International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 01 | Jan 2025 www.irjet.net p-ISSN: 2395-0072

"Performance Analysis of 400 kW Roof Top Solar Photovoltaic (RTSPV) System Installed at JNNCE, Shimoga, Karnataka - A Case Study"

N G Ajjanna[1], Anandini K[2], Mahalakshmi G[3], Vedashree G[4], Vishaka U[5]

[1]Asst Professor, Dept. of E&E, JNNCE, Shimoga, Karnataka.
[2,3,4,5] E&E Department final year Students of JNNCE, Shimoga, Karnataka.

Abstract:

Demand for electricity and energy bills is continuously increasing every year due to the rise in connected loads at the campus and the increase in energy cost per unit from the supply company. This paper presents a comprehensive performance analysis of a 400 kW Rooftop Solar Photovoltaic (RTSPV) system installed at JNNCE Shimoga, Karnataka. The study evaluates energy generation, system efficiency, and economic viability over a defined operational period. To meet the electricity needs of the JNNCE campus, reduce carbon emissions, and provide a practical learning facility for students in solar photovoltaic system a 400kW capacity roof-top solar PV system (RTPSV) has been installed. The study yields the result that the installation of a 400 kW Roof Top Solar Photo Voltaic system produces 4,68,370 units of electrical energy per annum. JNNCE consumed 5,59,795 units per annum. The solar power plant produces 83.66% of the electrical energy required by JNNCE. To meet 100% electricity from solar power plant 64 kW solar plant is to be added, which produces revenue of Rs 7,77,100 per year, Rs 31,74,000 investment required to install additional plant. The payback period for the additional plant will be 4 years 1 months. additional plant generates a savings of Rs 1,63,19,325 in its life time. Performance of the solar PV system before and after cleaning the panel is also determined, 0.4% of efficiency of the solar plant increases due to the cleaning of solar panel twice in a month.

Key words: Solar PV System, CO2 Emission, Payback Period, Performance Ratio.

Introduction:

The increasing demand for renewable energy sources, coupled with the growing concerns over environmental sustainability, has led to significant advancements in solar energy technologies. Among these, rooftop solar photovoltaic (RTSPV) systems have gained substantial popularity due to their ability to harness solar power directly from buildings, offering a decentralized, clean, and cost-effective energy solution [1]. In India, where solar energy potential is abundant, the installation of large-scale RTSPV systems has become a key strategy to reduce dependency on conventional fossil fuels, lower greenhouse gas emissions, and address the country's rising electricity demand [2]. This study focuses on the performance analysis of a 400 kW RTSPV system installed at the Jawaharlal Nehru National College of Engineering (JNNCE), located in Shimoga, Karnataka. The system, operational since its installation, provides clean energy to the college campus, reducing its carbon footprint and contributing to sustainable energy use. The performance of the system is evaluated by analyzing key parameters such as energy generation, efficiency, capacity utilization, and the overall economic benefits accrued from the integration of the solar system into the college's power grid [5]. The primary objective of this analysis is to assess the operational efficiency and reliability of the RTSPV system over time, with particular emphasis on understanding its energy production patterns, system losses, and impact on electricity consumption. Additionally, the study aims to identify any challenges faced during operation, such as performance degradation or maintenance issues, and offer recommendations for optimizing the system's performance in future installations. The findings of this analysis can serve as valuable insights for academic institutions, government bodies, and industries looking to adopt similar solar energy solutions to meet their power needs while promoting environmental sustainability [11].

Methodology:

The case study of 400 kW rooftop solar photovoltaic system involves data Collection, data analysis, performance analysis and performance evaluation by experimental method. The hardware components installed are examined onsite and following data is collected:

1. Before cleaning solar panel on 09-11-2024: Radiation in W/m2 using solar power meter, Inverter Power in watts from inverter at EE-1.

2. After cleaning solar panel on 27-11-2024: Radiation in W/m2 using solar power meter, Inverter Power in watts from inverter at EE-1.

From the obtained data the performance analysis of solar PV system installed at EE-1 block, JNNCE, Shimoga before cleaning and after cleaning the dust on solar panels is examined and compared. The power estimated from solar radiation at EE-1, Conversion Efficiency, and Energy in kWh is evaluated and compared by means of following graphs-

Radiation in W/m2 v/s Time in hrs., Inverter power in watts at EE1 v/s Time in hrs., Conversion Efficiency v/s Time in hrs., Energy in kWh v/s Time in hrs.

The electrical energy generation, consumption, export, import and shortage or excess of electrical energy from plant to grid is calculated and compared using 2022-2023 and 2023-2024 solar power generation in units from January to April data. Using the total energy consumption and generation data the graph of solar generation v/s months, total energy consumption in college v/s Months and generation and consumption. The efficiency of inverter and overall efficiency of the plant is calculated.

Block diagram of solar PV system:

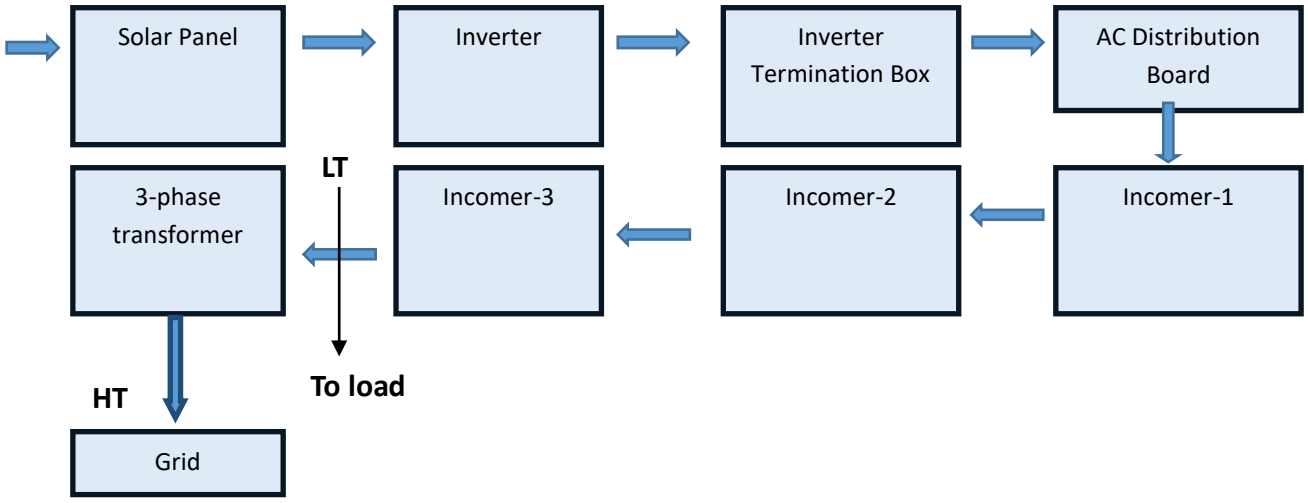

Figure 1: Block diagram of 400kW Roof-Top Solar Photovoltaic System installed at JNNCE

Solar panels, made up of photovoltaic (PV) cells, are the primary component that captures sunlight and converts it into direct current (DC) electricity through the photovoltaic effect. This direct current is fed to the inverters are essential for converting the DC electricity generated by the solar panels into alternating current (AC) electricity, which is suitable for use by the electrical grid or for local consumption. The termination box consolidates the AC output from each inverter and ensures they are properly routed to a common system bus or further electrical infrastructure, ensuring an organized and efficient distribution of power. The **AC Distribution Board:** (ACDB) is a key component in an AC system for distributing the output of the **inverters** to various loads, protective devices, or the grid. The ACDB is connected to the output of the **inverters** and typically includes circuit breakers, isolators, and other protection devices. It organizes and controls the flow of electrical power in the system. The ACDB consolidates the AC output from the solar inverters and distributes it to various parts of the electrical system, such as the local loads (e.g., lighting, appliances, HVAC systems, etc.) within the building or facility. If the system is grid-connected, the ACDB also facilitates the export of excess energy to the grid via the incomer. In a **400kW rooftop solar photovoltaic (PV) system**, the **Incomer** typically refers to the point where the generated AC power either connects to the **low-voltage (LT) side** of a **three-phase transformer** or interfaces with the grid or a load system. The **HT (High Tension) side of the three-phase transformer** is responsible for managing the voltage levels of the electrical power generated by the system, specifically when the system is **grid-connected.** The **HT side** of the transformer is designed to handle **higher voltage levels** and is typically connected to the utility grid. The transformer is used to either step up the voltage generated by the solar system (from the low-voltage side, which is the output of the solar inverters) to a level suitable for the grid, or in some systems, it could also be part of the reverse process (if stepping down for a localized need).

Single line diagram of 400kW RTSPV system installed at JNNCE,

Shimoga:

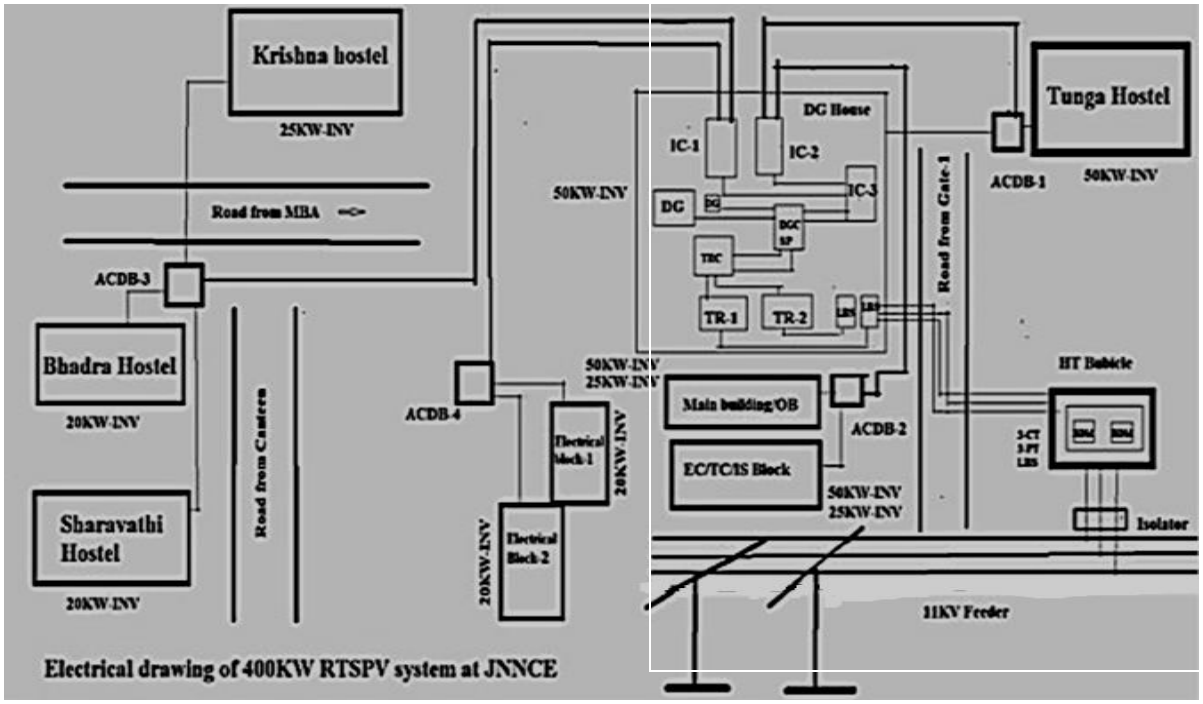

Figure 2 displays the single-line diagram of the 400kW RTSPV system consisting of 11 inverters of capacity 20/25/50kW,1230 solar panels of capacity 325Wp,4 units of ACDB to combine AC power produced at different buildings,9 numbers of inverter termination board (ITB) and 3 number

of incomers installed at JNNCE, Shimoga. 400kW of solar power plant terminated a single point at incomer 3. Single line diagram shows the components installed to produce electrical energy from solar plant. 90% of the Electrical energy required by JNNCE is met by the 400kW RTSPV system installed at JNNCE, excess or shortage of power is exported or imported by the electrical power grid. During a grid failure, the solar power plant will go off mode. Diesel power plants will generate energy. Two number of 3phase transformers of 250KVA are installed in the campus to handle 475KVA capacity of JNNCE connected load. The solar power plant is connected to the LT side of a 250KVA, 50hz,11/0.432 KV 3phase transformer, MESCOM supply is connected to the HT side of the transformer. The diesel power plant is also connected to the LT side of the transformer. Solar power generation is directly supplied to the load through the LT side of the transformer. A total of 400kW of RTSPV system is connected in the JNNCE Campus produces 5,20,000 units of energy per annum, generating a revenue of 50,0000

Performance analysis:

Table 1: Performance analysis of solar PV system installed at EE block JNNCE, Shimoga (Before cleaning the panel Date: 9/11/2024):

Time in hours	Radiation in W/m2	Inverter output Power in watts at EE-1(20 kW)	Power estimated from Solar radiation at EE-1	Conversion Efficiency	Energy generated in kWh
6	0.01	0	1.2	0	0
7	30.6	879	3672	24	0.2
8	187	3847	22440	17.14	2.4
9	187.6	7847	22512	34.86	8.7
10	197	9645	23640	40.8	18
11	199	14742	23880	61.73	28.5

12	195.2	14907	23424	63.64	41.6
13	182.6	2798	21912	12.77	50.4
14	176	4654	21120	22.03	60.8
15	110.1	7218	13212	54.63	69.6
16	95.3	5054	11436	44.19	76.2
17	57.4	996	6888	14.46	79
18	0.2	0	24	0	79.3
Average	124 W/m2	5584 W	14935W	30%	

Using solari power meter, the amount of solar radiation that reaches a surface is measured with respect in w/m^2 v/s time in hours. Radiation is maximum during 8AM TO 2PM. Table 1 shows inverter power in watts at EE-1 v/s Time in hrs. en though the radiation is maximum between 9 am to 2 pm, inverter power reading is reduced during 1pm to 2pm due to grid failure, hence conversion efficiency also gets reduced during 1pm to 2pm due to grid failure. Once the grid fails RTSPV goes to off mode.

Table 2: Performance analysis of solar PV system installed at EE-1 block JNNCE, Shimoga (After cleaning the panel Date: 27/11/2024):

Time in hours	Radiation in W/m2	Inverter Power in watts at EE-1(20kV)	power estimated from solar radiation at EE-1	conversion efficiency	Energy in kWh
6	0.02	0	2.4	0.00	0
7	35.2	503	4224	11.91	0.1
8	73.4	2994	8808	33.99	1.8
9	150.4	6333	18048	35.09	5.7
10	162.8	12563	19536	64.31	14.9
11	182	14164	21840	64.85	26.5
12	194.7	5868	23364	25.12	35.9
13	184	7832	22080	35.47	44.3
14	181.9	11274	21828	51.65	56
15	133.1	5175	15972	32.40	63.8
16	102.9	3208	12348	25.98	69.6
17	45.9	774	5508	14.05	71.1
18	0.1	0	12	0.00	72
Average	111.26W/m2	5437.53W	13,351.57W	30.4%	

Conversion efficiency is maximum during 10am to 12am, but due to grid failure the conversion efficiency is reduced in some hours even though the radiation is maximum. Here the table 2 is plotted between Energy in kWh v/s Time in hrs.

This graph shows that the generation is increasing for each hour from 6am to 6pm By considering Conversion efficiency of solar panel before and after cleaning, after cleaning the solar panel conversion efficiency is maximum compared to before cleaning the panel. This tells that accumulation of dust on the panel reduces the conversion efficiency..

4.2. Economic analysis:

Table 4: Generation and Consumption of electrical energy at JNNCE:

Months	2022-23Solar power Generation in units	2023-24Solar power Generation in units	2022-23 Total energy consumption in the college	2023-24 Total energy consumption in the college
Apr	46,680	57,360	50,580	56,110
May	49,920	53,400	58,995	56,400
Jun	38,280	34,560	55,955	50,810
Jul	28,920	31,440	55,795	48,190
Aug	32,280	44,640	47,305	51,015
Sep	40,920	32,400	45,470	46,150
Oct	44,460	42,120	42,160	49,220
Nov	41,880	36,480	46,955	46,930
Dec	41,280	47,600	51,305	56,425
Jan	52,680	45,240	48,180	57,415
Feb	49,800	44,400	44,850	53,375
Total	467,100	469,640	547,550	572,040

4.14 Solar generation v/s months

Here the chart 1 is plotted between 2022-23 & 2023-24 solar generation v/s months this shows the comparison of solar generation in each month of different year. Total energy consumption in college v/s months Variation in consumption of energy in college for each month details can be obtained from the above graph.

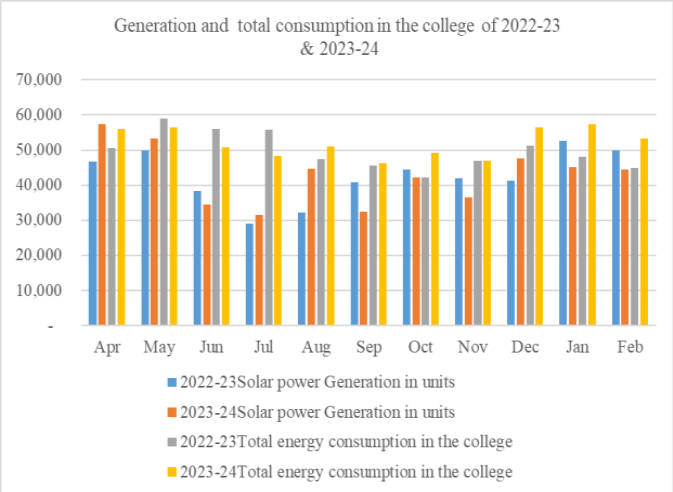

Chart 1: solar generation and consumption of energy in college for each month of 2022-23 & 2023-24.

Chart 1 shows the comparison of solar generation and consumption of energy in college for each month of 2022-23 & 2023-24

Economic analysis:

To calculate the energy shortage in the plant: Energy shortage = Energy consumed - Energy generated

= 5,59,795 kWh- 4,68,370 kWh

= 91,425 units per annum

So, the shortage of energy in the plant is 91,425kWh per annum.

To meet 100% of the energy requirement (i.e., to generate the same amount of energy as is consumed)
Energy shortage at JNNCE campus per annum is 91,425 units
Per month = 91,425/12=7618.75 units/month Per day = 7618.75/30=253.95 units/day
Therefore, 1kW= 4units
For 253.95 units/day=253.95/4=63.48kW

Thus, the plant would need an additional 63.48 kW capacity to meet 100% of its energy consumption.

Cost of 1kW=50,000 Rs

Hence Investment for 63.48kW will be

63.48*50,000 = Rs 31,74,000

Additional plant produces 91,425 units per year produces a revenue of 91,425*8.5= Rs 7,77,112 per year.
Hence payback period= Investment /Savings
=31,74,000/7,77,112
= 4.1Years
The savings for college from the installation of 64 kW solar PV in one-year amount to Rs 7,77,112.
The life time savings by the installation of additional solar PV system at JNNCE campus for remaining 21 years' is = 7,77,112Rs*21Years
= 1,63,19,325 Rs
From additional plant institution reduces its Co2 emission by 2750 tons/annum.

Results and discussion:

Before cleaning the panel, the conversion efficiency is 30 %. After cleaning the panels, assuming an increase in generation due to improved panel performance, the efficiency will improve that is 30.37%. Hence there is difference of 0.37%.

Conclusion:

Performance analysis was conducted by taking solar radiation readings with a solarimeter and inverter for the EE-1 building before and after cleaning the solar panel. Post-cleaning, energy generation increased due to the removal of dust, which had previously reduced efficiency. Economic analysis considered the college's energy generation and consumption data from the past two years. A comparison of electricity bills revealed that the costs were higher before the installation of the RTPSV (Roof top solar PV) system and decreased after installation. The study yields the result that the installation of a 400kW RTSPV system produces 4,68,370 units of electrical energy per annum. JNNCE consumed 5,59,795 units per annum. The solar power plant produces 83.66% of the electrical energy required by JNNCE. The installation cost was received within 4.6 years. The RTPSV system has reduced power consumption from the grid, lowered coal usage and CO2 emissions, decreased power losses, and improved air quality, making it an eco-friendly option. In order to meet 100% power from solar plant additional 64 kW capacity of RTSPV system is to be added. Payback period for the additional plant is 4.1 year. Generates a savings of Rs 1,63,19,325 in its life time.

Scope for future development:

Performance analysis is done for only one building out of 11 buildings in the college the work can be extended by considering performance of all the buildings in the campus. Only accumulation of dust is considered for performance analysis other parameters such as shadow, declination angle and facing of solar panel are also to be considered for performance analysis.

Reference:

[1] Solar energy technology and its roles in sustainable development, Clean Energy, Volume 6, Issue 3, June 2022, Pages 476-483

[2] Smith, J. (2020). Solar Power for Schools: Benefits, Challenges, and Implementation. Journal of enewable Energy Education, 15(2), 73-88

[3] Assouline et al., 2017 D. Assouline, N. Mohajeri, J.L. cartezzini Quantifying rooftop photovoltaic solar energy potential: a machine learning approach Sol. Energy, 141 (2017), pp. 278-296.

[4] Abdul-Azeez and Ho, 2015 I.A. Abdul-Azeez, C.S. HoRealising low carbon emission in the university campus towards energy sustainability Open J. Energy Effic., 04 (2015), pp. 15-27

[5] S.S. Abd Wahid, Z. Nawawi, M.I. Jambak, Y.Z. Arief, M.A.B. Sidik, M.W. Mustafa, Z.Adzis Evaluation of residential grid- Connected photovoltaic system as the potential energy source in Malaysia Telkomnika (Telecommunication Computing Electronics and Control), 14 (2016), pp. 1235-1241.

[6] Alfaraidy and Sulieman, 2019 F.A. Alfaraidy, H.A. Sulieman. The Economics of Using Solar Energy: School Buildings in Saudi Arabia as a Case Study The Scientific Journal of Koya University, 7 (2019), pp 6.

[7] Ajithgopi and Wai Keng, 2021 Ajithgopi, K.Sudhakar, N. Wai Keng Design and simulation of solar rooftop projects for an energy self-reliant university campus IOP Conference Series: Materials Science and Engineering, 1078 (2021), Article 012013.

[8] Anang et al., 2021 N. Anang, S.N.A. Syd Nur Azman, W.M.W. Muda, A.N. Dagang, M.Z. Daud Performance analysis of a grid- connected rooftop solar PV system in Kuala Terengganu Malaysia. Energy Build, 248 (2021), Article 111182.

[9] Bilir and Yildirim, 2017 L.Bilir, N.Yildirim Photovoltaic system assessment for a school building.

[10] Hanus et al., 2019 N.L. Hanus, G. Wong-Parodi, P.T. Vaishnav, N.R. Darghouth,I.L. Azevedo Solar PV as a mitigation strategy for the US education sector Environmental Research Letters, 14 (2019).

[11] Ajjanna, N. G., Suresh, H. B., Sreepathi, L. K. (2025). 'Analysis of Solar PV System and Solar Thermal Energy to Meet a Dairy Industry Energy Needs: A Case Study', *Iranica Journal of Energy & Environment*, 16(1), pp. 37-46. doi: 10.5829/ijee.2025.16.01.05.

BIOGRAPHIES:

N G Ajjanna Received a bachelor's degree in Electrical and Electronics Engineering from Kuvepu University in 1995, and a master's degree in Energy System engineering from Visvesvaraya Technological University in 2001. He is currently doing Research work in the field of Energy Management. Working as an Assistant Professor at the Department of Electrical and Electronics Engineering and coordinator of 400KW RTSPV system installed at JNNCE, Shimoga. His interesting areas include Energy Auditing, Energy conservation, DSM Techniques, and Renewable Energy Technologies. He has authored and published a Textbook on Energy Auditing and Demand Side Management.