Original Paper

An experimental approach towards cost benefit analysis of 850 kW solar PV plant

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Abstract. *Solar photovoltaic (PV) cell technology is the simplest way to generate renewable power and reduce our reliance on non-renewable energy sources. Because India is located on the earth's equatorial sunbed, it receives a lot of radiant energy from the sun. Most Indian states have approximately 250–300 d of clear, bright weather per year. Among all the states, Rajasthan* *is one of India's sunniest states, and it is a solar energy hotspot. Manipal University Jaipur (MUJ) is situated in Jaipur, Rajasthan, with 26.8^0 latitudes and 75.56^0 longitudes and a surface area of 122 acres. It receives high levels of solar radiation. All the hostel's block rooms have air conditioners (ACs), so the energy demand in the summer is high. The performance assessment of 850 kW installed capacity on hostel building-mounted solar photovoltaic power plant has been carried out, in view of obtaining better designing, operation/maintenance characteristics of the system. MUJ installed an 850-kW solar power plant for on-site generation and utilization to overcome this enormous electricity bill problem. The paper aims to collect the solar power generation of the plant from April 2019 to March 2020 and shows an investigation of the variation of energy consumption from the Electricity Board (EB), Jaipur Vidyut Vitaran Nigam Ltd (JVNL) of the university hostel block while using solar power and maintains the conventional system. The paper also explores the cost-benefit analysis of 850 kW solar power plants. The impacts of various economic parameters are also taken into consideration.*

1. Introduction

In the present era, solar photovoltaic technology for energy generation is expanding faster. The photovoltaic (PV) effect generates direct electricity from sunlight, with the names photo and voltaic representing light and energy, respectively. The purpose of a solar cell, a light-sensitive semiconductor device, is to generate direct electricity from the sun. Edmund Becquerel (Becquerel, 1839), a French scientist, was the first to identify the photovoltaic phenomenon in 1839. Even so, it was only in discovering quantum theory and solid-state physics that it developed its distinct personality. The first crystalline silicon solar cell with a 6% efficiency was found in by (Chapin et al., 1954) at Bell Laboratories. Following that, scientists worked tirelessly to produce highly efficient solar PV materials. As fossil fuels become scarcer and more expensive, renewable energy sources, such as solar energy, become more popular. Build solar PV systems in regions where solar radiation is available all year to create the highest electricity possible (Green, 1993, Sheoran et al., 2023, IRENA, 2012).

In India, most areas receive a solar irradiance of about 4 to 7 kWh/m²/day, and its terrestrial mass is expected to receive about 5000 trillion kWh of solar energy per annum. With the advancement of the Jawaharlal Nehru National Solar Mission beginning in 2010, solar photovoltaic system installations in India have been growing exponentially (Green et al., 2018), Bukya et al., 2023, Shankar et al., 2023).

Today's breakthrough for renewable energy sources in electricity generation is PV power systems. PV power systems offer the benefits of more effective use of the highest renewable energy source output and a long-term growth tendency. The output performance of grid-connected PV power systems is significantly influenced by the solar module's cell temperature, ambient temperature, and solar irradiation.

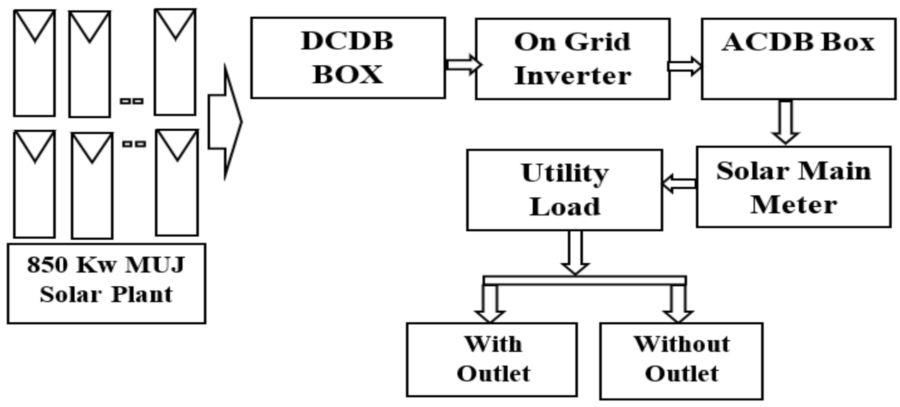

Figure 1. MUJ 850 kW solar Power Plant Schematic Diagram

In this research paper, an experimental analysis has been done on an 850-kW solar power plant installed in the MUJ Jaipur youth hostel. MUJ Jaipur is a world-renowned university established in 2011 to achieve academic excellence. It is located off the Ajmer-Jaipur-Rajasthan Highway. Although India provides electricity to every niche of the country, variations in the electricity bill are still reported in the regions of Rajasthan. We can solve this problem with the wide use and installation of the solar photovoltaic system. This document addresses and resolves the same issue by modelling the cost-benefits of 850 kW solar power plants.

2. Materials and Methods

For an efficient utilization of a solar power plants, a cost benefit and techno economic analysis is very important for determining the optimum conditions for efficient operation. The analysis of all of the economic aspects relating to a photovoltaic system is complex, considering that each installation must be evaluated in its particular context (local conditions, regulations, solar radiation, available areas, etc.)

S.No	Recycled & Recovered Materials	% Material Composition
1	Al	17.5
2	Glass	65.8
3	Silicon	2.9
4	Copper	1
5	Plastic	12.8

Table 1. Composition after Recycling

The software is widely used by researchers and academics to perform energy and cost benefit analysis for renewable energy systems, furthermore it is a freeware and easy to use. In our study, five criterions are selected for analyzing the financial viability for QASP (Payback Period, NPV, internal rate of return (IRR), benefit-cost ratio (BCR), and reduction in GHG Emissions). To state our aims briefly, this analysis will ascertain the time it would require recuperating the initial investment and determine what the yearly cash inflows will be throughout the life of the project. This analysis helps commercial and future investors evaluate the economic and financial benefits of investing in solar PV technology in similar areas to that of QASP, India.

Once the solar panel has completed their end life the following materials come in picture by using thermal, mechanical, or chemical technique, or by removing the panels as shown in Table 1 (Domínguez and Geyer, 2017). Tables 2 and 3 indicates the technical specifications of solar modules and inverters used in an 850-kW installed solar power plant.

Parameter	Rating
Solar Cell	Polycrystalline silicon 156 x 156 mm (6 inches)
Number of Cells	72
Dimensions	1956 x 992 x 40 mm (77.0 x 39.1 x 1.6 inches)
Weight	25.8 kg
Front Glass	4 mm (0.16 inches) tempered glass
Frame	Anodised aluminium alloy
Junction Box	IP67 rated (3 bypass diodes)
Connectors	MC4 compatible
Back Sheet	High resistant polyester
Encapsulating Material	Ethylene Vinyl Acetate (EVA)

Table 2. Technical Data of 320-Watt Anchor Panasonic Solar Panel (Panasonic, 2017).

Parameter	Rating
Absolute maximum DC input voltage (Vmax)	1000 V
Start – up DC I/P voltage (Vstart)	300-500 V (Default 360)
Rated DC I/P voltage V_{dcr}	715 Rated DC input V_{dc}
Rated DC I/P power P_{dcr}	51250 W
Number of independent MPPT	1
MPPT input DC voltage range	520-800 V_{dc}
Max DC I/P current (I_{dcmax})	100 A
Max I/P short circuit current	144 A
Number of DC input strings / pairs	12 or 16 string combiner version available
AC Grid connection type	3-Phase, 440 V
Rated AC power	50000 W
Max AC output power	50000 W
AC voltage range	422-528 V
Max AC output current (I ac max)	61 A
Rated o/p frequency (f_r)	50 Hz

Table 3. Technical Data of the Inverter (Solar Inverter, 2011).

3. Results

In this article we have experimentally investigate the cost benefit analysis of 850 kW solar power plant as situated in Manipal University Jaipur. Here we monthly note down the onside energy generation and their unit reading. Present experimental analysis has done under standard test conditions (STC), including 1000 W/m^2 of solar irradiation and a temperature of 25°C.

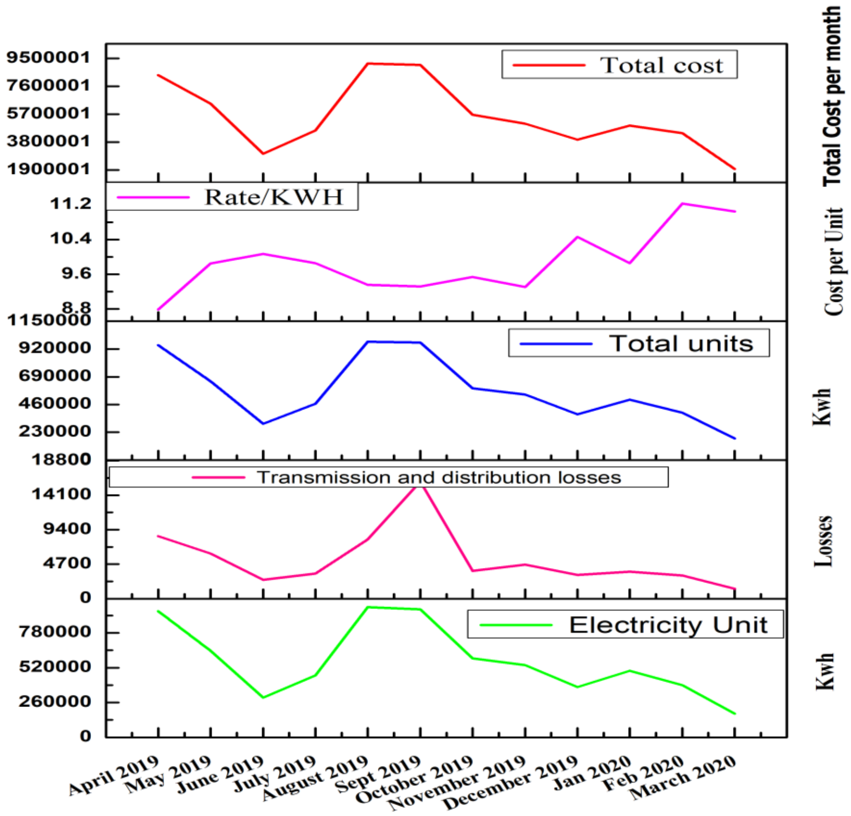

Figure 2. Annual Electricity Consumption and their Costing

All the solar side generated data has been taken and summed up. Figure-1. Indicates the schematic layout of 850 kW installed solar Power Plant in MUJ Jaipur hostel block.

Figure 2 gives the in-depth details of monthly energy consumption, transmission and distribution losses included in the total unit calculation; the losses considered from JVNL transformer to MUJ power distribution board. Figure 3 shows the energy consumption without outlets. The outlets energy consumption will be borne by private vendors.

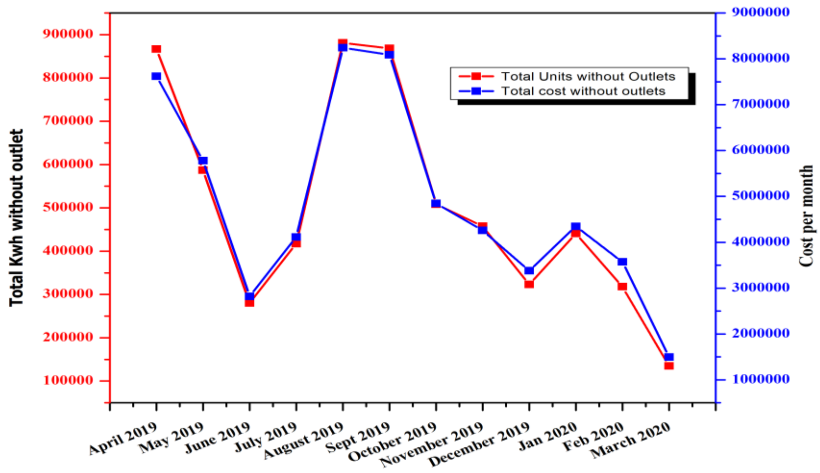

Figure 3. Total Electricity unit consumption without outlet

Figure 4 shows the electricity unit generation by solar plant and their costing for energy consumption calculation compensation of conventional energy and the solar power generation cost considered per unit is INR. 5. Figure 5 shows the total energy consumption patterns, the energy consumption from Electricity Board (EB) and solar with outlets and without outlets and their costing shown clearly.

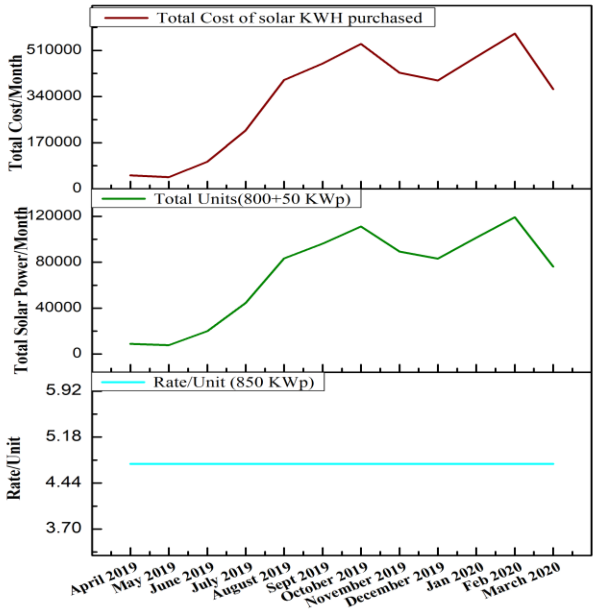

Figure 4. Electricity Unit generation by solar plant and their costing

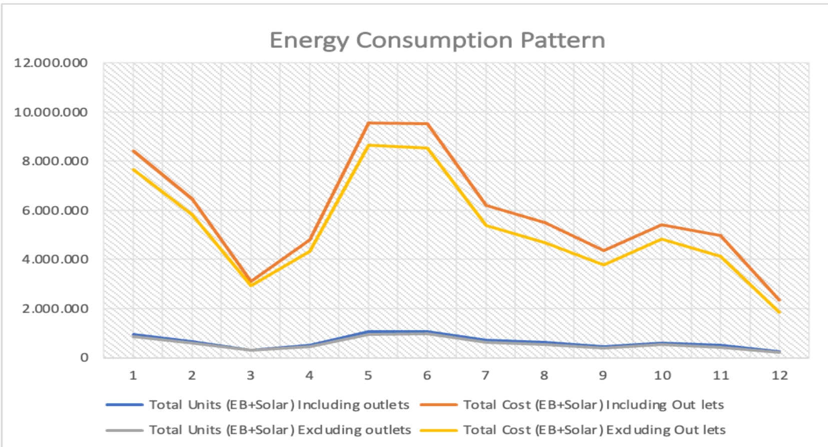

Figure-5. Energy consumption pattern

4. Discussion

The yearly electricity bill paid by MUJ to Jaipur Vidyut Vitaran Nigam ltd (JVNL) for the hostel block is about 6.909.850 INR. The installation cost was around 34.000.000 INR. The annual unit generated by the installed solar power plant is 840.663 and the yearly saving (April 19 to March 20) from this plant is 40,57780 INR. The energy recovery period at the plant is approximately seven years. After the energy recovery period, the plant will continue to produce electrical energy for the next 18 years. The cost benefits that occur during this period from the plant are around 85.192.776 INR. This economic advantage indicates the savings in electricity costs per solar plant in terms of clean energy and limited conventional energy reservoir savings.

From April 19 to March 20, the total unit generation by 850 kW solar power plant in the MUJ hostel campus is 840.663 and the per-unit cost is 5,63 INR.

Total saving from plant (April 19 to March 20) = 840.663 x 5,63 = 4.732.932,69 INR

Energy payback time = Total cost of solar power plant/yearly unit cost generation by the solar plant = 34.000.000/4.732.932,69= 7,18 yr

Assumed life cycle of plant = 25 year

After seven-year for the next 18 years, electricity generated by solar plants is almost free.

Total saving and free electricity produced by solar plant = 18 x 4.732.932,6 = 85.192.776 INR.

PV has expedited its growth in the power generating business as alternative energy to meet existing conventional energy constraints like fossil fuel extinction, environmental issues like the greenhouse effect, and growing electricity costs. PV electricity generation changes throughout the year as a result of solar irradiation. The test site is selected in Jaipur, India, at the 26.8^0 latitude and 75.56^0 longitude with a surface area of 122 acres. The monthly electricity bill paid by MUJ to JVNL for the hostel block is approximately 6.909.850 INR, and an 850-kW solar power plant has been installed on the MUJ campus to reduce this vast electricity expense. The MUJ PV facility has an investment cost of 34.000.000 INR. The installed solar power plant generates 840.663 units per year and saves 4.057.780 INR per year (from April 19 to March 20). As a result, with a total implementation cost of 34.000.000 INR, a 7-year payback period may be calculated.

5. Conclusion

In order to address current conventional energy constraints, such as the depletion of fossil fuels, environmental problems like the greenhouse effect, and rising electricity bills, PV has intensified its growth as an alternative energy source in the power-generating industry. The amount of solar radiation that enters the system varies throughout the year, which affects how much power is produced by solar PV. In an effort to lower this high cost of electricity, an 850-kW solar power plant has been installed on the MUJ campus, which covers 122 acres of land area and is situated at 26.8^0 longitude and 75.56^0 latitude. The investment cost for the MUJ PV facility is 34.000.000 INR. The installed solar power plant produces around 840.663 units of electricity annually. For the power used by the hostel block, MUJ pays JVNL about 6.909.850 INR every month. The present study states that between April 2019 and March 2020, savings from solar plant generating totaled 4.057.780 INR. With a 25-year lifespan and an estimated 7-year energy payback period, the proposed solar power plant can expect to generate nearly free electricity for up to 18 years, resulting in massive savings of around 73.040.040 INR. In light of the rapid rate of global climate change, the economic and technical studies we have considered showed that the solar PV system benefits MUJ hoteliers, lowers environmental pollution, and strengthens India's green economy.

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Competing Interests

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