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Research Article

Solar Energy Potential Estimation and its Utility for EPCO Campus, Bhopal to Ensure Energy Security

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Abstract
The paper presents the analysis of proposed grid connected solar photo-voltaic system in Environmental Planning and Coordination Organization (EPCO) campus, Bhopal. The goal is to minimize the electricity bill by utilizing the power generated from rooftop solar photo-voltaic system and hence contributing to convert the office building into a green campus.

Keywords:*Grid-connected, Rooftop, Solar photo-voltaic, Solar-radiations.*

1. Introduction

Energy has an important role in our life. The level of improvement and development is measured by the amount of energy used by the people. The demandfor energy is increasing because of increasing population, industrialization, and urbanization. Supply of fossil fuels in the world will last only few hundred years. The increase in the rate of consumption of energy and depletion in the supply of sources resulting energy shortage and inflation. This is termed as "Energy Crisis". So as an alternative renewable source of energy should be promoted to fulfill the future energy demands(Singh 2010).

Solar power produced from PV (photo-voltaic) cells is one of the alternative technologies for power generation which is continuously being investigated. Particularly residential PV plants have great potential to meet the significant amount of power requirement in the building (Redfield and Redfield 2010).

The advantages of using solar energy in India are as follows

i. Renewable Source of Energy.
ii. Environmental Friendly.
iii. Great Potential in India.
iv. Reduces electricity bills.
v. Long life& less maintenance.

2. Grid-Connected rooftop solar PV system

Grid-connectedPV power systems are power system energized by PV panels which are connected to the utility grid. The photo-voltaic system uses solar panels to convert sunlight into electricity. A system is made up of one or more solar PV panels, an AC (alternating current)to DC (direct current) power converter that holds the solar panels, and the interconnections and mounting for the other components [4].(Singh 2013)

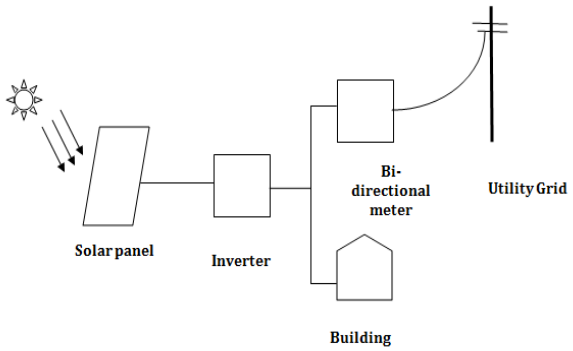

Fig.1 Working of grid-connected solar PV system

Depending on the accessible rooftop area PV panels will be placed on the top of the building. The output of the panels (DC power) will be connected to the power conditioning unit/inverter which changes over DC to AC. The inverter synchronizes with the grid. In the event that the solar generated power is more than the requirement, the excess generated power is naturally feed into the grid. For higher capacity systems connection through step up transformer and switch yard might be required to feed the power into the utility grid. On the basis of dust level, the system requires occasional cleaning (Sharma and Galipeau 2012).

*Corresponding author **Savita Vyas** and **Anoop Shrivastava** are Supervisor.

3. Objective

The objective of this work is to estimate the potential of grid-connected solar PV power in EPCO Campus, Bhopal and finally develop a system based on the potential estimations made for a chosen area of 1750m^2.In the end cost estimation of grid-connected SPV power plant is done to show whether it is economically viable or not.

4. Methodology

"Green Buildings" often called as "sustainable buildings" use natural resources like energy, water, materials, and land more efficiently. With better air quality and more natural light, green buildings typically contribute to providing a better life to the people. Green building energy savings primarily come from reduced electricity purchases and secondarily from reduced peak energy demand. In general, sustainable or green buildings are 28% more efficient than conventional buildings and generate 2% of their power requirement from photo-voltaic (PV) [6].(Kats 2003)

To convert EPCO campus Bhopal into a green campus, following initiatives can be taken

1. Utilization of available renewable energy sources in the campus.
2. Waste management.
3. Using energy saving devices.

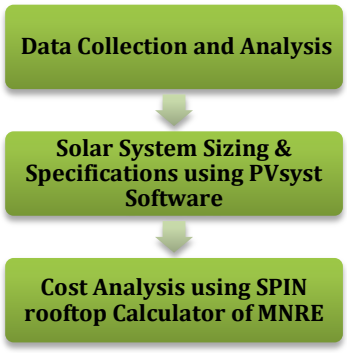

Fig. 2 Flow-chart for methodology

4.1 Data Collection and Analysis

Environmental planning and coordination organization (EPCO) campus is situated in, Paryavaran Parisar, Bhopal (M.P). EPCO campus houses the head office of MP PCB (Madhya Pradesh pollution control board), Disaster management, waste paper recycling unit, office for climate change, hostels, and staff colony. The plant is to be situated on the roof of EPCO main building. The terrace on the building has an area of about 1750 m^2 which could be utilized for SPV installation of 50 kW$_p$. The terrace of other offices inside the EPCO campus is also vacant and could be utilized for larger size SPV installation. It is proposed to utilize the vacant area available on the main building of EPCO for installation of 50 kW$_p$ which could serve as a grid-connected demonstration system and could be used for collection of data for analysis on the availability of solar power.

4.1.1 Existing Power Supply Arrangements

4.1.1.1 *MPKVVCL Supply:* Electrical power requirement for EPCO campus is met from Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Limited (MPKVVCL) via main supply from Bhadbhada sub-station, Bhopal. The power received at 11 kV is stepped down to 430 volts by distribution transformer (Oil cooled) of 200kVA located at the ground of EPCO campus. The maximum load of the EPCO main building is around 129.716 kW.

4.1.1.2 *Emergency Power Supply:* A single-phase inverter with a maximum load of 1kW is provided with 2 batteries of 12 kV each providing backup supply to important services like a conference room and essential lighting in the building during the period of load shedding.

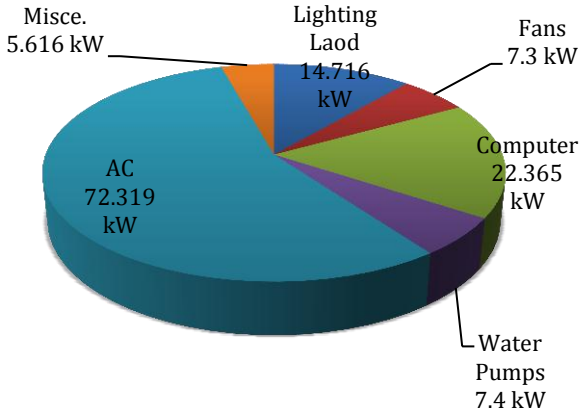

Fig. 3 Load distribution of EPCO building

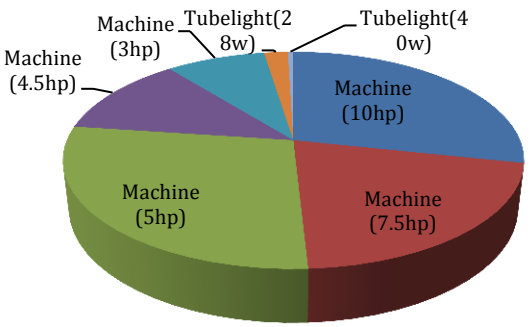

Fig. 4 Load distribution of Waste Paper Recycling (WPR)Unit

Total load = Load of (office building+ WPR unit)
= 129.716 + 26.452 = 156.168 kW

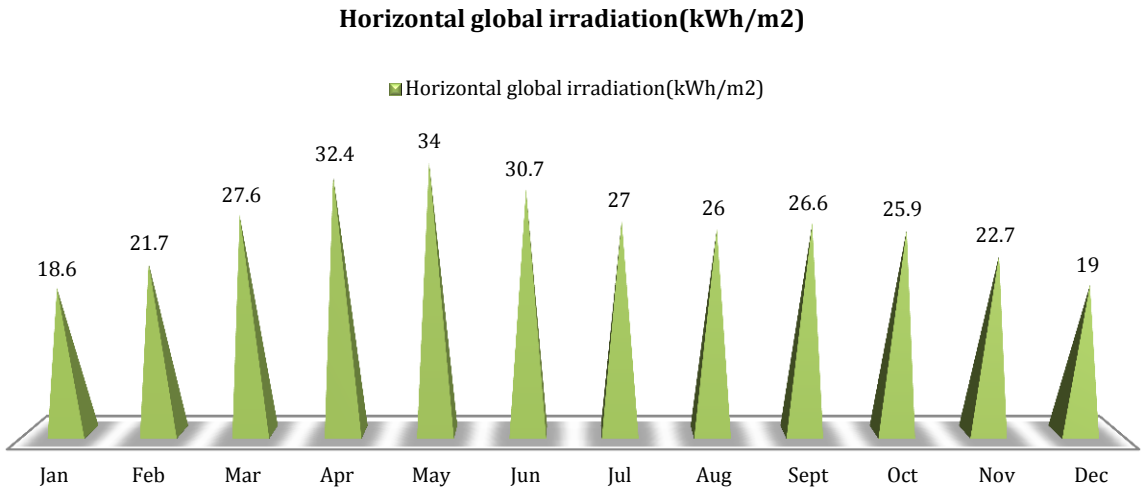

Fig.5 Horizontal global irradiation (kWh/m^2) at EPCO campus, Bhopal

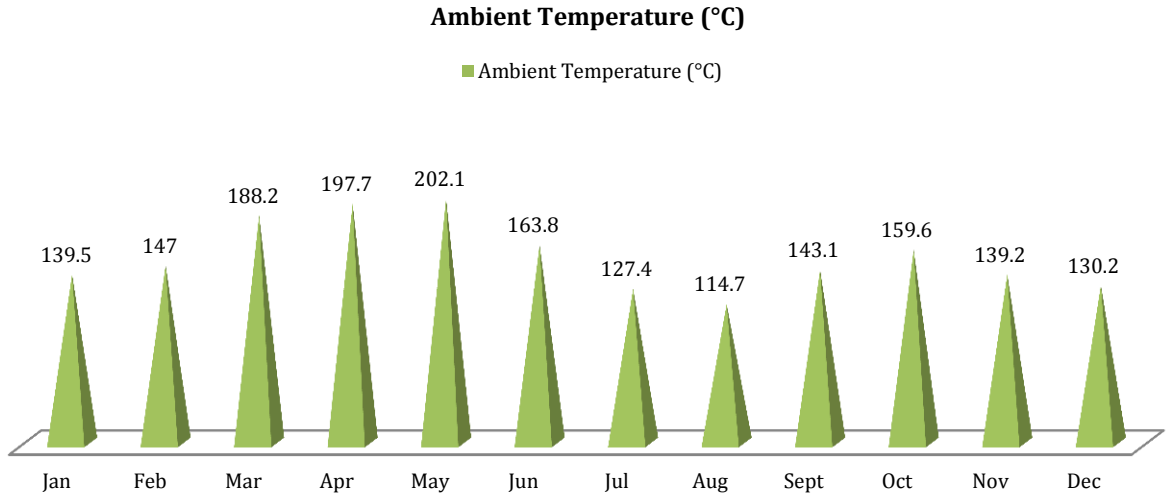

Fig.6 Ambient temperature (°C) at EPCO campus, Bhopal

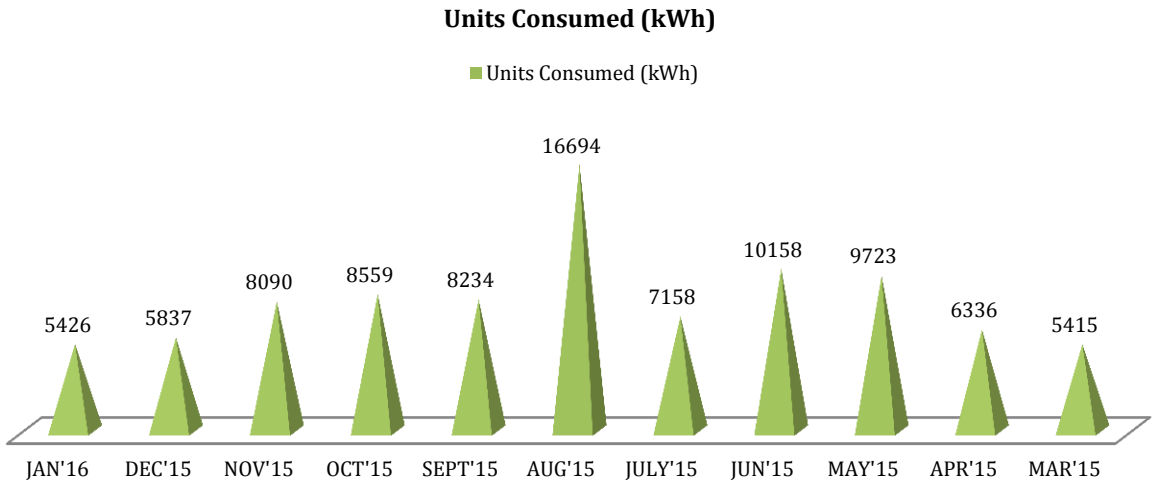

Fig.7 Month wise units' consumption at EPCO campus, Bhopal

4.2 Solar System Sizing and Specifications

The power generated from the solar plant is supplied to 50 kW load of the office building. It is required to design the solar PV system to meet the load requirement.

4.2.1 Simulation software (PVsyst software)

PVsyst is intended to be utilized by researchers, architects, and engineers. It is an extremely valuable educative tool. It incorporates a point by point logical Help menu that clarifies the methods and models that are utilized and offers an easy to understand approach with a manual for designing a project. PVsyst can import information from a wide range of sources, along with the personal information. Results are presented in the form of graphs, reports, and tables. Data of PVsyst can be exported in other software. PVsyst offers to study and plan photovoltaic system, which utilizes solar PV panels to convert solar radiations into electricity.

Selected modules to design the proposed 50 kW_p solar PV system and its specifications are given below in tables.

Table 1 Physical parameters of PV Panel (Manufacturer: TOPSUN, Model: TS-M300)

PV module type	Si- Poly Crystalline
Length	1960 mm
Width	988 mm
Thickness	40 mm

Table 2 Electrical parameters of PV panel

Maximum Power Rating	300 W_p
Short Circuit Current	8.40 A
Open Circuit Voltage	47.03 V
Max. PowerPoint Current	7.90 A
Max. PowerPoint Voltage	37.98 v

Table 3 Inverter specifications (Manufacturer: Power Electronics, Model: Free Sun FS0025LVT)

No. of Units	2
Rated Capacity	25kW
operating voltage	450-820V
Frequency	50Hz
Max. Efficiency	95.90%

Table 4 Grid Specifications

No. of Phases	3-Phase
Voltage Rating	440 Volts AC
Frequency	50 Hz

4.3 Cost Analysis

Cost analysis is done using Spin rooftop calculator of MNRE. The total cost of plant for 50 kW_p is estimated to be INR 40 Lakhs Rs. without subsidy. If 30% subsidy is expected from the government then cost will be reduced to INR 28 Lakhs Rs.EMI for Loan amount of Rs. 2,800,000 in loan period of 10 years @ 12 % will be Rs. 40,172 / month.

4.3.1 Payback Period

The payback period is the length of time required to recover the cost of an investment. The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions.[9](Shetty and Kulkarni 2014)

Table 5 Economic analysis

Months	No. of Units Consumed in Building (kWh)	No. of units Generated from the Solar Plant (kWh)	No. of Units Imported from the Grid (kWh)	No. of Units Send to the Grid (kWh)	Energy Charges (Rs.)	#Amount to be paid/ Credit (Rs.)
Jan'16	5426	6912		1666	32827.3	+10079.3
Mar'15	5415	7193		1778	29777	+10756.9
Apr'15	6336	6617		281	34848	+1700.05
May'15	9723	6206	3517		53476.5	-21277.85
Jun'15	10158	5149	5009		61455.9	-30304.45
Jul'15	7158	4273	2885		43305.9	-17454.25
Aug'15	16694	3949	12745		100998.7	-77107.25
Sep'15	8234	5253	2891		49815.7	-17490.55
Oct'15	8559	6576	1983		51781.95	-11997.15
Nov'15	8090	6555	1535		48944.5	-9286.75
Dec'15	5837	6591		754	35313.85	+4561.7

#Amount to be paid (-), Credit (+)

Pay – back Period =Total cost of PV system with all auxiliary equipments / Total annual cost saving after installation of PV System

Table 6 Payback periods of proposed 50 kW_p solar plant

	Self Funded		A combination of Debt & Equity	
	Without subsidy	Without subsidy	Without subsidy	Without subsidy
As per present cost	8years 10months	6years 2 months	13 years 7 months	9years 5 months
As per increasing tariff	7years 8 months	5years 7 months	11years 1months	8years 0 months

5. Results

Total electricity generation from Solar Plant is estimated to be 71.8 MWh per year and considering the lifetime of panels as 25 years the total generation in the entire lifetime of the plant is supposed to be 1795 MWh.

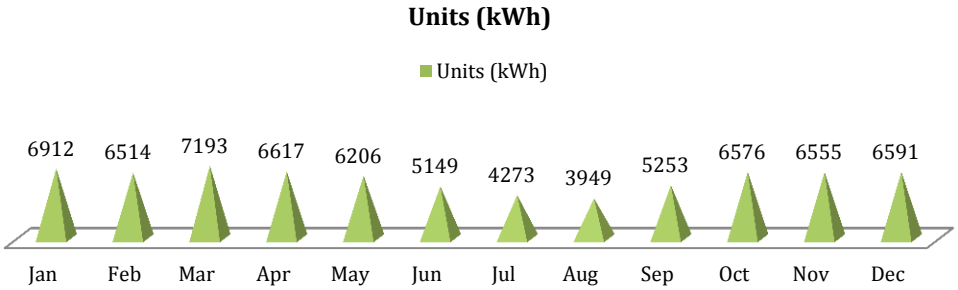

Fig. 8 Month wise estimated generation (kWh) from the proposed 50 kW_p solar PV plant

From Mar'15 to Jan'16 the total units consumed in the EPCO building = 91630 kW
From Mar'15 to Jan'16 months the total units generated by the proposed solar plant = 65274 kWh
(Considering the cost of 1 unit = 6.05 Rs.)
Reduction in electricity bill that can be obtained after installation of solar plant = 65274 x 6.05 = 3, 94907.70Rs.

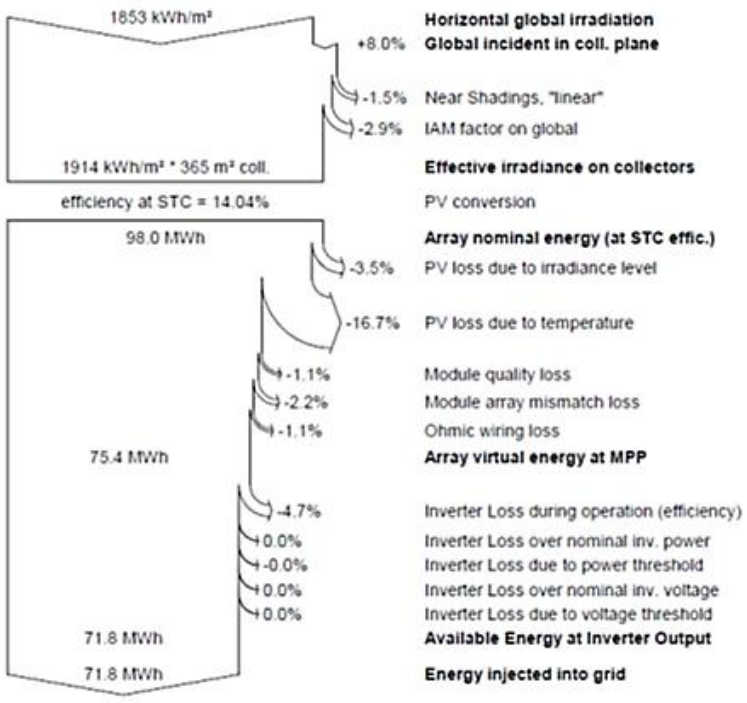

Fig. 9 Loss diagram for the proposed 50 kW_p solar plant

5.1 Comparative Analysis

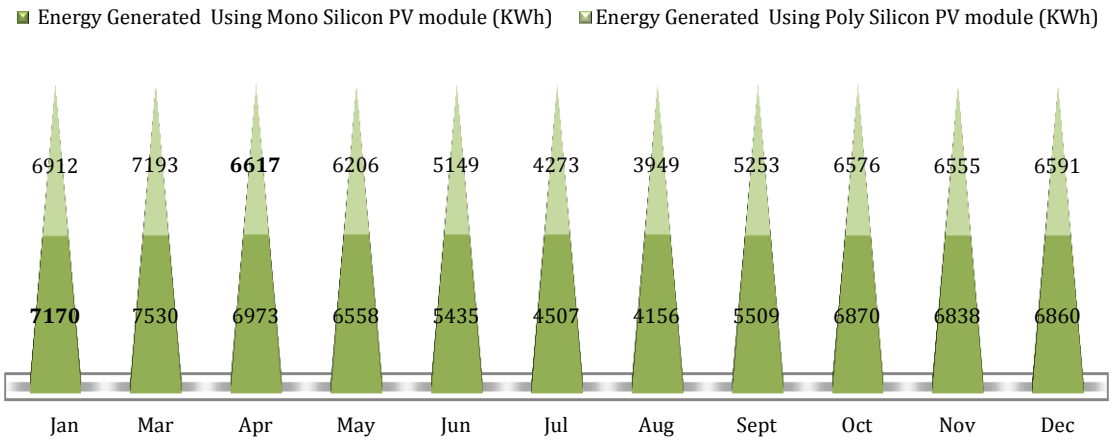

Fig. 10 Comparison of output using different solar PV technologies

Mono-crystalline silicon solar PV is the best technology to deliver efficiency. Polycrystalline silicon solar PV offer efficiency levels close to mono-crystalline panels, but at half the costs in some cases. It is clear from the above figure that mono-silicon PV modules are more efficient than poly-silicon PV modules but due their higher cost poly-silicon PV modules are used commonly.

Conclusion

The design described is based on the potential measured. Technical and economical analysis of 50 kW_p grid connected rooftop solar PV system is discussed.

System sizing and specifications are provided based on the design made. Annual electricity generation is around 71.8 MWh. For the entire lifetime of plant generated power is estimated to be 1795 MWh. Finally, cost analysis is carried out for the proposed design.

Total estimated PV system cost is Rs. 40 Lakhs without subsidy. Analysis for the 11 months (from Mar'15 to Jan'16) is done. Reduction in electricity bills that can be obtained after installation of plant is approximately 3, 94907.70Rs.

Carbon dioxide mitigated from this Solar Plant Installation will be 1537.5 tons. This installation is equivalent to planting 2,460 Teak trees over the lifetime. In the general reduction of CO_2 emission per 1 kWh of solar power is equal to 0.7 kg of CO_2.

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