiation analysis.
Step 2: Calculation of building load requirements.
Step 3: Choice of system voltage and components.
Step 4: Determine capacity of Inverter.
Step 5: DC cable Sizing.
Step 6: Solar PV array Specification and Design Layout.
Step 7: PV module orientation and land requirement.
Step 8: Cost Analysis.

A. Site Selection

- The site selection for a Solar Power Plant is pre-dominantly determined by solar insolation availability. Equally important are other essential factors / considerations such as:
  - ✓ Availability of adequate roof top space for Power Plant and green belt development
  - ✓ Availability of water and power during construction.
  - ✓ Availability of labour in the proximity.
  - ✓ Availability of load centres (towns) within vicinity.

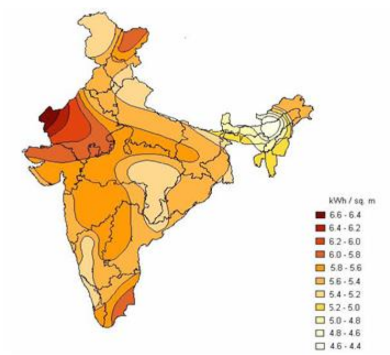
✓ Easy accessibility of the site.

- The proposed site where Power Plant is to be located in Wardha city of Maharashtra state and is found favouring all the above factors to a reasonable extent.

About Wardha District

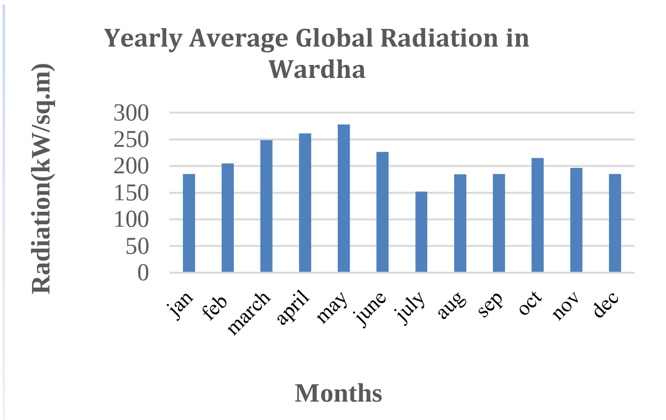
Wardha is located on north-eastern side of the Maharashtra state. It lies between 78^0 4 minutes east to 79^0 15 minutes east longitudes and 20^0 18 minutes north and 21^0 21 minutes north latitudes. The highest temperature reaches in the district to about 46^{0}C whereas the lowest temperature decreases about 9.4^{0}C.
Table: Monthly average radiation data of the site of the year 2016.

- Proposed Location and Land Availability
- City= Wardha
- Topographical & Geological Conditions
- Location of place on Earth
  (i) Latitude: 20.8049,^{0}N
  (ii) Longitude: 78.5661,^{0}E
- Altitude = 234m
- Average annual solar isolation
  a) Average direct normal radiation 5.38 kWh/m^2/day
  b) Average global horizontal radiation 5.64 kWh/m^2/day



Mean Global Solar Radiant Exposure at Wardha.

Months	Daily solar radiation-Horizontal kWh/m²/d
January	1.85062
February	2.05013
March	2.48481
April	2.61393
May	2.78232
June	2.26261
July	1.52094
August	1.84741
September	1.85228
October	2.15214
November	1.96209
December	1.85030
Annual	(2.102 **Kwh/m²/d**)



B. Choice of system DC voltage and components

Once the building load is calculated, Dc voltage other PV system require to be to be fixed. Generally, it should be taken as high as possible so that less current will be required to meet the high energy requirement. Lower the current through cables lower will be the electric energy loss, because cable has resistivity and high current will cause joule heating of cable. Otherwise, much thicker wires are required which will increase cost of the system.

C. Calculated Load of Administration Building[2]

1. Library (no. x hours x wattage)

	Fan	Tube Light	Computers	Exhaust Fan	Air Condition(AC)	TV	Ducting
Library Hall	4x2x80 =640 Watthour	7x2x18 =252 Watthour				3x7x60 =1260 Watthour	2x4x2238 =17904 Watthour
Book Hall	4x7x80 =2240 Watthour	14x7x18 =1764 Watthour	4x7x100 =2800 Watthour		1x0.5x1650 =810 Watthour		
Bath room		4x7x18 =504 Watthour		2x0.5x60= 60 Watthour			

Ground floor

	Fan	Tube Light	Computer	Exhaust fan	AC	TV	CFL	Xerox M/C
Xerox room	1x6x80 =480 Watthour	1x7x18 =126 Watthour						1x6x1250 =7500 Watthour
Principle room	4x4x80 =1280 Watthour	4x40x4=640 Watthour 4x5x1 =300 Wh	1x3x100 =300 Watthour		1x3x1650 =4950 Watthour			
Board room	6x1x80 =480 Watthour				3x0.5x1650 =2475 Watthour		12x15x2 =360 12x2x40=960 Watthour	
Office room	20x7x80 =11200 Watthour	34x7x18 =4284 Watthour	18x7x100 =12600 Watthour	2x0.5x60 =60 Watthour				

Admin block

2. Total electrical load (Watt hour per day)

Library

- Library hall=20056 Wh/day
- Book hall=6614 Wh/day
- Bathroom=504 Wh/day

Ground floor

- Xerox m/c room=8106 Wh/day
- Principle room= 7470 Wh/day
- Board room=3315 Wh/day
- Office room=22144 Wh/day

3. Total electrical load= 68209 watt hour per day

I. Calculate solar system size

- Average Sunshine Hours = Daily Sunshine Hour in Summer+ Winter+ Monsoon /3
- Required Size of Solar Panel = (Electrical Load / Avg. Sunshine) X Correction Factor

If we Use 250 Watt, 24V Solar Panel in Series-Parallel Type Connection then

II. Calculate No. of Solar Panel / Array of Solar Panel

- In Series-Parallel Connection Both Capacity (watt) and Volt are increases
- No of String of Solar Panel (Watt) = Size of Solar Panel / Capacity of Each Panel
- No of Solar Panel in Each String= Solar System Volt / Each Solar Panel Volt
- Total No. of Solar Panel = No. of String of Solar Panel x No. of Solar Panel in Each String

Calculate Electrical Load

- Load for Computer = No x Watt
- Load for Computer = 23×100 =2300 Watt
- Load for Fan = No x Watt
- Load for Fan = 39×80 = 3120 Watt
- Load for CFL Light = No x Watt
- Load for CFL Light = (16x15)+(16x40) = 880 Watt
- Load for tube light =62x18=1116 watts
- Load for exhaust = 2x60 =120 watts
- Load for AC = 5x1650=8250 watts
- Ducting = 2x2238=4476
- Total Electrical Load = 2300+3120+880+1116+120+8250 =20262Watt

Calculate Size of Inverter

- Total Electrical Load in VA= Watt /P.F
- Size of Inverter =Total Load x Correction Factor / Efficiency

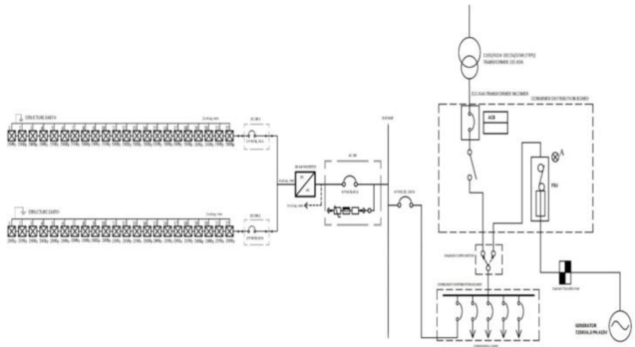
D. Costing of plant

Equipments	Quantity	Price (Rs)
Vikram solar panel (250 W)	44 x7,500	3,41,000
Inverter (30 kW)	1 x 2,54,00	2,54,000
Cable, MCB, WIRES)		25,000
Infrastructure		35,000
Service charge	19,46,000 X (15/100)	1,09,800
Travelling expenses	60,000	60,000
Maintenance cost of 5 years		60000
Total		8,84,800

E. Payback Period of system

Total cost of Plant = 884800Rs.
Plant Capacity = 12 kW
Generation per Day = 12 x 8 (operating hours)
= 96 kWh /day
Annual Generation = 96 x 365
= 35040 kWh/annum
Annual Saving = 35040 x 8(Per unit charge)
= 280320 Rs
Subsidy = (30/100) x Total Cost
= 0.3 x 884800
= 265440Rs.
Payback Period= (Total cost- Subsidy) / Annual saving
= (884800-265440)/280320
= 2.20Years

5. DESIGN OF GRID CONNECTEDGRID CONNECTED PHOTOVOLTAIC SYSTEM



6. CONCLUSIONS

The objective of this paper was to design a grid connected photovoltaic system on radiation data (available for the location) to optimize the space requirement and the cost of installation. A grid connected photovoltaic system for meeting the electrical energy demand for Datta Meghe institute of engineering technology and research is presented as a case study for explaining the methodology adopted.

From the work presented, it can be concluded that the design based on monthly average daily energy generated gives 44 panels. Total cost required for establishment of plant is about Rs. 8,84,800 and payback period estimated is about 2.20 years, considering the subsidy provided by the government on PV system installation.The initial investment is very high but the rate of return is less. Assuming the life span of the panel to be 20 years as claimed by the industry; the remaining 50% of the life span of the system, an electrical energy generation will be at a very small cost because of batteries and the maintenance.

Keeping in view, the present power shortage and also frequently interruption of power supply particularly for institution in rural areas to which DMIETR campus belongs, it is economical to utilize solar energy for meeting electrical energy requirement. This will improve reliability of power supply at a reasonably low cost which benefits the organization.

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