Conservation of Energy by Installing Solar PV System

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Abstract - *The need for electric energy is increasing with each passing day in parallel to the developments in technology. However the rise in cost in meeting these needs and that damage is done to nature while energy is being obtained brings clean energy sources such as solar energy for consideration. Therefore, the use of solar panels is increasing exponentially. Solar panels can be used in homes, street lighting, public buildings, and garden lighting and in agriculture, are especially used in meeting the energy needs in specific remote locations. In this study, new approach is suggested in calculating the number of lights and fans required for the building using lumen method of calculation for the newly renovated buildings whereas remaining energy harnessed to directed to the existing college buildings. In the suggested approach solar panels are laid throughout the available rooftop area using conventional calculation method. The number of batteries and hybrid inverters required for the system is also calculated. As a result even though the initial investment is high, the savings in long run is huge. The proposed system is designed for the renovated buildings of the JSSATE College Bengaluru, Karnataka, India and it is calculated that the system will meet its energy need from the solar panel system installed without using convection electric connection.*

Key Words: **Solar panel, Battery, Inverter, Cost estimation, Savings.**

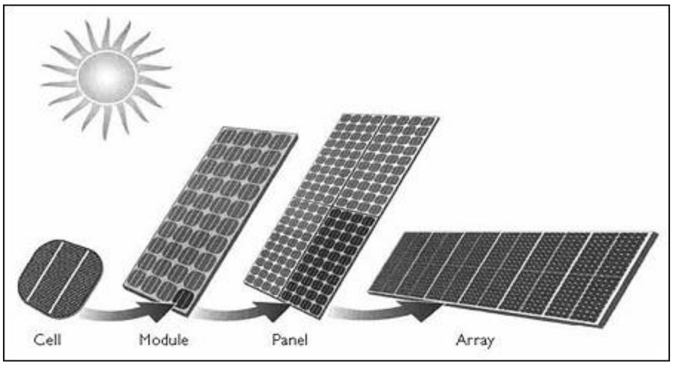
1. INTRODUCTION

The decrease in fossil fuel reserves on earth, climatic changes, problems surrounding the issues of reliability and waste problems of nuclear power plants have pushed people to seek energy resources that have low unit costs, do less damage to nature and are renewable. To counter this, intensive efforts have been spent to exploit the sun in producing electric energy.

The sun is a clean and renewable source of energy. A prominent way of producing electricity directly is to use photovoltaic cell systems. Photovoltaic cells are semiconductors that convert the sun rays coming onto their surfaces into direct current electric energy without any intermediate agents. The photovoltaic (PV) effect was first found by the French Physicist Edmond Becquerel in 1839. The first solar cell, on the other hand, was invented by Charles Fritts in 1884.

The outputs of PV cells, which stood at a mere 1 % in 1914, rose to 6 % in 1954. This percentage reached 46.5 % as of 2014 [1].

In order to increase power output, a number of solar cells are bound together in series or in parallel and then mounted on a surface. This device is called a PV module. Systems varying from a few watts to megawatts can be formed by connecting the modules in series or in parallel depending on the demand for power. In this way, systems up to MW levels can be formed [2]. The transformation of PV cell into PV array is shown in Fig.1.



PV systems offer advantages such as green energy, reduce fuel consumption, minimum maintenance cost, easy installation, noiseless operation and producing no waste. However, they also have major disadvantages such as requiring expensive investment due to being products of advance technology, and needing large storage spaces.

In this study, optimum method is suggested for calculation of number of fans and lights required for the buildings using lumen method of calculation [4].

In our project, installation procedure of solar panels throughout the available rooftop area is done, considering the hours when the loads that will consume the electricity will be used. Load is calculated using lumen method. Hence energy generated is utilized completely, that way effective utilization of solar energy is made. As a result even though the initial cost of the project is high the savings and profit in life span of PV system is huge.

1.1 Solar Panel Systems

A solar panel system contains mainly battery group, charge regulator, inverter and auxiliary electronic circuits. The number of solar panels is determined according to the amount of energy needed. Since the sun is not out at all hours of the day, the battery group is included as a backup in the system to provide the system with continuous energy. Therefore, it is necessary to use a battery charge regulator to prevent the battery from being damaged due to overcharge or discharge. Given that many loads are fed by alternating current, it is inevitable to use an inverter to convert the direct current obtained from the panel into alternating current. It will be more appropriate to add a double axis solar tracking system.

2. METHODOLOGY

It is possible to summarize the steps in producing electricity using solar panels as follows:

- Determination of number of lights required using lumen method.
- Determination of solar energy production in the area of application.
- Selection of hybrid inverter and batteries.
- Determination of monthly and annual savings.
- Determination of capital returns and profit from the project.

3. TOTAL LOAD CALCULATION

3.1. Calculation of Number of Bulbs by Lumen Method

Lumen method is a simplified method to calculate the light level in a room. The method is a series of calculations that uses horizontal illuminance criteria to establish a uniform luminaire layout in a space. In its simplest form, the lumen method is merely the total number of lumens available in a room divided by the area of the room.[3] In order to perform this calculation, many factors, coefficients, lamp lumen data and other quantities must be gathered. The formula used in the calculation of the daily power need is given in (1)

$$T_{lu} = \frac{A \cdot l}{df \cdot uf} \tag{1}$$

T_{lu} in (1) expresses the total luminous required, A being the area of the building, l is the lux which depends of type of building, d_f is the depreciation factor and u_f being the utility factor.

Using above formula for different building total lumens required is calculated followed by adopting 20W and 30W LED bulbs total number of lights required is calculated and found to be 25 and 28 respectively.

3.2. Calculation of Number of Fans

The number of fans required for the optimum airflow and air replacement for buildings is calculated using the given in (2)

$$Cfm = \frac{V}{Tf} \tag{2}$$

Cfm in (2) expresses the cubic feet per minute of volumetric flow of air, V being the total volume of the selected building, T_f is the total time or interval of air flow.

Using the above formula for all the building cfm and volume is calculated and time flow or interval is selected to be 3 minutes. Adopting 56 inch and 42 inch ceiling fans total number of fans required is found to be 11 and 12 respectively.

By running all the calculated appliances for the period of 9 hours daily in the renovated building the total load consumed is found to be 36 units.

4. TOTAL SOLAR ENERGY PRODUCTION

4.1. Energy Harnessed in Terms of Kilowatts

The total solar energy that can be harnessed depends on the many factors such as total area available for the solar panel installation, total full sun hours in the location and the efficiency of the solar panels installed.

Area available in our study for the installation is 1400 m^2 and the efficiency of the solar panels adopted is 16%. By considering the energy available in one full sun hour to be 1000 watts per m^2, the energy that can be harnessed per m^2 by using 16% efficient solar panel is given in (3)

$$E_p = \frac{Er}{\eta} \tag{3}$$

E_p in (3) expresses the energy produced, E_r being the energy received from the sun per m^2 and η is the efficiency of the solar panel.

Using the above formula the energy thus produced per m^2 of area is found to be 160 watts. Using similar approach, space required for installation of 1 kilo watt plant is 10 m^2 considering the spacing that has be provided between solar panel arrays. Hence the total energy that can be produced in the available area of 1400 m^2 is 140 kilowatts.

4.2 Energy Harnessed in Terms of Units

To find the energy thus harnessed to express in units which is the basic measurement of electricity, the total sun hours in the location needs to be found, which can be obtained either by referring meteorological handbook or by NASA website of meteorology by giving inputs of our location.

The project is done in the JSSATE College Bengaluru, Karnataka, India. The co-ordinates for this location are found to be 12.9028^0 Latitude and 77.904^0 Longitude. Using this input Table 1 is obtained from NASA website of meteorology.

Table -1: Meteorological Chart

Month	Air temperature (^{0}C)	Daily solar radiation (kWh/m^2/h)
January	22.4	5.36
February	25.0	6.06
March	27.5	6.56
April	27.2	6.38
May	26.7	6.03
June	24.9	4.84
July	24.3	4.50
August	24.5	4.47
September	25.1	5.03
October	24.1	4.63
November	22.8	4.50
December	21.9	4.74
Annual	24.7	5.26

Designing the system for the least number of sun hours. From the table 1 we get that in the month of august in our location the sun hours is found to be 4.47, adopting which the total energy produced is given in (4)

$$E_u = E_p \,.\, S \qquad (4)$$

E_u in (4) expresses the energy produced in terms of units, E_p being energy produced in kW and S is the total sun hours obtained from table 1. Using the above formula the energy thus obtained is found to be 625 units per day.

5. CALCULATION OF SOLAR COMPONENTS

5.1. Battery Calculation

Batteries in PV systems should have such a capacity that they should be able to meet the energy need of the system when electric energy cannot be obtained from PV panels. Capacities of batteries vary depending on temperature. Therefore, values of temperature should also be taken into account in calculations. The temperature coefficient value of the battery is shown in Table 2.

Table -2: Temperature Coefficients of Battery

Temperature (°C)	Coefficient
26.7	1.00
21.2	1.04
15.6	1.11
10.0	1.19
4.4	1.30
-1.1	1.40
-6.7	1.59

Total battery capacity of the PV system can be calculated using (5).

$$B_c = D_b . DD . C_t . B_{cd} \qquad (5)$$

B_c in (5) expresses the total battery capacity needed, D_b the number of days when energy will be obtained from the battery, DD discharge depth, C_t the temperature coefficient of the battery, and B_{cd} the daily battery capacity need.

The average temperature in the Bengaluru region of Karnataka is 24.7°C. Therefore, the temperature coefficient of the battery was taken as 1 in this study.

Considering the battery backup for our system generating 625 units of electricity we need a battery of power 52083 Amp hours. By proving battery of 150 Ah each we need 347 number batteries to completely store energy harnessed per day.

5.2 Inverter Calculation

A solar inverter or PV inverter converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical balance of system component in a photovoltaic system, allowing the use of ordinary AC-powered equipment.

In modern days hybrid inverters are generally used which is a combination of inverter and charge controller. In our study we have adopted sine wave hybrid inverters of capacity 5kW of efficiency 90% for effective operation. The output power of inverter is given in (6)

$$O_p = \frac{Ip}{\eta} \qquad (6)$$

O_p in (6) expresses output power, I_p being input power and η is the efficiency of the inverter.

Using above equation the output power calculated is 155555.5 watts and Hence we need 32 inverters of 5 kW power for our project.

6. SOLAR PANEL CALCULATIONS

6.1 Power Value of the PV System

Electric devices have a certain power value. When the power of a PV is determined, the average daily working hours of the devices during the day and the number of days they will be used per week are taken into consideration. The formula used in the calculation of the daily power need is given in (7).

$$P_d = P . t_d \qquad (7)$$

P_d in (7) expresses the daily power consumption of the system, P being the power of the device, t_d the daily duration of use of the device.

Using the above equation the daily power consumption is found to be 36 kWh per day for renovated college buildings.

6.2 Solar Panel Calculation

Adopting the 350 watts panels in the approach whose dimensions is found to be 1.92 m in length and 1.0 m in width, it takes around 3 panels to produce 1kW of energy and it occupies 10 m^2 rooftop areas.

Available area for installation in our study is 1400 m^2 henceforth the total number of solar panels that can be installed is 420 producing 140 kW of energy per day.

7. COST ESTIMATION

7.1 Cost of Solar Panels

In this project 350 Wattage of solar panel is being installed and the number of solar panels required is found to be 420 in numbers. Cost of each 350 Wattage panel is 15000 Indian rupees; hence the total cost of solar panels is around 63 lakh rupees.

7.2 Cost of Inverter and Charge Controller

Adopting the hybrid inverter which comes with inbuilt charge controllers reduces the space required and cost. We are providing 5kW of hybrid inverter of efficiency 90% is being installed whose cost is 68000 rupees and the number of such inverters required is 32 so the total cost of inverter is around 22 lakh rupees.

7.3 Cost of Batteries and Solar Trackers

Batteries of 150 Ah power is required which will cost around 15000 rupees and such batteries are required in 347 numbers so the estimated cost will be around 52 lakh rupees.

Solar trackers of double axis is being installed which will cost 13000 rupees per kW of solar panels. Hence for 140 kW all over so the estimated cost will be 22 lakh rupees.

Summing up all the cost of equipment the total investment or capital is found to be 1.5 crores.

7.4 Monthly Reduction in Electric Bill

In our study we are generating and using 625 units of electricity from solar panels installed instead of conventional electric current hence we are saving the money corresponding to the 625 units of electric current.

In the study area which is Bengaluru, Karnataka, the cost per unit electricity is 7.90 rupees so the daily savings is estimated to be 4938 rupees and monthly reduction is upto 1.5 lakh rupees.

7.5 Capital Returns

Capital return calculation is important as it provides the information about the return of initial investment in years. In our project initial investment is 1.5 crores and the annual savings is around 18 lakh rupees. The number of years in which capital returns is given in (8).

$$T = \frac{C}{A} \qquad (8)$$

T in (8) expresses the time required for the capital returns, C being the capital investment and A is the annual savings.

Using the above equation the number of years of capital returns is found to be 9 years.

7.6 Savings of Life Time

Considering the life span of solar panels is around 25-30 years. The savings from the rest of the 21 years of savings will be around 4 crore rupees.

8. CONCLUSION

In this study, new approach is suggested in calculating the number of lights and fans required for the building using lumen method of calculation for the newly renovated buildings whereas remaining energy harnessed to directed to the existing college buildings. In the suggested approach solar panels are laid throughout the available rooftop area using conventional calculation method. The number of batteries and hybrid inverters required for the system is also calculated.

It was proposed in the design for the college renovated buildings. Which is going to be operated 9 hours daily for 365 days of year and that energy for running all the appliances will be met by the energy harnessed from the installed PV system. The PV system installed in the area of 1400 m^2 involves 420 solar panels of 350 wattage, 347 number of 150 Ah batteries, 32 number of 5kW hybrid inverters and double axis solar tracking system.

The system designed is proposed for JSSATE college Bengaluru, Karnataka. The initial investment is found to be 1.5 crores and the savings in the life time of solar panel is found to be 4 crores.

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