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Off-grid PV system for lighting load of UIET, KUK (Design and estimated cost)

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Abstract: *In India electricity demands increasing very rapidly so load on generation and distribution system. The conventional resources for electricity production like coal, nuclear etc are inefficient to meet the energy demands and also grid is not available at remote places. So we have to increase the use of renewable resources like solar, wind and biomass etc. Off-grid solar PV systems are popular now days and it is best solution for remote area electrification. In this paper a possible design of PV system for lighting load of University Institute of Engineering and Technology, Kurukshetra University, Kurukshetra is suggested. The lighting load is estimated and then other calculations are done.*

List of Symbols

W - Watt
kW – Kilowatt
E_L– Estimated load
η_{bo} – Efficiency of balance of system like inverter and wire losses
M_{Loss}– Factor of losses like temperature losses, dust etc
PSH– Peak sun hours
S – Peak solar intensity at earth surface
N_s – Number of module in series
N_p – Number of module in parallel
B_c – Battery bank capacity
B_{req} – Batteries required
B_s – Batteries in series
B_p- Batteries in parallel
P_{inv}– Inverter power
N_{vg} – Number of voltage regulator

1. LIGHTING LOAD ESTIMATION

University Institute of Engineering and Technology (UIET), Kurukshetra University, Kurukshetra build with three floors, garden and parking area which having several tube lights. For this total lights of UIET is counted and wattage of each light is noted than daily hour usage of lights are estimated. The table below shows calculation for load estimation.

Table 1 – Load estimate

Name of floor	No. of tube	Watts	Hour used/ day	Watt hour/day
Ground floor	383	40	5	76600
1st floor	379	40	5	75800
2nd floor	318	40	5	63600
Grounds and parking	10	40	8	2000
Total	1090	1090x40 =43600		218000

Total lighting load of UIET = 43600 W or 43.6kW.

2. SYSTEM VOLTAGE SELECTION

In off- grid PV system voltage of system is 12V/24V/48V and now days even more higher voltage also selected in very high load system. System voltage selection is based on daily load, so if load is high higher system voltage is selected. Higher system voltage reduces conversion losses of inverter. Here daily load is high so 48vdc system voltage selected.

3. PV PANEL SELECTION

PV panel selection is based on cost, warranty, performance and maintenance. Available area for installation is also considered. High power panel reduces total panel requirement and improve overall system efficiency. Here EmmVee 24V panel is selected which is a 295Wp panel. Panel specification given below.

Manufacturer/ Brand	EmmVee
Peak power	295 watts
Module Efficiency	14.7%
Peak power voltage	36.51 volts
Peak power current	8.08 amps
Open circuit voltage	44.78 volts

Short circuit current	8.30 amps
Number of cells	72 cells
Max. System voltage	1000 volts DC
Length	2007 mm
Width	990 mm
Depth	35 mm
Weight	28.5 kg

4. PV ARRAY SIZE CALCULATIONS

PV array size calculations is somehow depends on the solar irradiance data of the site where this going to be installed. So average solar isolation for the Kurukshetra is given in table below. This is also called average sun hours when peak solar intensity is received (PSH).

Table 2 – Average solar isolation

MONTHS	22 Year Average (Source: NASA) $kWh/m^2/day$
Jan	3.58
Feb	4.38
Mar	5.59
Apr	6.10
May	6.40
June	6.20
July	5.50
Aug	5.14
Sep	5.23
Oct	4.71
Nov	4.01
Dec	3.36
Annual Average	5.01

Now the PV array size for given system is given as

$$P_{pv} = \frac{E_L}{\eta_{bo} \times M_{Loss} \times PSH} \times S$$

Where

PSH = 5.01 (peak solar hour for UIET, KUK form above table)

M_{Loss}= 83% (module loss factor like manufacturing defect, dust and temperature losses)

η_{bo} = 85%

S = 1 kW/m^2

$$P_{pv} = \frac{218}{0.85 \times 0.83 \times 5.01} \times 1 = 61.8 \cong 62\ kw$$

Number of module in series (N_s)

$$N_s = \frac{V_{system}}{V_{module}} = \frac{48}{24} = 2\ modules$$

Number of module in parallel (N_p)

$$N_p = \frac{P_{pv}}{N_s \times P_{module}} = \frac{62 \times 1000}{2 \times 295} = 105.08 \cong 106\ modules$$

Total Module = $N_s \times N_p = 2 * 106 = 212\ modules$

5. BATTERY BANK CAPACITY CALCULATIONS

Battery bank capacity depends on days of autonomy, depth of discharge. Solar batteries are sized in ampere hour. Here days of autonomy (A_n) taken is 1 (24 hours) and solar batteries now days having 70% to 80% depth of discharge so here 75% DOD is taken. So battery bank capacity (Bc) is calculated as:

$$B_c = \frac{A_n \times E_L}{DOD_{max} \times V_{system} \times B_{Loss}}$$

$$B_c = \frac{1 \times 218 \times 1000}{0.75 \times 48 \times 0.85} \cong 7130\ Ah$$

The battery here selected is Exide 6LMS which has 150 Ah capacity and having 12v nominal voltage. So the number of batteries (B_{req}) required is

$$B_{req} = \frac{Bc}{Bselected} = \frac{7130}{150} \cong 48\ batteries$$

Number of batteries in series (B_s)

$$B_s = \frac{V_{system}}{V_{battery}} = \frac{48}{12} = 4\ batteries$$

Number of batteries in parallel (B_p)

$$B_p = \frac{B_{req}}{B_s} = \frac{48}{4} = 12\ batteries$$

6. INVERTER SIZE CALCULATIONS

The inverter size depends on power drawn by appliances running at same time and surges if motor load is present and also the system expansion in future. So the inverter size is calculated as:

$$P_{inv} = (Tkw + P_{sur}) \times 1.25$$

$$Pinv = 43.6 \times 1.25 \cong 55\ KVA$$

As here no surges or motor load is present in system so P_{sur} is zero.

7. SOLAR REGULATOR OR CHARGE CONTROLLER SIZE CALCULATIONS

The regulator which used in system should having rating which matched to both PV panel and battery and also it is capable to handle current from PV. The size of voltage regulated is calculated as:

$$I_{rated} = N_p \times I_{sc} \times F_{safety}$$

Here F_{safety} is safety factor for system. 1.25 is selected here.

$$I_{rated} = 106 \times 8.30 \times 1.25 = 1099.75 \cong 1100\ A$$

Here Phocos CML 20A/48vdc solar regulator or charge controller selected

So number of voltage regulator required is given as:

$$N_{vg} = \frac{I_{rated}}{I_{selected}} = \frac{1100}{20} = 55\ voltage\ regulator$$

8. AREA FOR INSTALLATION

Total Roof area of UIET = 3400m^2
Area of selected panel = 1.9503m^2
Total area required for installing solar panel
$Area$= 204*1.9503 = 397.86m^2 =4282.53ft^2

9. RESULT TABLE

Table 3 – Result table

Components	Description	Results
Load	Total load	218 kwh/day
Pv Array	Total size	62 kw
	In Series	2
	In parallel	106
	Total panel	212
Battery Bank	Capacity	7130 Ah
	In series	4
	In parallel	12
	Total	48
Inverter	Capacity	55 KVA
Charge controller	Capacity	1100 A
	Required number	55
Area	Total = 3400m^2	Required = 397.86m^2

10. COST ESTIMATE OF THE SYSTEM

Table 4 – Cast estimate

Component and Model	Quantity×Unit price(INR)	Total (INR)
Modules-EmmVee	212×17000	36.04 lakh
Batteries-Exide 6LMS	48×15600	7.488 lakh
Inverter-STATCON Power Controls Ltd.	1×7.15 lakh	7.15 lakh
Controller-Phocos CML 20A	55×3200	1.76 lakh
BOS (wires, breakers, connectors etc.)	These costs 10 to 20% of system cost	5.24 lakh
Total cost		57.68 lakh

11. GOVERNMENT SUPPORT

Government support is necessary to promote the use of renewable energy resources. The various schemes like JNNSM etc are running by government to support financially to project developer. Some detail of government scheme is given below.

MNRE capital subsidy scheme

The scheme provides subsidy and interest bearing loan to the solar project under various conditions. Different off-grid solar PV systems having maximum capacity up to of more than 100 kWp (Kilowatt peak) per site are eligible for subsidy schemes. MNRE would provide financial support through a combination of 30 % subsidy and/or 5% interest bearing loans to the eligible solar grid or off gird projects. By March 2013, the benchmark price for photovoltaic systems with battery back-up support was Rs.200/- per Wp and Rs. 130/- per Wp for without storage battery. For financial year 2013-14, the benchmark price for PV systems with battery back-up support was Rs.170/- per Wp and Rs. 90/- per Wp for without storage battery. These rates are for off grid solar power plant of total installed capacity from 10 KWp -100 KWp.

For special category states like North East, Sikkim, J&K, Himachal Pradesh and Uttarakhand Capital subsidy of 90% of the benchmark cost is available. In addition, for standalone rural solar power plants with both technologies i.e. solar PV and solar thermal in remote and difficult areas such as Lakshadweep, Andaman & Nicobar Islands, and districts on India's international borders capital subsidy up to 60% of benchmark price is exclusively available. The release of funds under MNRE capital subsidy scheme is by two installments of 70% on sanction and 30% on completion. It means that the solar project can be started after the receipt of capital subsidy and necessary approval from MNRE and the state nodal agency.

12. CONCLUSIONS

In this paper, the lighting load of UIET is estimated which is 218 kwh/day. PV array size and other components sizes are calculated according to load demand. As UIET collage have grid connection so no back-up generator required. This possible design of PV system is to reduce the power requirement of UIET from Grid and sifting lighting load on solar power. For this 48vdc system 212 panels, 48 batteries and 7 voltage regulator required. The balance of system like wires, connectors etc are required.

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