IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 6, Ver. II (Nov.-Dec .2016), PP 53-57
www.iosrjournals.org

Design of an off Grid Photovoltaic system for New Office Buildings

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Abstract: *Renewable energy sources are increasingly being used to reduce the burden on conventional utility based system and simultaneously to reduce the carbon footprint. This work proposes a PV based Off Grid that can be used in new office buildings. The growth of DC operative appliances like laptop, LED bulbs, mobiles are rapidly increasing and therefore a DC/DC converter is a good alternative to meet the electricity need from the local DER (Distributed Energy Resources) and helps in improving the system efficiency. Here the solar energy will be converted to AC using an inverter and a battery for ac loads and the DC energy obtained from the sun will be conditioned controlled and used directly to provide DC supply to professional office equipment like computers and related peripherals which operate with DC power. This method will decrease the operating cost of professional equipments in long run as compared with the average lifespan of a solar panel.*

Keywords: *DC Nano Grid,* Distributed Energy Resources, *MPPT, Payback period, PV Systems.*

I. Introduction.

Photo Voltaic (PV) systems can be used to generate electricity from solar energy for various applications. [1] Fossil fuels are expected to be depleted with this century, PV Power systems are an alternative means of providing electricity to the developing world without the concern for fuel supply security. [2] Today, billions of people all over the world lack access to electricity. An Off grid PV Systems uses photovoltaic technology only and is not connected to a utility grid. The systems use the DC output of the PV modules to power DC loads, while a bank of battery is used to store energy for use as per requirements. [3] The DC output of the batteries can be used immediately to run certain low DC Voltage loads such as lighting bulbs or computers. It can be converted to AC voltage by an inverter to run AC-loads that constitutes most appliances. Off-grid PV system provides affordable electricity in area where conventional electricity grids are unreliable or non-existing. A PV power system for offices enables the owner to generate some or all of their daily electrical energy demand on their own building roof, exchanging daytime excess power for energy needs on night time also. PV systems can also include battery backup with uninterruptible power supply (UPS) capability to operate selected circuits in the office for hours or days during a utility outage.

This document deals with systems located on offices which are not connected to utility power. This work proposes a solar PV Off Grid that can be used in newly constructed office buildings (since it will be impractical to change the AC utility systems in existing offices and residences). The growth of DC operations appliances like laptop, mobiles are rapidly increasing and therefore a DC/DC converter is a good alternative to meet the electricity need from the local DER (Distributed Energy Resources) which may also help in improving the system efficiency. This will be an advance form of the Solar DC Nano Grid. [4] A Solar DC Nano Grid can be an essential driving element to meet future professional power demand.

II. Methodology

The electrical loads required for an office are assumed to be lights, fans, and computers; then their power rating were noted. The time of operation is fixed from 10.00 am to 4.00 pm (6 hours) during the day. The total energy demand in watt-hour per day in the office building was also estimated. This system is designed for 5 bulbs, 2 fans and 3 desktop computers. The total energy demand obtained was then used to determine the capacity of proposed Off-grid photo voltaic system.

2.1 Load Estimation

The daily load estimate was determined by calculating the power demand (Kwh/day) for all types of loads in the office. The estimated demand is given below.

Load	Rated power in watts	No. of devices	Hours per day	Total watts	Watts/day	Total KWh /day
Desktop computers	100	3	6	300	1800	1.8
Lights	12	5	6	60	360	0.36
Fans	70	2	6	140	840	0.84
Total						3.0

Table 1. Daily energy demand estimate for an office

Here, the inverter efficiency must be taken for AC loads. Daily battery load (energy) from AC loads = 2640Wh / 0.9 = 2934 Wh. Daily battery load (energy) from DC loads = 360Wh.Hence the total load (energy) as seen by the battery is obtained by adding the dc load together with ac load after taking the figure of 0.9 as inverter efficiency is 2934 + 360= 3294Wh

2.2 Battery selection

Assuming that there is no power from the PV Panel, at this condition the battery should support for 6 hrs operation. The daily energy usage was 3294Wh. We select a battery system voltage of 48 Volts. So the daily Ah demand on the batteries will be Ah = Wh / system voltage = 3294Wh / 48 = 69Ah for the required backup of 6 hours. [5]

A period of 5 days is selected as days of autonomy.The minimum Ampere hour required by the battery is 69 x 5 = 345 Ah. The Battery should not discharge below 25%, i.e. 345Ah should constitute 75 % of the original required value of Ah i.e. $\frac{75 \times C}{100} = 345\text{Ah}$.

Thus Battery Capacity, C = $\frac{345 \times 100}{75} = 460\text{Ah}$.

So the Battery Capacity is approximated to be 480Ah.

2.3 Selection of PV Module

In selecting a PV Module, the main criteria are the performance and warranty. One module (Panel) will produce a peak power of 250 watts for an average quality panel of 48v. [6]

Total load is 3.294 KWh/day = 3294 Wh /day

$\frac{3294}{6}$ = 549 watts instantaneous

549 watts = VI Cos ϕ

$\frac{549}{\cos\phi}$ = VI

Power factor, Cos ϕ is taken as 0.8. So 549/0.8 = VI = 686 VA approximately (Power factor is considered for total load including DC). If the battery system in 48 V the current required will be $\frac{686}{48}$ = 14.29Amps

So this will require less area cross conduction and the wire size requirement is normal. Also I^2R losses and battery heat is reduced. Hence our panels should support 686VA. One Panel peak output considered = 250 Wp

So no. of panels required = $\frac{686}{250}$ = 2.75 Panels

The degradation of the module itself is due to a collection of factors. Normally a loss factor of 0.8 is considered. Thus, 2.75/0.8 Panels = 3.5 = 4 Panels approximately. The lowest irradiance occurs in the month of July. In practical cases one panel will provide 100 watts owing to the losses. The silicon cells themselves have infinite life, except for the slight degradation due to thermal effects. So, 2 Panels has to be added extra and hence a total of 6 Panels are required.

2.4 Number of panels in Parallel and Series

In order to determine the energy requirement from the PV array, it is necessary to increase the energy from the battery bank to account for battery efficiency. The daily energy requirement expressed in Ah from the battery by taking care of the battery efficiency is 69Ah / 0.9 = 76.7Ah (The average columbic efficiency in terms of Ah of a new battery is about 90%). Assume the worst months Peak Sun Hours is 4. Therefore the required PV array output current is: 76.7 Ah / 4 PSH = 19.2 A. With an oversize factor of 10%, the adjusted array output current is 19.2 x 1.1 = 21.1A.

A 250 watt solar module typically has the following data:

Max. Power, Pmp,(W)	250W
Power Tolerance,(+/-)	5%
Nominal Voltage	24v
Max. Power Voltage, Vmp (V)	30.72
Max. Power Current, Imp (A)	8.14
Open Circuit Voltage, Voc (V)	37.8
Short Circuit Current, Isc (A)	8.63
NOCT-Nominal operating cell temp. (Celsius)	45

Table 2: 250 Wp module data (Reference: SU-KAM 250 Watts)

Current at NOCT (A) is approximated as 8.3 A. Assuming a dirt de-rating and manufacturer's tolerance of 5% each, then the adjusted output current of the above module is: Adjusted Module current = $I_{(NOCT)}$ x 0.95 x 0.95= 8.3A x 0.95 x 0.95 = 7.49 A. To determine the number of panels in parallel, the PV array output current required in Ampere is divided by the output of each module in Ampere. Number of strings in parallel =21.1A /7.49 = 2.82. i.e. 3 Panel approximately. For the design of a 48 V System, from the PV Panel datasheet we select the nominal voltage is around 24 V. Then $\frac{48}{24}$ = 2 panels are needed in series.

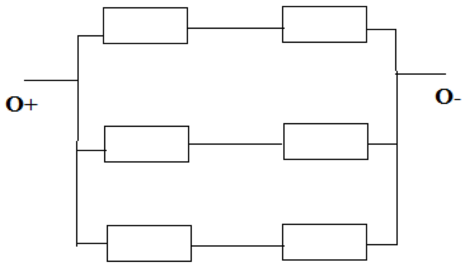


Fig.1 PV panel arrangement

Total number of modules in the array = 3 x 2 = 6 panels.

2.5 Controllers

Controller to be mentioned here is Maximum Power Point Tracker (MPPT). A MPPT is an electronic DC to DC converter that optimizes the match between the solar array and the battery bank or utility grid. When using a MPPT the calculations are in Wh and the sub-system losses in the system include:

· Battery efficiency (Watt hour)
· Cable losses
· MPPT efficiency [7]

All the losses are collectively given an approximated value of 0.8. Energy required from the PV array = 3294Wh / 0.8 = 4118Wh. Assume the worst months PSH is 4.

Therefore the required peak PV array output power is: 4118Wh / 4 PSH = 1030W_P. Therefore the adjusted array output with an oversize factor of 1.1 is 1030WP x 1.1 = 1133W_P. The peak rating of the array as per design is 6 x 250 W_P = 1500 W_P is sufficient to meet this requirement. [8]

2.6 Inverter

The inverter should have the capacity of the calculated load i.e. For 686VA, an 80 A, 1 KVA inverter will be sufficient.

If the daily energy requirements are greater than the daily PV input into the system, it is common for some form of auxiliary charging to be used to provide energy in an uninterrupted manner. [9] This is usually a diesel or petrol or gas powered generator.

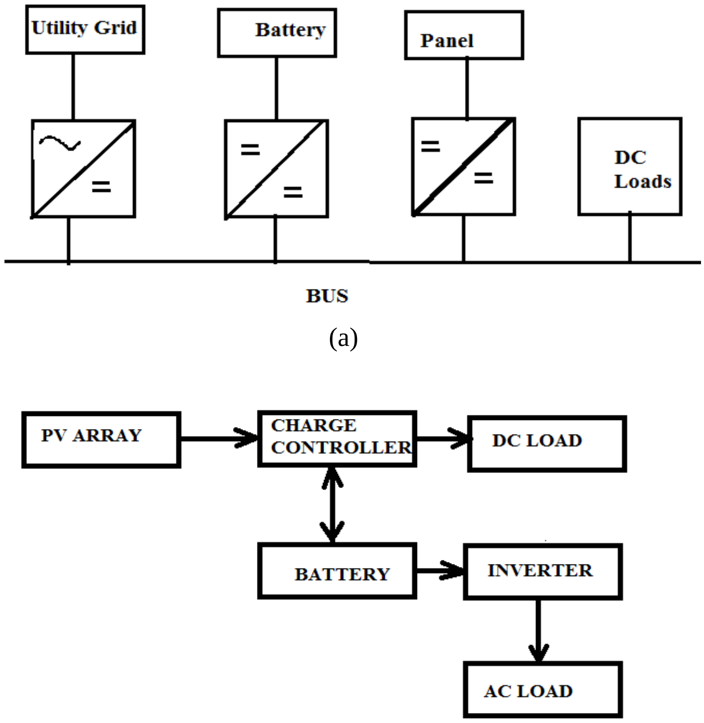
2.7 Office Layout

The area of the office roof is taken as 360 sq m. We assume that there are least 2 rooms. Each panel is considered to have an area of 4 sq. mt. With proper orientation of the roof, we can accommodate the PV panel arrangement as shown in fig.1.

2.8 Wiring

The main distribution cable of conduit should have a capacity for 40 Amperes and a cross sectional area of $3mm^2$. The type of the wire will be of copper.

The distribution wires for each room will be 1.5 mm^2 copper cables with 25A Capacity. There will be plug points including light, fan & computer. A 100 m length is assumed for each room i.e. the total length the wire required will be 200 Mts. The length of the main cable from the solar panel to the main panel cable will be at least 10 m.



(a)

(b)

Fig. 2 block diagram of the (a) DC Nano grid and (b) Off Grid PV system

2.9 Cost Consideration

Cost for each item in the project was calculated on market rates and the total cost was given below:

Sl. No.	Item	Cost
1.	Average Solar Panels will costs 65 rupees for 1 watts i.e. total of 6 x 250 =1500W require an gross amount of 1500 x 65 [10]	97,500 INR
2.	Batteries – 48 V, 480 Ah	60,000INR
3.	Inverter	6000 INR
4.	Voltage Regulator	7000 INR
5.	Panel Board, Switches, Protection	5000 INR
6.	MCB, ELCB, conduit Pipe, wires, Labour Cost, Miscellaneous	10,000 INR
	Total estimate for the project	1, 85,500 INR

Table 3: Cost estimate for the project

2.10 Payback period

The payback period can be calculated by considering the current rate of a diesel generator, fuel cost and its maintenance cost. To support the energy requirement mentioned above, such an estimate without generator costs around 95000 INR. So the payback period is approximately 2 years, which is shorter duration as compared with the average life span of the solar panels.

III. Conclusion

In this paper, a prototype based electrical energy demand (load) of an office was estimated. System sizing and specifications were provided based on the estimated load. The cost estimate of the system is relatively high when compared to that of fossil fuel generator used but the payback period of the system is estimated is obviously much shorter than the lifespan of the selected PV modules which is 25-30 years. The recommendation would be that the system can be made utility- interactive to enable the purchase of surplus solar energy from users.

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