DESIGN OF SOLAR PV SOURCE FOR AN EDUCATION COMPLEX

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Abstract—

Continuous electric power supply is indeed essential requirement for all type of consumer. Many activities like internet connection, communication network, class room and laboratory teaching, office routine etc get affected or come to stand still due to interruption of electric power in an education complex. This paper presents an alternative solution through solar photovoltaic based electric power source for an education complex situated in remote area. The University complex considered for study is situated in rural area of Kokan Maharastra in India facing acute power shortage especially in sunny days. However, University surrounding is bestowed with huge open space and shade free solar radiation suitable for solar power generation. Study conducted on average solar radiation revels that around 250-280 sunny days with average power of 1000Wperm^2. Study includes total load calculation, segregation of load on priority basis, area available for placing solar panel, total solar radiation available on daily, monthly and yearly basis, designing of suitable model, designing of efficient storage system, cost analysis including life cycle cost, payback period.

Keywords— Electric Grid, Solar PV system, Average solar radiation, Life cycle cost, Payback period.

I. INTRODUCTION

In India, where in summer and for most of the seasons there is load-shedding of around 12-14 hours in rural areas, this severally affects many domestic and agricultural for many of the agriculture business, which is the main occupation of most of the People [6]. Due to scarcity of lands and increased awareness in education many education institutions are getting established in rural areas. Electricity being most common requirement of all such sectors, it is essential to think about seamless electric supply for effective and efficient functioning of these systems.

Another face of rural electric supply is the cost to install and service the distribution lines which is considerably high for remote areas. Also there will be a substantial increase in transmission line losses in addition to poor power supply reliability. In most of the remote and non electrified sites, extension of utility grid lines experiences high capital investment, high lead time, low load factor, poor voltage regulation and frequent power supply interruptions. Hence, a convenient, cost-effective and reliable power supply is an essential factor in the development of any rural area. Thus, to overcome all the disadvantages possessed by the conventional method of electricity generation and transmission distributed energy generation is being preferred and promoted.

With the world running out of non-renewable fuel sources, researchers have been trying all squares out to find the best renewable source to power the world once the reserves are over. If there is some alternative to the conventional source of electricity, there can be a reduction in the loss of crops and inconvenience in rural areas can be minimized. As rural area is bestowed with ample amount of solar radiations without much of distractions it is most suitable for efficient energy generation from it. This situation inspires for use of renewable sources for energy generation. What earlier researcher have found out is good but they still have to make it the best, however, still efforts are in progress to develop techniques that completely exploit these sources of unlimited energy. Some techniques have changed the expensive and non-efficient faces of solar power, still there exists which has the potential for improvement.

This paper presents optimal way of maintaining seamless power supply to an education unit through renewable energy source. There are several ways by which electricity can be generated locally using renewable sources such as solar, wind, biogas, etc. [1]. At present, standalone solar photovoltaic and wind systems have been promoted around the globe on a comparatively larger scale [1]. These independent systems cannot provide continuous source of energy, as they are seasonal. Therefore, suitable energy storage systems are essential for these systems in order to satisfy the fluctuating power demands. Usually storage system is expensive and the size has to be reduced to a minimum possible for the renewable energy system to be cost effective. The discussion is structured as follows.

Section II describes about solar photovoltaic system potential and its configuration. The system requirement and design is discussed in section III while costing of the system is discussed in section IV.

II. Solar Photo-Voltaic System

A. Renewable Energy Sources:

India is potentially one of the largest markets for solar energy in the world. The estimated potential of power generation through solar photovoltaic system is about 20 MW / Sq.km in India [7]. The estimated potential of various renewable energy sources in India by IREDA is shown in table-I.

Table 1: Renewable Energy potential in India [4, 5]

S.No	Energy source	Potential
01	Solar	20MW/sq.km
02	Wind	20,000 MW
03	Small Hydro	10,000MW
04	Ocean Thermal	50,000MW
05	Tidal	10,000MW
06	Biogas	12 Million plants
07	Bagasse based cogeneration	3500MW
08	MSW	1000MW

There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reaches the earth's surface is enough to provide for global energy consumption 10,000 times over. On average, each square meter of land is exposed to enough sunlight to produce 1,700 kWh of power every year [1]. It is useful for providing grid quality, reliable power in rural areas where the line voltage is low and insufficient to cater to connected load. The Govt. of India is planning to electrify 18,000 villages by year 2012 through renewable energy systems especially by solar PV systems [1]. This offers tremendous growth potential for Indian solar PV industry. The Govt. of India had a target of achieving 150 MW installed capacity in year 2007. It presented a tremendous business opportunity in manufacturing of solar modules and other components.

B. Solar PV System Configuration:

Solar PV is a semiconductor device which converts sunlight into electricity. Therefore, a solar PV panel or a solar PV module when exposed to sunlight generates voltage and current at is output terminal. This voltage and current can be used for our electricity requirements. The amount of electricity a solar panel can generate depends on the amount of sunlight available to it. The higher the intensity of the sunlight, more the electricity generated from it. The amount of electricity generate is also depends on size of the module; the larger the size of module the higher will be the amount of electricity generated from it. The electricity that is generated from a PV module is DC in nature. The conventional loads connected to supply source are both AC and DC in nature.

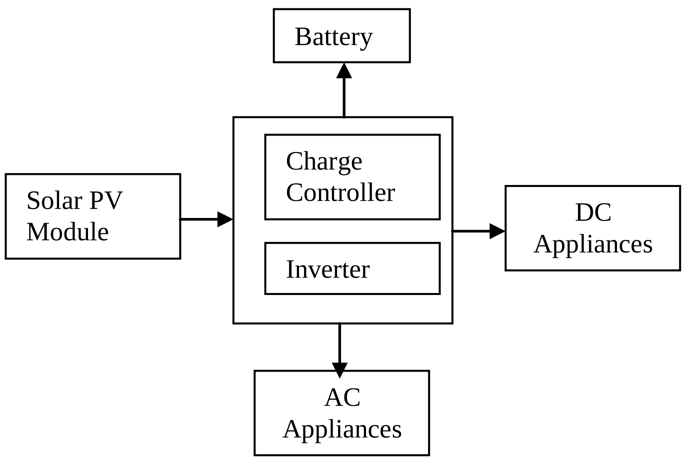

Fig 1: simple Block diagram of proposed PV system

The major components of the system are solar PV module, Battery, Charge controller and Inverter. Solar PV module generates electricity in DC form. But normally many education institute appliances use AC power for operation. Therefore there is a need to convert PV module generated DC power into AC power. This can be achieved by DC to AC converter called as Inverter. Therefore inverter is an important part of PV energy system. Also there is need to protect the battery from overcharging and discharging beyond the limit. In both cases the battery life decreases. This protection requires a devise called charge controller. Also some of the loads can be made to run on DC which is controlled through charge controller directly. Usually charge controller is built-in in the inverter but it can be purchased separately.

III. System Design

A solar PV system design can be done in four steps:

A. Load estimation.
B. Estimation of number of PV panels.
C. Estimation of Battery bank.
D. Cost estimation of the system.

This section includes all the parameters required for designing the solar PV system and they are discussed one by one.

A. *Load estimation:*

The approximate load estimation of the total connected load of the University is given below.

Table 2: Total connected load of an university

Occupancies	Load in Watts
20 Classrooms	16000
Library	30360
Domes	6700
Offices	7860
Exam Department	1680
Vice-chancellor's Office	1100
Corridor	18590
Staff Rooms	5200
Total connected Load.	87490

The total consumption in the entire day when the whole connected load is switched on will be given by,

Total consumption= $88\ \text{kW} \times 10\ \text{hrs} = 880\text{kWhr}$.

B. *Estimation of number of PV panels:*

For the estimation of the number of PV panels required to meet the load demand, the actual output that could be generated under normal radiation condition is the primary concern. Considering a module of 85 Wp. The watt-peak ratings are generally designed for the solar radiation of 1000W/m^2 but the university campus is getting around 800 W/m^2 on an average every day. So the actual output will be lesser than the expected output.

Considering the operating factor of 0.75 which is very fair, the actual output of a 85Wp solar PV panel will be, $85 * 0.75 = 63.75 \approx 64\ \text{watts}$.

The power available at the end use is less (due to lower combined efficiency of the system) $= 64 \times 0.81 = 51.84 \approx 52\ \text{watts}$.

Table 3: Datasheet of 85 Wp module

Module Type	BLD85-36M (Mono crystalline)
Peak Power	85Wp
Maximum Power Voltage	18.05 V
Maximum Power Current	4.71 A
Open Circuit Voltage	21.94 V
Short Circuit Current	5.29 A
Cell Efficiency	16%
Module efficiency	12.87%
Area of the panel	1200x550x35mm (LxWxH)$\approx 0.66m^2$

Energy produced by one 85 watt peak panel in a day

$= \text{actual power output} \times \frac{7\text{hrs}}{\text{day}} = 52 \times 7 = 364\ \text{whr}$/day.

So number of solar panels required to satisfy given estimated daily load

$$= \frac{(\text{total watt-hr rating})}{(\text{daily energy produced by a panel})}$$
$$= 880 \times \frac{1000}{364} = 2417\ \text{panels} \approx 2420\ \text{panels}.$$

According to the datasheet of the PV module assumed, each solar panel is having an area of 0.66m^2.

Total area required for the installation of PV panel will be $= 2420 \times 0.66 = 1600\text{M}^2$.

C. *Estimation of battery bank and Inverter:*

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years.

The size of battery is calculated as follows:

Battery Capacity (Ah)=

$$\frac{\text{Total Whrs per day used by appliances} \times \text{Days of autonomy}}{(0.85 \times 0.80 \times \text{nominal battery voltage})}$$

$$= \frac{880000\,(\text{whr/day}) \times \frac{1}{24}(\text{day})}{0.85 \times 0.80 \times 24} = 2246\ \text{A} - \text{hrs}$$

Number of battery required = $\frac{2246}{120} = 18.72 \approx 19$ batteries

Total load of the university

$$= 88.00 \times 1000 = 88000\text{watts} = 88000\ \text{VA}$$

The inverters are available with the ratings of 100, 200, 500, 1000, 5000VA

Number of inverter required will be

$$= \frac{88000}{5000} = 17.6 \approx 18\ \text{inverters}$$

D. Cost estimation of the system:

a) Cost of the solar panel $= 100 \times 85 \times 2420 = 2{,}05{,}70{,}000$ Rs.

Cost of battery =
cost per battery × number of battery required =
$7000 \times 19 = 1{,}33{,}000$ Rs.

But the life of battery is on average 5-6 years. So including the replacement charges for battery, Total Cost of battery system will be = 6, 65,000 Rs.

b) Cost of battery charge controller

$= \text{cost per kWhr} \times \text{kWwhr loading} = 1750 \times 880 = 15{,}40{,}000$ Rs.

c) Cost of inverter=

inverter cost per 5kVA × number of inverter required

$= 15000 \times 18 = 2{,}70{,}000$ Rs.

But the life of inverter is on average 5-6 years. So including the replacement charges for inverter, Total Cost of inverter will be = 13, 50, 000 Rs.

Table 4: The total approximate cost of the system:

Component	approximate cost (Rs)
Solar panel	2, 05, 70, 000
Battery	6, 65, 000
Battery charge controller	15, 40, 000
Inverter	13,50, 000
Total cost	2, 41, 25, 000 rupees

Table 5:Technical specification of the system:

Model	Specification
1.General	
a)No. of days of autonomy	1.
b)System output voltage	230V (A.C), 50 Hz
2. Solar PV array	
a)module type	Mono crystalline silicon
b)Array wattage	85Wp.
3. Battery	
a)Battery type	Lead acid cell
b)Battery capacity	12V,120 Ah
4. Inverter	
a)Nominal power	5000 VA
b)Input Voltage	24V
c)Output Voltage	230V(A.C.)
d)Output Frequency	50 Hz.

E. Pay back period calculation:

The solar PV system installed will generate around 880 kwhr i.e. 880 units per day. So the annual generation of electric power will be around $880 \times 280 = 2,46,400$ units annualy.

It seems highly likely that electricity rates will continue to increase given that fuels which are most often used to create electricity such as natural gas and coal are non-renewable.

Life of solar panels in normal atmospheric condition can be 26-26 years when maintained properly. In this example we have used a fairly conservative estimate of a 5% increase per two year for the next 26 years.

Table VI: saving due to solar PV system.

Year	Saving in rupees(Lakhs)
1st -5th	51. 30 048
6th to 10th	57. 90 400
11th to 15th	66. 15 840
16th to 20th	73. 5, 040
21st to 26th	101.91104

The pay back period of the proposed system will be around 19-20 years, and the rest of the years will be beneficial to our university. There is a clear profit of 1, 01, 91, 104 rupees.

IV CONCLUSION

Rural India is facing acute shortage of electric power due to geographical condition, increased power losses and high cost of energy. The education institutions in rural area therefore affected in utilising the entire modern infrastructure used for education due to their dependency on continuous electric supply.

However these rural areas are bestowed with large amount of solar power untapped. This type of renewable energy is inexhaustible, clean and they can be used in a decentralised way, originating from the most part in the form of the sun's radiant energy. This energy is ubiquitous, long-lived, essentially free of carbon emission, and have the potentiality to contribute significantly to mounting the energy needs of the globe

A detail study of exploring solar power for an education institution is presented here with figures and facts. Apart from reliving the dependency from the grid this helps in diversifying our energy supply, reduce dependence on imported fuels, and improves the quality of the air we breathe, offset greenhouse gas emissions, and stimulate our economy by creating jobs in the manufacturing and installation of solar energy systems. The solar radiations are available sufficiently over the country. So India must take initiative to adopt the Grid free solar PV system to fulfilment of present demand-supply gap.

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