Quantitative assessment of roof top solar photovoltaic power: A case study from university hostel of Dr. Rajendra Prasad Central Agricultural University, Pusa

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Abstract

University hostels are the places where dreams of students cherish and blossom. In academic as well as extracurricular activity, there is a need of undisturbed electric supply in hostels. But, due to certain constraint, the civilian electricity supply doesn't meet the demand. In such case, alternative source, such as rooftop solar power supply plays a vital role. A case study has been done at University Boys’ Hostel of Dr. RPCAU, Pusa. In this paper, assessment of rooftop solar power availability has been done to achieve the power requirement of university boy’s hostel. Further, a layout of solar power plant has also been proposed. In this study, after designing the layout plan, a financial assessment of the project has also been done, considering recent market price. The entire planning has been carried by considering the actual space available at the roof top for installation of the solar panels. The results from this study suggest that total total power requirement in university boy’s hostel to meet the load was about 43 kWp/day. And also total cost of installation was about Rs 52 lakhs.

Keywords: Solar power, rooftop solar panels, off grid solar PV, financial assessment, photovoltaic

Introduction

The use of renewable technology for generating power is growing at a faster rate in the current era. Considering the low availability of conventional fuels and the constant price increase, the use of solar power must be used to its fullest in areas where solar radiation is available throughout the year. The sun is radiating an enormous amounts of energy, called solar energy and it radiates more energy in one day than the world uses within one year. Every hour enough solar power reaches on the Earth to supply a year's energy requirement for our country. Like most stars, the sun is a large gas ball mainly made up of Hydrogen and Helium gas. In a process called nuclear fusion the sun makes energy in its inner core. India lies between latitude 7° North and latitude 37° North. The average incident of solar energy over India ranges from 4-7 KWh / m², with around 1500-2000 hours of sunshine a year. Solar cell is a device that directly converts the energy of light into electrical energy through the photo-voltaic effect and its does not emit any harm full gases.

This paper presents a complete assessment of a PV plant for RPCAU Boys Hostel at Pusa which consisting of five blocks. The concept of developing environmentally friendly photovoltaic plants has been discussed, (Chen et al., 2012) [8] and suggests that enormous green energy source produced from the sun would gain the best opportunity to grow up. We will seize the ability to build the most suitable environmentally friendly PV power plant. Considering this as an opportunity to suggest a clean source of energy for complete energy demand of the RPCAU boy’s hostel, a solar PV plant design and its assessment has been carried out.

A case study in Jaipur (Khatri R., 2016) [1] designing and assessment of solar photovoltaic plant to meet girls hostel energy demand at MNIT University Jaipur. A solar PV plant was designed with its financial and environmental assessment considering recent market prices. All the aspects related to a solar PV plant were considered for financial feasibility of PV plant near this location. A study was carried out on solar cell (Ilyas et al. 2013) [2]. Solar Photovoltaic Technology, Planning and Designing a Stand Alone Solar Power System for Multi Building in
an Organization where Solar energy played an important role for the power supply in case of emergency by replacing Diesel Generator set.

The environmental aspect related with the energy generated with PV plant i.e. reduction in carbon emission and carbon credits earned was also considered. A study of solar power system is conducted (Valerio, 2010) to determine energy requirement of the cheese industries with respect to use of solar energy and also estimate the profitability of installation of solar power system. A review has been to estimate (Sherwani et al., 2010) of life cycle assessment (LCA) of solar PV based electricity generation systems. Mass and energy flow over the complete production process starting from silica extraction to the final panel assembling has been considered. Life cycle assessment of amorphous, mono-crystalline, poly-crystalline and most advanced and consolidate technologies for the solar panel production has been also studied.

This paper cover all the preferences addressed by the (Soni and Gakkhar, 2014) in their paper i.e. Costs, Payback period as an economical parameter, location and CUF as a technical parameter and type of cell and performance ratio as PV parameters. Calculation of solar photovoltaic potential on residential rooftops was based on geographic information systems, Light Detection and Ranging data with statistical analysis to identify how much solar photovoltaic potential exists for residential rooftops in the town of Kailua Kona on Hawaii Island (Carl, 2014). The process of acquiring photovoltaic power involved (Akash et al. 2016) designing, selecting and determining specifications depending on a variety of factors, such as geographical location, weather condition, solar irradiance, and load consumption and also studied on detailed design of a standalone rooftop solar PV system to provide uninterrupted power supply for a hostel building is presented. It outlines the detailed procedure for specifying each component of the stand-alone rooftop solar PV system and its performance analysis using simulation software.

A study was demonstrated Gorl (2016) that solar photovoltaic rooftop has emerged as a potential green technology to address climate change issues by reducing reliance on conventional fossil fuel based energy. As the Solar photovoltaic rooftop power system can be the best option and hence by taking the following objective the planning has been done to install a suitable Off grid solar photovoltaic rooftop power system. Keeping in view the frequent power cut in the Pusa campus, there is a need of power backup during power cut considering the opportunity to propose clean and environmental friendly source of energy for backup purpose in boy’s hostel. This study helped to quantify the magnitude of possible solar photovoltaic (PV) potential on residential rooftops within the study area.

Objective
1. To assess the power requirement of the electrical appliances in University Boys hostel, Pusa.
2. To assess the solar power available at rooftop of University Boys hostel, Pusa.

Methodology
The methodology adapted was based on the literature survey and the process flow of the paper is shown in the Fig. 1. This paper provides design and analysis of a 43 kWp/day SPV plant with different parameters associated with real time market prices and future escalation of the prices. It also includes the description of experimental layout, assessment of power requirement of electrical appliances, observation to be taken and develop a plan for installation of rooftop solar panels with references to the objective of this paper.

![Flow chart for assessment of PV plant](image-url)
Experimental site
The campus of Dr. RPCAU is located at Pusa under Samastipur district of Bihar. Pusa is situated at 53.12 m above sea level and at 25°30' N Latitude and 85°40’ E Longitudes (Kumar et al., 2012) [11]. In university a big boy’s hostel which have five blocks, three separate mess building and two common room. In all building have large rooftop areas and hence good potential for installation of solar panels on its roof. Details of rooms are given in Table 1.

| S. No. | Block | Rooms |
|--------|-------|-------|
| 1      | 1st   | 33    |
| 2      | 2nd   | 33    |
| 3      | 3rd   | 33    |
| 4      | 4th   | 33    |
| 5      | 5th (PG) | 102 |

Rooftop area available
In the rooftop of each block, there are some free space available and some space are used (water tank, tap, stair and other purpose). Free space of rooftop are usable for installation of solar panels. The rooftop areas of different blocks were measured manually with the help of measuring tape.

Total load estimation
A detailed survey was conducted of each room and parts of the hostel to determine the amount of load connected with it. The total load depends on the wattage applied to the appliances and its operating hour. The installation is mainly for backup purpose i.e. when the electric power is cut.

Solar photovoltaic power plant designing
Design of solar photovoltaic power plant consists, estimation of size of PV modules, capacity of inverter, and battery. For designing solar PV plant geographical details and weather data of the site is required. Fig. 3 provides a monthly average radiation data for Pusa.
**Panel generation factor**

Panel Generation Factor is a key factor in the design of a solar photovoltaic plant that produces an average of Wh / day for every Wp capacity in the panel and is different for different regions.

\[
\text{Panel Generation Factor} = \frac{\text{Daily Solar Radiation}}{\text{Standard Test conditions Irradiance for PV panels}} \tag{2.1}
\]

For Standard test condition Irradiance for PV panel is 1000 Wh/m²

**Energy required from PV modules**

The energy needed from the photovoltaic modules will be the daily energy demand of the hostel and system loss compensation, which is usually taken as 30%.

\[
\text{Total energy required} = (\text{Energy Demand} \times \text{System Losses Compensation Factor}) \tag{2.2}
\]

System Losses Compensation factor = 130%.

**Watt Peak rating for PV modules and number of modules**

Total Watt peak rating for PV modules has been calculated to identify system capacity which depends on the energy needed from modules and panel generation factor.

\[
\text{Watt Peak rating for PV Modules} = \frac{\text{Energy required from PV modules}}{\text{Panel Generation Factor}} \tag{2.3}
\]

The total no of modules required for the proposed plant depends on the peak rating of the modules.

\[
\text{Number of module required} = \frac{\text{Total Watt Peak Rating}}{\text{PV module Peak Rated Output}} \tag{2.4}
\]

**PV module specifications**

- Peak power output watt (Wp) 150
- Current at peak power output amp (Imax) 8.06
- Voltage at peak power output volt (Vmax) 17.82
- Short circuit current amp (Isc) 8.95
- Open circuit voltage volt (Voc) 21.6
- Dimensions (mm) 1060 * 986 * 30

**Capacity of battery and number of battery**

Designing an onsite power plant always requires a storage medium and in case of PV plant, batteries is the most common storage medium. In present case as it is an educational institute it is very important to have reliable backup during examination period. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days. Dr. RPCAU is located in Pusa with minimum power cut periods therefore single day of autonomy has been considered while considering capacity of the battery for the hostel requirements.

\[
\text{Batter Capacity Required} (\text{Ah}) = \frac{(\text{Total Wh required}) \times \text{Days of Autonomy}}{\text{Nominal Battery Voltage} \times (1 – \text{DOD}) \times \text{Battery Efficiency}} \tag{2.5}
\]

The total number of battery required for the proposed plant depends on the battery capacity required and single battery capacity.

\[
\text{Number of battery required} = \frac{\text{Battery Capacity Required}}{\text{Single Battery Capacity}} \tag{2.6}
\]

**Capacity of inverter**

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as of the battery. The inverter must be large enough to handle the total amount of watts being used at a time. The inverter size should be 25-30% bigger than total watt of appliances.

\[
\text{Inverter capacity} = (\text{Total watts of appliances} \times \text{System Losses Compensation Factor}) \tag{2.7}
\]

**Total area required**

Total area required for installation of rooftop PV depends upon panel efficiency. Required area has been calculated by considering 250 Wp module/1.5 m² with an efficiency of 16.67%.

**Financial assessment of the plant**

Renewable energy technologies have enjoyed a period of rapid growth in recent years. They will have to become price competitive to sustain their growth. For the financial assessment of the plant the realistic values or the current market prices of the components associated with the project must be taken. The project cost includes

I. Cost of Modules.
II. Cost of Batteries.
III. Cost of Inverters.
IV. Miscellaneous {Operation and Maintenance cost, Installation Cost, Electrical Items (Cables etc.), Packing and Freight}.

**Cost of module**

The global module cost is decreasing every day, the market trends shows that currently it is around Rs.60-80 per Wp in India. In present study we consider Rs.80 per Wp in India.

**Cost of Batteries**

Batteries store energy being produced by a given generating source, and when this source is unavailable this energy can be used by the load. The inclusion of storage in any energy generating system will increase the availability of the energy. Cost of one battery = Rs. 15000

**Cost of Inverter**

Inverter is an electronic device which is able to convert a DC potential normally derived from solar panels or battery into a stepped-up AC potential which may be quite comparable to the voltage that is found in domestic AC outlets, the market trends shows that currently it is around Rs.2 per Watt in India.

**Miscellaneous cost**

Miscellaneous cost including Operation and Maintenance cost, Installation Cost, Electrical Items (Cables etc.), Packing and Freight, it comes out to be nearly Rs. 10/Wp (Chandel et al., 2014) [10].

**Result and Discussion**

The analysis of a solar PV plant designed for a RPCAU boy’s hostel is carried out. The PV technology is not used only for reducing the consumption of fossil fuels but it can be a continuous source of energy for critical areas like hostel of universities where uninterrupted supply is demanded. As this is a case study it will imply on the places like Rajasthan or an
area with abundant solar energy available for nearly whole year. In this paper the efforts have been made to identify the requirements of the plant for continuous supply of energy to the hostel and its feasibility was identified with its environmental and financial assessment. This will be useful for energy planning and developing new strategies for PV implementation.

**Rooftop area available**

Total rooftop area available in 1st block was 387.85 m² and unusable area (that area occupied by water tank, tap, stair and other purpose) was 226.73 m². So net area available for rooftop PV installation was 161.12 m² and net area available for rooftop PV installation of 2nd, 3rd and 4th block same as 1st block. In PG block total rooftop area available was 546.25 m² and unusable area was 302.87 m². So net area available for rooftop PV installation was 243.38 m² is shown in Table 9.

| S. No. | Name of blocks / building | Total area available | Unusable area | Net area available for rooftop PV |
|--------|---------------------------|----------------------|---------------|----------------------------------|
| 1      | 1st block                 | 387.85               | 226.73        | 161.12                           |
| 2      | 2nd block                 | 387.85               | 226.73        | 161.12                           |
| 3      | 3rd block                 | 387.85               | 226.73        | 161.12                           |
| 4      | 4th block                 | 387.85               | 226.73        | 161.12                           |
| 5      | PG block                  | 546.25               | 302.87        | 243.38                           |

**Load estimation**

A detailed survey of each room of hostel and sections of the hostel was carried out to identify the amount of load connected to it. We have calculated that total energy required per day by calculating sum of energy required by each appliances in each block. Tables 2–7 provides the complete details of the different equipment’s their wattage and hours of operation (on the basis of survey) Energy requirement in 1st, 2nd, 3rd and 4th block were same and which was 30.3 kWh/day and in PG block energy requirement was 43.8 kWh/day. So total energy requirement was 172.06 kWh/day.

**Table 2: Total rooftop area available**

| S. No. | Name of blocks / building | Total area available | Unusable area | Net area available for rooftop PV |
|--------|---------------------------|----------------------|---------------|----------------------------------|
| 1      | 1st block                 | 387.85               | 226.73        | 161.12                           |
| 2      | 2nd block                 | 387.85               | 226.73        | 161.12                           |
| 3      | 3rd block                 | 387.85               | 226.73        | 161.12                           |
| 4      | 4th block                 | 387.85               | 226.73        | 161.12                           |
| 5      | PG block                  | 546.25               | 302.87        | 243.38                           |

**Table 3: Energy required for rooms in 1st, 2nd, 3rd and 4th Blocks.**

| S. No. | Name of appliances | Number | Rating (W) | Hour of operation | Energy required (kWh) |
|--------|--------------------|--------|------------|-------------------|-----------------------|
| 1      | CFL                | 3      | 15         | 4                 | 0.180                 |
| 2      | Fan                | 2      | 60         | 6                 | 0.720                 |
|        |                    |        |            |                   | For one room          | 0.900                 |
|        |                    |        |            |                   | For 33 room (one block)| 29.700               |
|        |                    |        |            |                   | For 132 room (four block)| 118.800             |

**Table 4: Energy required for common area for lighting in 1st, 2nd, 3rd and 4th Blocks**

| S. No. | Common area | Name of appliances | Number | Rating (W) | Hour of operation | Energy required(kWh) |
|--------|-------------|--------------------|--------|------------|-------------------|----------------------|
| 1      | Bathroom    | CFL                | 3      | 15         | 4                 | 0.180                |
| 2      | Gallery     | CFL                | 3      | 15         | 4                 | 0.180                |
| 3      | Stairs      | CFL                | 4      | 15         | 4                 | 0.240                |
|        |             |                    |        |            |                   | In one block          | 0.600                |
|        |             |                    |        |            |                   | In four block         | 2.400                |

**Table 5: Energy required for rooms in PG block**

| S. No. | Name of appliances | Number | Rating (W) | Hour of operation | Energy required (kWh) |
|--------|--------------------|--------|------------|-------------------|-----------------------|
| 1      | CFL                | 1      | 15         | 4                 | 0.60                  |
| 2      | Fan                | 1      | 60         | 6                 | 0.36                  |
|        |                    |        |            |                   | For one room          | 0.420                 |
|        |                    |        |            |                   | For 102 room          | 42.840                |

**Table 6: Energy required for common area for lighting in PG block**

| S. No. | Common area | Name of appliances | Number | Rating (W) | Hour of operation | Energy required(kWh) |
|--------|-------------|--------------------|--------|------------|-------------------|----------------------|
| 1      | Bathroom    | CFL                | 6      | 15         | 4                 | 0.36                 |
| 2      | Gallery     | CFL                | 6      | 15         | 4                 | 0.36                 |
| 3      | Stairs      | CFL                | 4      | 15         | 4                 | 0.24                 |
|        |             |                    |        |            |                   | Total                | 0.960                |

**Table 7: Energy required for others (Common room, mess, Gallery)**

| Particulars | Department | Appliances | Rating (W) | Requirement | Hour of operation | Energy required(kWh) |
|-------------|------------|------------|------------|-------------|-------------------|----------------------|
| Common room | CAE        | CFL        | 15         | 2           | 4                 | 0.120                |
|             |            | FAN        | 60         | 2           | 4                 | 0.480                |
|             |            | LCD TV     | 100        | 1           | 4                 | 0.400                |
| PG          |            | CFL        | 15         | 3           | 4                 | 0.180                |
|             |            | FAN        | 60         | 2           | 4                 | 0.480                |
|             |            | LCD TV     | 100        | 2           | 4                 | 0.800                |
| BIOTECH     |            | CFL        | 15         | 1           | 4                 | 0.600                |
|             |            | FAN        | 60         | 1           | 4                 | 0.240                |
Design of solar photovoltaic power plant consists, estimation of size of PV modules, capacity of inverter and battery. It’s all component are described below

Panel generation factor
The graph shows variation of solar insolation on monthly basis. The minimum solar insolation in December because less intensity of sunlight and less day light hour. Maximum insolation in April because more intensity of sunlight and more day light hour. The average annual solar insolation was 5.22 kWh/m²/day.

Source of this data is taken from website of NASA Surface meteorology and Solar Energy.

Energy required from PV modules
Total energy required from module was calculated by putting energy demand in the equation (2.2). In which Energy demand in hostel was 172.06 kWh/day and by considering 30% system losses. So total energy required from module was 224 kWh/day.

Watt Peak rating for PV modules
The value of Watt Peak rating for PV computed by equation (2.3). In which putting the value Energy required from module (225 kWh/day) and Panel generation factor (5.22). So Watt Peak rating for PV modules was 43 kWp/day.

Number of PV module
The number of PV module depends on Total watt peak rating and Peak rated output. For calculating number of module by putting the value of Total watt peak rating (43 kWp/day) and peak rated output (150 Wp) in equation (2.4). So number of PV module was 289.

Capacity of battery
The capacity of battery computed by putting the all value in equation (2.5).

Nominal Battery Voltage = 12 V
Days of autonomy = 1
DOD = Depth of discharge = 0.4

Battery efficiency = 85%.
So Battery capacity was 28114.38 Ah.

Number of battery
Total number of battery is computed by putting the value of Battery capacity and Single battery capacity in the equation (2.6). The value of battery capacity was 28270 Ah and single battery capacity was 150 Ah. So number of battery is 188.

Battery specification given in Table below.

Capacity of Inverter
The capacity of inverter has been calculated by putting the value of total watts of appliances (32.05 kW) and system losses in equation (2.7). We considered system losses of 30%. So capacity of inverter was 42 kW.

Total area required
Area required for installation of panel of 250 Wp was 1.5 m². Then area required for installation of panel 43 kWp was 258 m². Total usable area are 887.86 m² which is sufficient for installation of rooftop solar panel.

Assessment of solar power available at rooftop
At rooftop available area was 887.86 m². Maximum capacity of solar panel can be installed is 148 kWp. Calculation has been done by considering 1.5m² area required to install 250 Wp module.

Financial assessment of the plant
It is estimated that the cost of all particular (module, battery, inverter etc.) which is given in Table 8

Table 8: Total energy requirements in University boy’s hostel

| Particular       | Energy required (kWh/day) |
|------------------|---------------------------|
| 1st block        | 30.3                      |
| 2nd block        | 30.3                      |
| 3rd block        | 30.3                      |
| 4th block        | 30.3                      |
| PG block         | 43.8                      |
| Other (mess, room, gallery) | 7.06 |
| Total            | 172.06                    |

Solar photovoltaic power plant designing
Design of solar photovoltaic power plant consists, estimation of size of PV modules, capacity of inverter and battery. It’s all component are described below

Solar energy module
Other (mess, common room, gallery)

| Particular       | Cost (Rs.)       |
|------------------|------------------|
| Module Cost      | 34,40,000        |
| Batteries Cost   | 28,20,000        |
| Inverters Cost   | 84,000           |
| Miscellaneous Cost | 4,30,000   |
| Total Cost       | 67,74,000        |

Table 9: Cost breakup of solar plant

Conclusion
Keeping in view, the necessity of power during power cut and the advantages associated with installation of photovoltaic rooftop power plant the work has been carried out for the planning and installation of such photovoltaic power plant in the University Boys’ Hostel of Dr. RPCAU, Pusa. This paper has attempted an assessment of a Solar PV plant for RPCAU boy’s hostel and examines its financial viability with parameters associated and real time market prices. The findings of the presented study are concluded as:

Total energy required in hostel is 172.06 kWh per day and Capacity of PV plant required to meet the load is 43 kWp per day.

Net rooftop area available for PV plant installation is 887.86 m². Area required for installation of PV plant is only 258 m².

Maximum solar power achievable at rooftop of University boys’ hostel is 148 kWp.

Total investment on PV plant to meet the load in the University boys’ hostel is Rs. 67, 74, 000.

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