Original Paper

PVsyst modeling of 800 kWp capacity grid-tied solar photovoltaic power plant for academic institution

Swati Sharma, Mahipal Bukya, Pancham Kumar

Received: 26 July 2023 | **Accepted:** 20 September 2023 | **Published:** 4 October 2023

1. **Introduction**
2. **Analysis and modeling of the solar plant using PVsyst**
3. **Results and Discussion**
4. **Conclusion**

Keywords: PVsyst; renewable energy; solar photovoltaic.

Abstract. *The design case study of solar photovoltaic system technology utilising PVsyst is presented in this research. The use of solar photovoltaic systems to produce electricity has increased recently in academic institutions. India is exceptional at producing electricity from both renewable and non-renewable sources. India receives 5,000T kWh of solar energy on average each year, and a major contribution to producing solar-based electricity comes from*

Rajasthan, Gujarat, Karnataka, Tamil Nadu, and Telangana-like states. The key objective of this work is to evaluate an 800 kWp grid-tied solar photovoltaic power plant using the PVsyst software platform for the Manipal University Jaipur campus. In our investigation, efforts have been made to mitigate the power losses that resulted from exposure to light, soiling from temperature changes, wiring, inverters, power electronics, interconnections, and grid availability. The PV modules, solar irradiation, and the photovoltaic system's location all affect how well it performs. According to the findings of our analysis, the average horizontal irradiation across the globe is 5.28 KWh/m2/day, and the PR of a PV plant is 86.25 %. The projected plant's annual output capacity was determined to be 1359796 kWh, which is entirely CO2-free, and it reduced an academic institution's annual power expenditure by Rs 11354296.6.

---

1. Introduction

The equatorial sunbed of the planet, which gets a lot of solar radiation, makes India one of the world's best placed nations for generating electricity from both renewable and non-renewable sources. There is an urgent need for alternative energy sources is driven by the quick depletion of fossil fuel supplies and the expanding facts of global warming. Since it may be utilised to satisfy the world's energy needs, renewable energy offers immense potential (Adaramola, 2014), Alsadi et al., 2018)). There are plenty of renewable energy resources in India's numerous states, including those in Karnataka, Rajasthan, Gujarat, and Telangana. The most popular approach is PV technology, which aims to improve the country's power supply's availability, cost, and dependability (Manisha Sheoran., et al. (2022). The negative effects of using outdated resources at a time when energy demand is increasing have fueled the growth of the solar PV sector. As a result, the Indian government (GOI) promoted the establishment of solar companies and enterprises at cheaper rates and has set an objective to install the 500 GW of renewable power by the end of 2030 (Press Information Bureau, 2017)) for power generation using solar PV Technology. It is now necessary to use renewable energy sources, such as solar, wind, biomass, and small hydropower, to address the issue as fossil fuel-based energy becomes more and more rare. However, the energy generated through the renewable sources is not always available under different environmental conditions (Shankar et al., 2022)). Therefore, the sporadic nature of solar PV technology is a challenging issue (Shankar, A et al., 2023)). Numerous power plants, including solar, wind, hydropower, biomass, geothermal, and many more, have been built for increasing amounts of power generation to maintain a balanced condition of energy generation and combat the depletion of fossil fuel resources. Figure 1 shows the current renewable energy generation in India during 2022-2023, the majority of which comes from solar power.

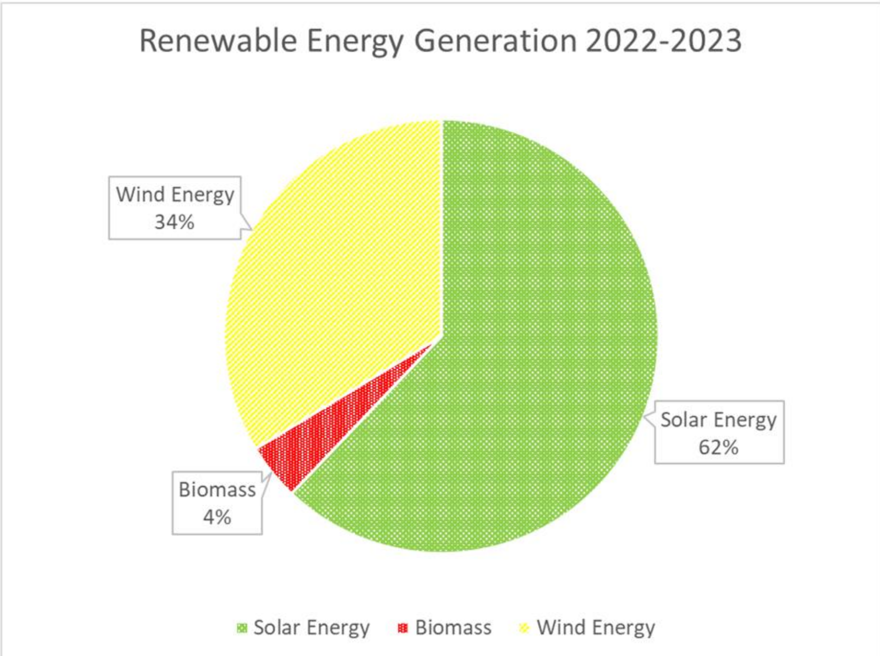

Figure 1. The renewable energy target for the duration 2022-2023 by Indian government

There is no doubt that solar energy has been proven to be one of the best renewable energy sources because solar energy stands out among renewable sources due to its reliability and accessibility. Unlike wind and hydro power, solar energy is consistent, as the sun reliably shines daily. Moreover, solar panels can be installed almost anywhere, from rooftops to remote areas, making it more versatile than geographically dependent sources like hydroelectricity. Solar power also trumps biomass and geothermal energy in terms of scalability and environmental impact, as it does not require large land areas or disturb ecosystems. The importance of solar energy can be determined by the solar constant which is a fundamental physical constant that represents the amount of solar electromagnetic radiation received at the outer atmosphere of Earth on a unit area perpendicular to the Sun's rays. It is approximately equal to 1361 Watts per square meter (W/m^2). This value remains relatively constant because the Solar energy output remains stable over time. The solar constant is a crucial parameter for understanding and calculating the amount of solar energy available at the earth surface. However, the actual amount of solar energy reaching the earth's surface varies throughout the day and across different locations due to factors such as atmospheric absorption, scattering, and earth tilt and orbit. Despite these variations, the solar constant provides a standardized reference point for scientists and engineers to estimate solar energy availability and design solar PV systems (Xiao et al., 2007). Additionally, the solar constant can be determined by the amount of solar radiation reaching Earth which ensures a vast, sustainable energy resource that can be harnessed globally, making solar energy a front-runner in the transition to a clean and sustainable energy future. In literature, to overcome the low efficiency and obtain desirable power in partial shading conditions, the maximum power point tracking system (MPPT) helps extract the maximum power from solar photovoltaic systems (Bollipo et al, 2021). All the conventional algorithms at standard temperature and irradiance provide better performance and reach maximum power. But in practice, the irradiance and the temperature keep changing. If the case persists for rapidly changing irradiance, all the conventional MPPT systems will fail to track the maximum power (Xiao et al, 2007). Based on the parameters and values of the requirements of the MPPT offline and online methods, the control signals are generated based on the solar PV system. The online approach provides instantaneous values for PV systems. In the literature, various MPPT techniques have been reported. The voltage-current-based MPPT approach, perturbation and observation-based MPPT approach, temperature and irradiance method, intelligent techniques, and fuzzy logic-based optimisation methods. Based on this, the maximum power generation through the online method creates an ambiguous variation in generating power in solar PV systems (Sher et al., 2015) as they are often observed due to multifaceted factors. These encompass daily and seasonal sunlight fluctuations, weather dynamics, shading effects, and equipment performance disparities. Literature suggests that inconsistent power output can result from complex interactions among these variables, making accurate predictions challenging. Additionally, differences in PV panel technologies, installation angles, and maintenance practices further contribute to variability. Researchers explore advanced forecasting models, smart grid integration, and improved system monitoring to mitigate these uncertainties. Understanding and addressing these multifarious influences is essential for enhancing the reliability and efficiency of solar PV systems. Thus, this paper attempts to concentrate on the modelling of an academic building's 800 kWp solar power plant for more power generation and better efficiency. The functioning blocks of the solar power plant are depicted in Figure 2 (Kumar et al, 2023, Garg et al., 2022).

The solar array for the planned 800 kWp plants is made up of a configuration of solar panels coupled in series and parallel. The Direct Current Distribution (DCDB) box is used to connect the array to a grid-tied inverter. The DCDB box performs protective measurements similar to those of surge protection and Miniature Circuit Breakers (MCBs). An inverter transforms the input from a DC solar array into an AC output that is compatible with the grid and synchronised with it. For further safety, the output of the inverter is linked to an Alternating Current Distribution (ACDB) box with built-in MCB and surge protection devices.

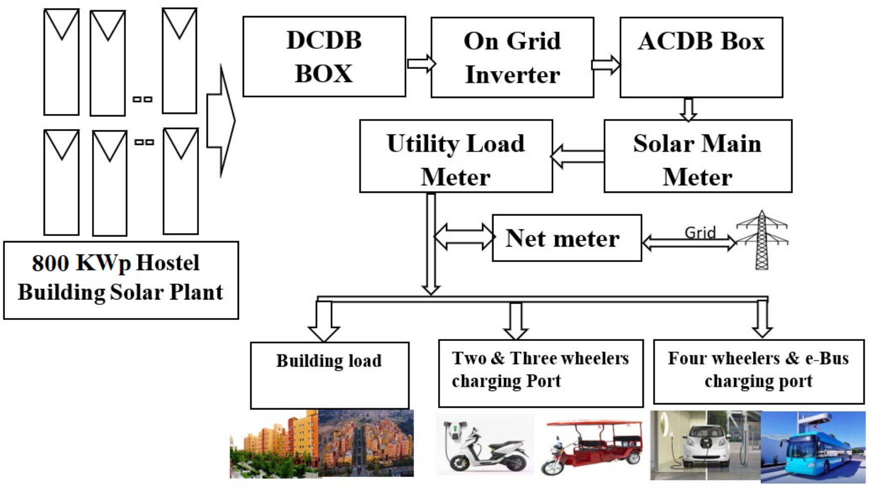

Figure 2. 800 KWp academic building solar power plant schematic diagram

Inverters have the capacity to take anti-islanding protective measures. The output of the ACDB is connected to the main solar meter, where we can track statistics on solar generation, and to the utility panel. Devices for solar net metering are used for energy import and export. In Figure 3, the actual plant images are shown, along with a single-line design of the plant and the interconnected arrangement of the solar array, inverters, and other components. Figure 3(a) illustrates the geographical positioning of the solar plant site; Figure 3(b) depicts the arrangement of the solar panels within the plant; Fig. 3(c) shows the inverters; Figure 3(d) presents the remote monitoring system utilized; and Figure 3(e) shows the ACDB and DCDB boxes. Several nations have constructed solar photovoltaic power plants far beyond the average level worldwide. India has huge solar-radiated energy-generating potential. It benefits from a lot of sun irradiation because of its advantageous location, which lasts virtually the entire year.

Figure 3. MUJ installed 800 kWp solar power plant photo

India's land mass is expected to absorb around 5000 trillion kWh of solar energy per year, with the majority of the nation receiving 4.7 kWh/m2/day of solar irradiance (Bukya et al., 2023)). Due to the fast cost reductions in PV modules throughout the world, PV (photovoltaic) systems are anticipated to become one of the primary sources of power in the future. A grid-connected PV-generating network's performance is analysed and measured primarily using the simulation system. PVsyst software is used in this study to measure and analyse the performance of the grid-connected PV system (Kumar et al., 2015), Manisha Sheoran et al., 2022).

2. Analysis and modeling of the solar plant using PVsyst

The performance of a grid-connected PV system with a capacity of 800 kWp was investigated using the PVsyst simulation platform. PVsyst V7.3.4 is a comprehensive software tool used for the design, analysis, and simulation of solar photovoltaic (PV) systems. It helps assess the energy production, financial feasibility, and performance of PV installations. PVsyst incorporates various factors like weather data, shading, system components, and site-specific information to optimize PV system designs and predict energy generation. It is a valuable tool for professionals in the solar industry, helping them make informed decisions and maximize the efficiency of solar projects. All the power losses that occur due to irradiation, soiling, temperature, wiring, inverters, power electronics, interconnections, and grid availability are considered. There are a total 2496 number of 799 Wp Trina Solar makes solar photovoltaic modules, and eight 80 kW, 3-ϕ, 400 V delta energy make inverters are used to construct an 800 kWp grid-connected solar photovoltaic system. The technical datasheets of solar photovoltaic modules and inverters are shown in Tables 1 and 2, respectively.

Technical datasheet of 799-Watt Trina solar panel along with the output of solar panel at standard test conditions and Input/Output diagram for energy injected into the grid as shown in Figure 4.

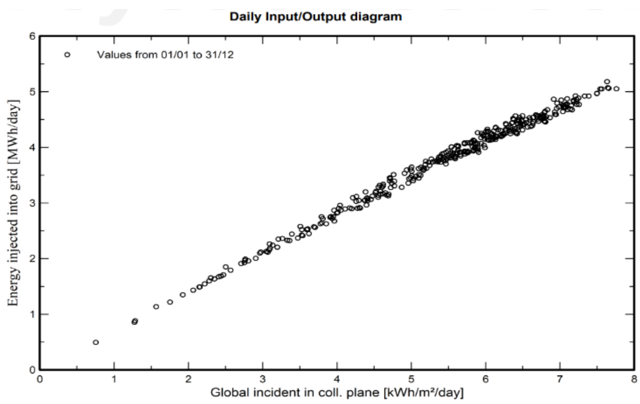

Figure 4. Input/Output diagram for energy injected into the grid

Model		TSM-DE 19-799 Wp Vertex	
Pnom STC Power (Manufacturer)	799 kWp	Technology	Si-mono
Module Size (Modules)	2496 Modules	Rough module area (Amodule)	4179 m^2
Number of cells		Sensitive area cells (A cells)	m^2
Specifications for the model (Manufacturer or measurement data)			
Reference temperature (Tref)	50 °C	Reference irradiance (Gref)	1936 kW/m^2
Open circuit voltage (Voc)	37.9 V	Short Circuit Current (Isc)	18.52 A
Max. power point voltage (Vmpp)	31.6 V	Max. power point current (Impp)	17.40 A
=> maximum power (Pmpp)	742 kWp	Isc temperature coefficient (mulsc)	7.4 mA/°C
One-diode model parameters			
Shunt Resistance (Rshunt)	200 Ω	Diode saturation current (IoRef)	0.040 nA
Series Resistance (Rseries)	0.12 Ω	Voc temp. coefficient (MuVoc)	-105 mV/°C
Specified Pmax temper. Coeff. (muPMaxR)	-0.34%/°C	Diode Quality Factor (Gamma)	1.00
		Diode factor temper. Coeff. (mu Gamma)	0.0001/°C
Reverse- Bias Parameters, for use in behavior of PV arrays under partial shadings or mismatch			
Reverse characteristics (dark) (BRev)	3.20 mA/V^2	(Quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V
Model results for standard conditions (STC: T=50°C, G=1936 kW/m², AM=1.25)			
Max. power point voltage (Vmpp)	31.3 V	Max. power point current (Impp)	1088 A
Maximum power (Pmpp)	742 kWp	Power temper. Coefficient (U mpp)	
Efficiency (/module area) (Eff_mod)	21.1%	Fill factor (FF)	0.784
Efficiency (/cell area) (Eff_cells)	22.7%		

Table 1. Technical datasheet of 799-Watt Trina solar panel (Trina solar (2020))

The inverter efficiency curve and system output power distribution is depicted in Figure 5. Figure 6 depicts the solar PV array configurations. All modules are set at a 0° azimuth with a 15° inclination facing south and are free of any shading influence.

Figure 5 shows that a total of 2496 solar panels are used to build 192 strings of 13 series modules. Eight 80kWp inverters with 16 MPPT units are employed, and their output is pumped into the grid.

Inverter – Solar Inverter M80H (480 VAC)			
Model	**Solar Inverter M80H (480 VAC)**		
Commercial Data		**Data Source**	
Protection:	IP65		
Control:	Display operational data	Width	615 mm
		Height	950 mm
		Depth	275 mm
		Weight	84.00 kg
Input characteristics (PV array side)			
Operating mode	MPPT	Nominal PV Power (Pnom DC)	80 kW
Minimum MPP Voltage (Vmin)	200 V	Maximum PV Power (Pmax DC)	89 kW
Maximum MPP voltage (Vmax)	800 V	Power Threshold (Pthresh)	396 W
Absolute max. PV Voltage (Vmax array)	1000 V		
Min. Volatge for PNom (Vmin@Pnom)	635 V		
"String" Inverter with input protections		**Multi MPPT Capability**	
Number of string inputs	18	Number of MPPT inputs	2
Behavior at Vmin/Vmax	Limitation		
Behaviour at Pnom	Limitation		
Output Characteristics (AC grid side)			
Grid Voltage (Imax)	Triphased 480 V	Nominal AC Power (Pnom AC)	80 kWac
Grid Frequency	50/60 Hz	Maximum AC Power (Pmax AC)	88 kWac
Maximum efficiency	98.8 %	Nominal AC current (Inom AC)	97 A
European average efficiency	98.4%	Maximum AC current (Imax AC)	106 A

Table 2. Technical datasheet of inverter

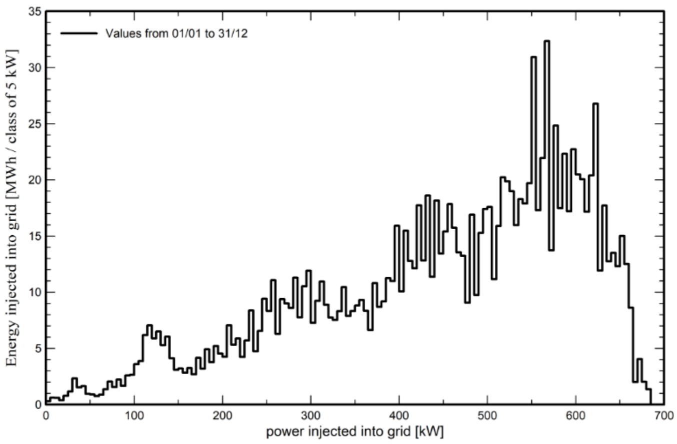

Figure 5. System Output Power Distribution

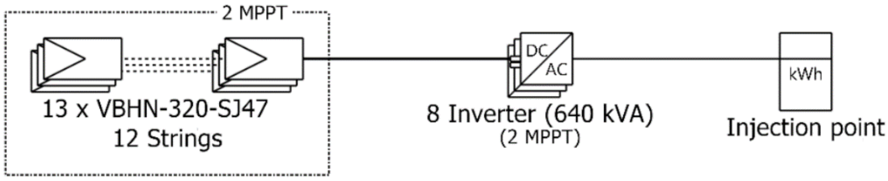

Figure 6. Solar PV Array Configurations

3. Results and Discussion

Maximum energy generation occurs in February, while minimal energy generation occurs in July, according to the PVsyst simulation. Figure 7 summarizes the entire performance evaluation and performance ratio of the 800 KW Solar PV Plant at the educational institution. Figure 8 depicts a power loss diagram for a solar PV plant with 800 kW of capacity owing to irradiance, soiling, temperature, wiring, inverter, power electronics, interconnections, and grid availability.

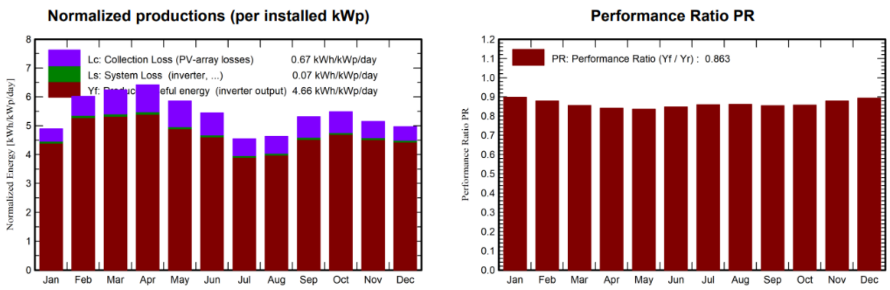

Figure 7. Performance Evaluation and Performance Ratio of the 800 KW Solar PV Plant.

Legends: E Array - Effective energy at the output of the array; E - Grid – Energy injected into grid; PR – Performance Ratio

Most electricity is added to the system in April, and the least in July. The average horizontal radiation was calculated to be 1793 kWh/m² worldwide. It was determined that there was a total of 1973.8 kWh/m² of incident energy on the collector plane. A performance ratio of 86.25% was recorded for the PV system.

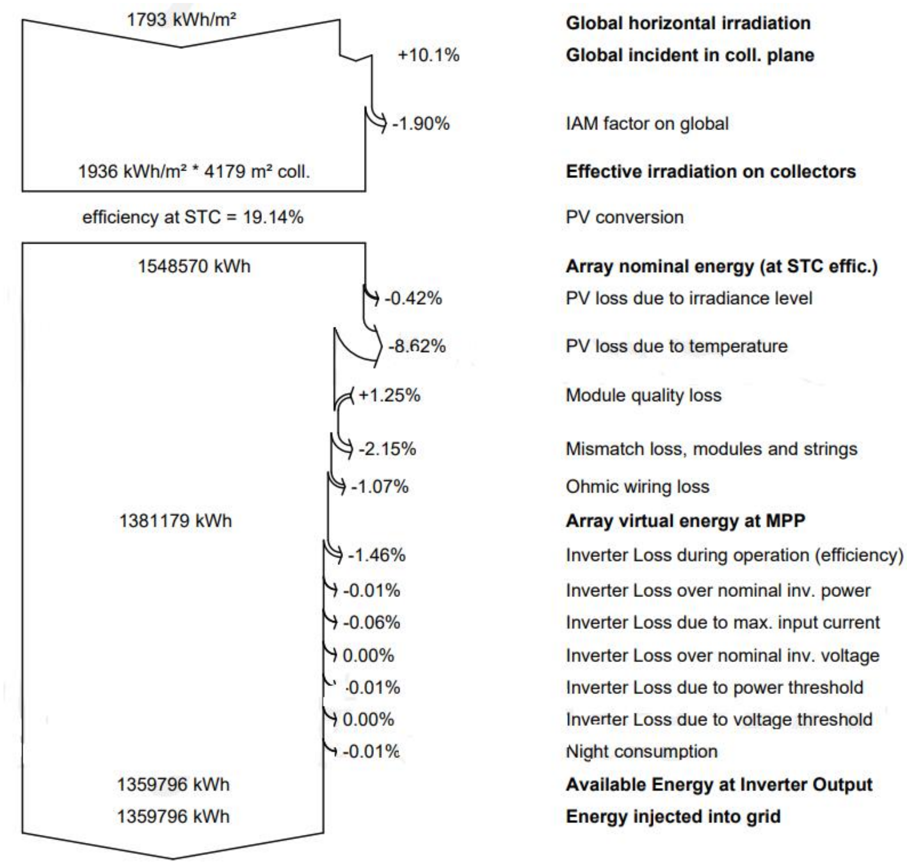

Figure 8. Loss diagram over the whole year

4. Conclusion

PVsyst software is used to design solar systems for educational organizations. The outcomes obtained by PVsyst provide valuable insights into the photovoltaic (PV) module. The performance ratio exhibits an increase as load demand decreases and the energy produced is proportional to that of the load. Additional analysis is conducted to evaluate the system's performance, revealing that it is deemed highly commendable and satisfactory when subjected to a load of around 800 kW. The grid-connected, roof-mounted 800 kWp solar PV system's performance was assessed, and monthly and yearly output characteristics were established. The PVsyst software tools were used to simulate the data. The present research's most significant findings are outlined. The grid receives the largest energy injection in March and the least in August. With a PR of 86.25%, the 800 kWp solar PV system is operating effectively. During the examination, it was found that the Solar PV array produced 1359796 kWh of CO_2-free solar energy in the fiscal year 2022. The reduction in its annual power bill of Rs11354297. Around Rs. 28,38,57,425 would be saved from the power cost during a 25-year period. This is clearly a significant contribution to generating electricity from renewable sources.

Acknowledgements

Thanks to Manipal University Jaipur, Project Team and Maintenance Engineers for their assistance for data collection and technical reports for reference.

References

Adaramola, M. S. (2014). Viability of grid-connected solar PV energy system in Jos, Nigeria. *International Journal of Electrical Power & Energy Systems*, 61, 64–69. https://doi.org/10.1016/j.ijepes.2014.03.015

Ahmadi, M.H., Ghazvini, M., Sadeghzadeh, M., Nazari, M.A., Kumar, R., Naeimi, A. & Ming, T. (2018), Solar power technology for electricity generation: A critical review, *Energy Sci. Eng.* 6, 5, 340-361. https://doi.org/10.1002/ese3.239

Alsadi, S., & Khatib, T (2018) Photovoltaic Power Systems Optimization Research Status: A Review of Criteria, Constrains, Models, Techniques, and Software Tools. *Appl. Sci.* 8, 1761. https://doi.org/10.3390/app8101761

Bollipo, R.B., Mikkili, S. & Bonthagorla, R.K. (2021). Hybrid optimal intelligent and classical PV MPPT techniques: A review, *CSEE J. Power Energy Syst.* 7, (1), 9-33. https://doi.org/10.17775/CSEEJPES.2019.02720

Bukya, M., Kumar, P. & Kumar, R. (2023). On-Grid Solar Photovoltaic Power Plant Analysis Under PVsyst Simulation Software Platform. In: Dwivedi, S., Singh, S., Tiwari, M., Shrivastava, A. (eds) Flexible Electronics for Electric Vehicles. *Lecture Notes in Electrical Engineering*, vol 863. Springer, Singapore. https://doi.org/10.1007/978-981-19-0588-9_41

Garg, P., Bukya, M. and Kumar, P. (2022). Cost Benefit Analysis of 50 kW Solar Power Plant for Educational Hostel Building, *2nd International Conference on Innovative Sustainable Computational Technologies (CISCT)*, Dehradun, India, 2022, pp. 1-5. https://doi.org/10.1109/CISCT55310.2022.10046533

Kumar, P., Bukya, M., Shankar, A., Garg, P. & Gowtham, N. (2023) An experimental approach towards cost benefit analysis of 850 kW solar PV plant. *Visions for Sustainability*, 19, 7213, 255-266. http://dx.doi.org/10.13135/2384-8677/7213

Kumar B. S. and K. Sudhakar (2015). Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India, *Energy Reports*, vol. 1, pp. 184–192, 2015. https://doi.org/10.1016/j.egyr.2015.10.001

Sheoran, M., Kumar, P., Sharma, S. & Bukya, M. (2022), Current situation analysis of solar PV waste management in India, *Materials Today: Proceedings*, 58 (2), 773-782. https://doi.org/10.1016/j.matpr.2022.03.118.

Press Information Bureau (2017), Ministry of New and Renewable Energy, Government of India. [Online URL: https://archive.pib.gov.in/archive2/erelease.aspx]

Sharma S, Kurian, C.P. & Paragond L.S. (2018). Solar PV System Design Using PVsyst: A Case Study of an Academic Institute, 2018 *International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT),* Kannur, India, 2018, pp. 123-128, https://doi.org/10.1109/ICCPCCT.2018.8574334.

Trina solar (2020) The vertex back sheet monocrystalline module trina solar, [Online URL: https://www.trinasolar.com/en-apac].

Shankar, A. and Bukya, M. (2022) Decentralization to decarbonize the Indian economy. *Visions for Sustainability*, 19, 7153, 223-239. http://dx.doi.org/10.13135/2384-8677/7153

Shankar, A., and Bukya, M. (2023) Demystifying the economic and energy potential of Building-Integrated Photovoltaics in achieving India's intended Nationally Determined Contribution. *Visions for Sustainability*, 19, 7291, 241-254. http://dx.doi.org/10.13135/2384-8677/7291

Sher, H.A., Murtaza, A.F., Noman, A., Addoweesh, K.E., Al-Haddad, K. & Chiaberge, M. (2015) A new sensorless hybrid MPPT algorithm based on fractional short-circuit current measurement and P&O MPPT, *IEEE Trans. Sustain. Energy*, 6 (4),. 1426-1434. https://doi.org/10.1109/TSTE.2015.2438781

Xiao, W., Dunford, W.G., Palmer, P.R. & Capel, A. (2007), Application of centered differentiation and steepest descent to maximum power point tracking, *IEEE Trans.*

Ind. Electron., vol. 54, no. 5, pp. 2539-2549, Oct. 2007. https://doi.org/10.1109/TIE.2007.899922

Authors

Swati Sharma
Department of Electrical Engineering, Jamia Millia Islamia New Delhi, India.

Mahipal Bukya *(corresponding author)*
Department of Electrical and Electronics Engineering, Manipal Institute of Technology Bengaluru, Manipal Academy of Higher Education, Manipal, India. mahipalbhukya@gmail.com

Pancham Kumar *(corresponding author)*
Faculty of Electrical Skills Education, Bhartiya Skill Development University Jaipur, India. pancham006@gmail.com

Funds

This study received no specific grant from any funding agency in the public, commercial, or no-profit sectors.

Competing Interests

The authors hereby state that there are no financial or non-financial competing interests.

Citation

Sharma, S., Bukya, M. & Kumar, P. (2023) PVsyst modeling of 800 kWp capacity grid-tied solar photovoltaic power plant for academic institution. *Visions for Sustainability*, 20, 7941, 175-188. http://dx.doi.org/10.13135/2384-8677/7941