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Analyze the Techno-Commercial Requirements of a Solar Power Plant for Illumination System of B.I.T, Deoghar Campus

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Abstract—*In this paper, the potential and cost-effectiveness of a solar photovoltaic power plant for meeting the energy demand of the B.I.T, Deoghar Street Lighting System is analyzed. Present Mercury Vapor (MV) Lamp need to be replaced by LEDs of same illumination which requires less power consumption. The power requirement with LED Lamps for street lighting of campus has been estimated for a day. The design of 5kW capacity solar PV plant has been proposed. Cost and land requirements are analyzed for proposed project.*

1. INTRODUCTION

There is a great need for renewable and clean energy sources. Several researches have been performed globally in order to evaluate the feasibility and performance of different renewable energy sources. Solar energy is the largest available carbon-neutral renewable energy source and a small PV power plant is a feasible option to meet the power requirements of small loads at distribution level. Solar Power Generation reached to 303GW until July 2016 [1]. PV plants for distribution generation reduce the power requirement from the grid with maintaining high reliability and quality [2]. As the electricity tariffs are rising, the importance of PV plants is also increasing.

Various works regarding optimum design of PV plants was carried out. A techno commercial analysis of solar PV grid connected system was done by considering the model of Makkah, Saudi Arabia. The Hybrid Optimization of Multiple Energy Sources (HOMER) software was used to study the technical and economical aspects [3]. A techno economic analysis for integrated PV/ Thermal system for building applications is done in Sri Lanka. The nZEB (net zero energy building) concept is used. The simulation is done for various climate conditions and sensitivity is analyzed. It is observed that increase in solar panel capacity reduces the grid interactions [4].

PV system is used with diesel generators in hybrid mode and its techno-commercial analysis was carried out. With simulation results, technical performance of system can be accepted but economically the system is not very suitable [5]. A comparison for solar power generation methods (photovoltaic and parabolic trough) was carried out for Turkish Republic of North Cyprus. It was concluded that investment cost of parabolic trough power plant is high but it occupies small area than conventional PV plants [6]. A case study of solar/wind /diesel generator hybrid power system was carried out for techno-commercial analysis. The setup cost for wind and solar power plant is calculated and its value is compared with the hybrid power plant. It was concluded that the customer should use the renewable energy first and additional power can be trade to grid [7]. A techno-economic analysis of solar photovoltaic power plant for 2.5 MW capacity is carried out. Cost of land, PV modules, Battery Bank, Inverter Cost, installation and Maintenance cost was calculated for suggested solar plant for Garment Zone of Jaipur City. Financial performance indicators are also analyzed for suggested solar photovoltaic power plant [8].

Based on Suggested PV plant for Garment Zone, Jaipur [8], a PV plant is proposed here which can meet the energy demand of B.I.T Street Light. Street lights of B.I.T., Deoghar comprises of 64 MV Lamps, the total power requirements for street lighting is 8kW. The wattage per point of MV lamp is 125 W with illumination of 1200 lm. Total power consumption of the lamp is 3.67 A/kW. First MV lamps are needed to be replaced by LEDs due to its low power requirements and reduction in energy demand.

Present system also consists of 64 poles with a distance of 17m between them. The type of cable used is PVC aluminum armored cable (2-core, 6 mm^2). Same cable will be sufficient to supply LED lighting system.

Techno commercial analysis of PV plant includes estimation of PV module sizing, inverter sizing, battery sizing and module circuit design.

2. ENERGY DEMAND OF ANALYZED SYSTEM

The estimated average monthly energy requirement for 64 MV lamps is 2400 kWh. By replacing with LEDs the energy requirement will be reduce to 1344 kWh.

3. SOLAR PV PLANT DESIGNING

The peak power requirement for street light is calculated and estimated to 4.48kW. A PV plant for 5kW capacity will sufficiently provide the power to existing load and a load of 500kW can be added to PV Plant in future. The techno-commercial analysis requires data for proper design of PV module, battery size and design of module circuit. Technical details of each division are placed in this section.

3.1. Energy required from PV Module

The energy required can be calculated by multiplying the peak energy requirement of load multiplied by energy lost by PV system [8], [10].

Peak energy requirement of the BIT Street Light system was 1344 kWh/month =44.8 kWh/day.

Total energy lost in the PV system =30%

Energy required from PV Modules

=1.3×44.8 kWh/day = 58.24 kWh/day

3.2. Panel Generation Factor

Panel Generation Factor (PGF) is use to determine the size of solar PV cells. It is use to determine the number of panels required for a particular PV plant [8]-[10].

$$\text{PGF} = \frac{Solar\ irradiance \times Sunlight\ \ hours}{Standard\ test\ conditions\ irradiance}$$

$$= \frac{600 \times 9.58}{1000} = 5.75$$

Value of PGF depends on solar irradiance at a particular location.

3.3. Peak Rating for PV Modules in Watt

Peak rating can be calculated using the energy required to be produced from the solar PV modules and the PGF [8], [10].

Peak rating for PV modules in watt

$$= \frac{Energy\ required\ from\ PV\ modules}{PGF}$$

$$= \frac{58.24}{5.75} = 10.13\ kW$$

3.4. PV Modules

SANYO HIT-215NHE5 (Hetero-junction with Intrinsic Thin layer) PV modules are selected for the power plant and the solar cell of the module is made of a thin mono crystalline silicon wafer surrounded by ultra-thin amorphous silicon layers. Characteristics of the HIT cell module are given in table 1 [8].

Table 1: Characteristics of a HIT-215NHE5 PV module

S. No.	Parameter	Units	Values
1	Maximum power (P_{max})	W	215
2	Max. power voltage (V_{pm})	V	42
3	Max. power current (I_{pm})	A	5.13
4	Open circuit voltage (V_{oc})	V	51.6
5	Short circuit current (I_{sc})	A	5.61
6	Warranted min. power (P_{min})	W	204.3
7	Output power tolerance	%	+10/-5
8	Maximum system voltage	V_{dc}	1000
9	Temperature coefficient of P_{max}	%/ ℃	-0.3
10	Temperature coefficient of V_{oc}	V/℃	-0.129
11	Temperature coefficient of I_{sc}	mA/℃	1.68

3.5. Total no. of PV Modules Required

Total numbers of PV modules required in the power plant are estimated by using the total watt peak rating required and the PV module peak rated output [8].

Total no. of PV modules required

$$= \frac{Peak\ rating(watt)}{peak\ rated\ output\ \ of\ PV\ Modules} = \frac{10.13 \times 10^3}{215}$$

$$= 47 \sim 48\ Modules$$

3.6. Battery Sizing

Value of different parameters of battery can be find out in table 2: [8],[10]

Table 2 : Battery Parameters

Battery Parameters	Values	Units
Total battery watt hours used in a day	44.8	kWh /day
Losses in Battery	15	%
Extent of Discharge of Battery	40	%
Nominal Battery Voltage	96	V

Battery Capacity

$$= \frac{Total\ watt - hours\ per\ day\ \ \times \text{days of autonomy}}{0.85 \times 0.6 \times nominal\ battery\ voltage}$$

$$= \frac{44.8 \times 10^3 \times 1}{0.85 \times 0.6 \times 96} = 915.03\ Ah$$

3.7. Inverter sizing

Size of inverter depends on the peak watt requirements of load. The rating of inverter should be higher than the total street lighting load and the input voltage of inverter should be equal to nominal voltage of batteries [8]. Total wattage required in the BIT, Deoghar Street lighting system is 4.48

kW. The inverter must be large enough to handle the total peak watt requirement of the zone at any time.

The inverter size should be 25-30% bigger than the total wattage of the appliances and machines [10]. It can be calculated as in table 3.

Table 3 : Inverter Size

Inverter Parameters	Value	Units
Inverter Size (4.48kW x 1.3 times)	5.824	kW

One Inverter of 6kW rating will be sufficient to fulfill the demand.

3.8. PV Module Circuit

Value of different parameters of PV module circuit can be find out as shown in table 4 [8], [10].

Table 4: PV Module Parameters

PV Module Parameter	Units	Values
Open circuit voltage (V_{oc}) of each PV module	51.6	V
Number of Modules to be connected in series	780/51.6 =16	No.
Maximum power voltage (V_{mp}) of each PV module	42	V
Maximum power voltage (V_{dc}) at inverter input	16x42 =672	V
Total no. of PV arrays to be used for producing 672V_{dc}	48/16 =3	Arrays
Maximum open circuit voltage	780	V

3.9. Land Requirement

Value of land requirements is calculated in table 5[8].

Table 5: Land Requirements

Requirements	Values	Units
PV modules required	48	No.
Dimension of one PV module	1.57 × 0.798	Sq. m
Modules in an array connected in series	16	No.
Width of each PV array	16 x 0.798 = 12.77	m
Arrays in PV field	3	No.
Width of the solar field	12.77 x3 = 38.31	m
Pitch distance between two arrays (including module length of 1.57m)	3	m
Length of solar field	1×3 + 1.57 = 4.57m	m
Land required for PV field	38.31 × 4.57 = 175.1	Sq. m

4. TOTAL PLANT COST

Total plant cost of this PV system comprises of module and inverter cost, design engineering and management cost, operation and maintenance cost and installation cost [8].

4.1 Module and Inverter cost

Cost of inverter of 6kW capacity = Rs. 90,000

Cost of each PV module = Rs. 34,378.5

Cost of 48 modules = 48×34,378.5 = Rs. 16,50,000

4.2. Designing, engineering and management cost

Design, engineering and plant management hours per kW = Rs300/man-hour

Total labor cost for design, engineering and project management hours per kW= 2h [11]

Total design, engineering and project management cost for 5kW=Rs. 3000

4.3. Operation and Maintenance Cost

Fixed operation and maintenance cost

= Rs. 5480/kWh [12]

Variable operation and maintenance cost

= Rs. 4950/kWh [12]

4.4. Installation cost

Labor cost for installation = Rs. 150/man hour

Installation man hour required for per kW = 12 h

Total Labor cost for installation of 5kW PV Power Plant = Rs. 9,000

Table 6: Cost of Various Parameters

S. No.	Particular for off-site PV power plant	Rs.
1	Module cost	16,50,000
2	Inverter cost	90,000
3	Batteries cost	52,000
4	Installation cost	9,000
5	Land cost*	0.0
6	Design and Engineering Cost	3,000

*Land is available in Institute.
Cost of Installation hardware—civil, shade, Fencing is not calculated here.

5. CAPACITY FACTOR

Capacity factor is an important element that decides the economics of the solar PV plant.

It is defined as [8]

$$CF = \frac{Annual\ kW - hours\ generated\ for\ each\ kW\ AC\ peak\ capacity\ (\frac{KWh}{KWp})}{8760h\ in\ a\ year}$$

Energy required to be generated from the plant

= 44.8 kWh/day

Annual energy to be generated from the plant

= 44.8 × 365 = 16.35 MWh

Peak capacity requirement of the PV plant = 5kW

$$CF = \frac{16.35 \times 10^3/5}{8760} = 0.3732 = 37.32\%$$

6. RECOVERY OF COST

Particulars	MV Lamp	LED Lamp
Power consumption/day	80kWh	45kWh
Total cost of units/day	80×5.5=Rs. 440	45×5.5= Rs.247.5
Total cost of units/month	440×30= Rs.13200	247.5×30= Rs.7425
Total price of Lamp (Bulb+Fixture+choke)	Rs. 2300	Rs. 6800

Cost difference of one Lamp = Rs. 4500

Total cost difference = 64×4500 = Rs. 2, 88,000

Total unit cost difference /month = Rs. 5775

Recovery time = 2, 88,000/5775 = 50 months

Low tension industrial and medium power service tariff = Rs. 5.5/ Unit [13]

Cost of MV lamp = Rs. (193 + 1105 + 1000)

7. CONCLUSION

This project was aimed to find the techno- economic feasibility of solar PV plant for street lighting system of BIT, Deoghar campus.

The power requirement of existing system with MV Lamp is calculated. It is proposed to replace MV Lamps with LEDs. The total power requirement will be 4.48 kW with LEDs. The cost of replacement is included in project cost.

The land requirements, PV panels, Battery size, Inverter rating and cost of complete project is calculated. This cost is compared with monthly energy billing of institute street lighting system and calculated that cost will be recovered in 50 months.

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