A Project Report

on

To Design and Performance Analysis of a Grid Connected Roof Mounted Solar PV System by Using PV*SOL in Rural Area

in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY (B. TECH)

IN

ELECTRICAL ENGINEERING

Submitted by:

Tapan Bhargav (0901EE191125)

MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE

GWALIOR, M.P. - 474005

(*A Govt. Aided UGC Autonomous & NAAC Accredited Institute, Affiliated to RGPV Bhopal*)

April 2023

CANDIDATE'S DECLARATION

I/We hereby declare that the project titled To Design and Performance Analysis of a Grid Connected Roof Mounted Solar PV System by Using PV*SOL in Rural Area submitted for the award of **Bachelor of Technology** degree in **Electrical Engineering** is my original work and the project has not been submitted elsewhere for the award of any other degree, diploma, fellowship, or any other similar titles.

Tapan Bhargav (0901EE191125)

Place: Gwalior (M.P.)

Date: 15-05-2023

This is to certify that the above statement made by the candidate is correct to my knowledge and belief.

Guided By

Name of Institute Mentor
Dr. Yashwant Sawle
Dept. of EE
MITS, Gwalior

Approved By

Dr. Sulochana Wadhwani
Prof. & Head, EED
MITS, Gwalior

ACKNOWLEDGEMENT

I would like to express my sincere appreciation to my supervisor Dr. Yashwant Sawle for his guidance, encouragement, and support throughout the course of this work. It was an invaluable learning experience for me to be one of their students. From them I have gained not only extensive knowledge, but also a careful research attitude.

I am also thankful to **all the faculty of EED** for their cooperation with me in facilitating the infrastructure and lab facility during my work.

I am highly indebted to Dr R.K. Pandit, Director M.I.T.S., Gwalior (M.P.) for the facilities provided to accomplish this internship.

I would like to thank Dr S. Wadhwani, Head Department of Electrical Engineering, M.I.T.S., Gwalior (M.P.) for his constructive criticism throughout my internship.

I would like to thank Mr. Vikram Rajput, T&P Coordinator MITS, Gwalior & Internship Coordinators, Department of Electrical Engineering for their support and advice to get and complete internship in above said organization. I am extremely grateful to my department staff members and friends who helped me in successful completion of this internship.

Date: 15-05-2023 **Name of Student Tapan Bhargav**

Place: Gwalior **Enrollment No. 0901EE191125**

ATTACHED CERTIFICATE

ABSTRACT

This Report is presenting a Designing, Performance Analysis and assessment of a rooftop PV system connected to a grid for an Industry in rural area of Gwalior, Madhya Pradesh, India. Solar energy is a form of renewable energy so it can be easily transformed into electric energy. The estimation study shows a kw grid-connected Solar PV system and can Produced enough electric energy as compared to the power Consumption and diminish the energy consumption in the network and also bring down the dependency of grid. This paper consists of Design, functioning and This study also includes a financial research analysis of the PV system using the PV Simulation program PV*SOL premium and a financial analysis of such a system under specific conditions. Solar energy is currently the most attractive energy source in utility-scale power generation when looking at costs alone. The recent decade witnessed an urgency in transitioning to net zero and pivoting to renewables for attaining so. According to Our World in Data, the cost of utility-scale solar photovoltaic electricity came down by around 89% over the last decade. As 2023 starts, there is the potential for global solar power generation capacity to surpass 1 Terawatt, and huge multinational corporations are now undertaking numerous renewable projects. These firms frequently also proclaim astronomical development goals. In this mix of things, solar energy is positioned to take the lead in power generation as nations work to meet ambitious decarbonization goals.[1]. The basic drawback of solar photovoltaic system is its poorer efficiency because the panels depend so heavily on erratic weather conditions., i.e., the temperature and sun radiation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I: Case study

1.1 Introduction

Solar energy is currently the most attractive energy source in utility-scale power generation when looking at costs alone. The recent decade witnessed an urgency in transitioning to net zero and pivoting to renewables for attaining so. According to Our World in Data, the cost of utility-scale solar photovoltaic electricity came down by around 89% over the last decade. As 2023 starts, there is the potential for global solar power generation capacity to surpass 1 Terawatt, and huge multinational corporations are now undertaking numerous renewable projects. These firms frequently also proclaim astronomical development goals. In this mix of things, solar energy is positioned to take the lead in power generation as nations work to meet ambitious decarbonization goals.[1]. The basic drawback of solar photovoltaic system is its poorer efficiency because the panels depend so heavily on erratic weather conditions., i.e., the temperature and sun radiation. As a result, getting the most power possible from the panel is a little challenging, which lowers system efficiency. Different MPPT (Maximum Power Point Tracking) approaches are utilized to boost system efficiency and capture the most power possible from the panels [2][3]. The obtained panel voltage and current are dc quantities that must be transformed into ac quantities using inverters in order to power ac loads or connect to the grid. Grid-connected systems and Standalone systems are the two types of solar PV systems. In a grid-connected system, both the linked grid and the loads will receive power from the solar PV system. Different configurations of grid-connected solar PV inverters, such as central inverters, string inverters, and multi-string inverters, are possible. The biggest disadvantage of the central inverter setup, which is the simplest, is that the strings of the panel will function at various MPPs. when varied solar irradiation falls on the module The advantage of string inverters is that they can operate at a common MPP regardless of the irradiance value. The cost, required power, and project area are taken into consideration while choosing an inverter arrangement. The solar PV system will power the loads that are directly linked to it in the standalone system. Both systems are capable of feeding both ac and dc loads. Most often, standalone devices are recommended for use in domestic settings.[4]. When compared to other sources, photovoltaic systems may produce energy in a straightforward method. When compared to other systems, the number of separate components employed in solar PV systems is quite low. Additionally, it does not use any components of a considerable size. [5]. The most crucial factor to take into account throughout the design process is the photovoltaic solar system component's performance. There are a variety of photovoltaic system configurations depending on the voltage system and busbar used to link the source and loads. [6], [7]. Industrial solar panels are advantageous because they can be used for both on-grid and off-grid solar panel systems, making it possible for industries to employ solar panel power that can be used at night.

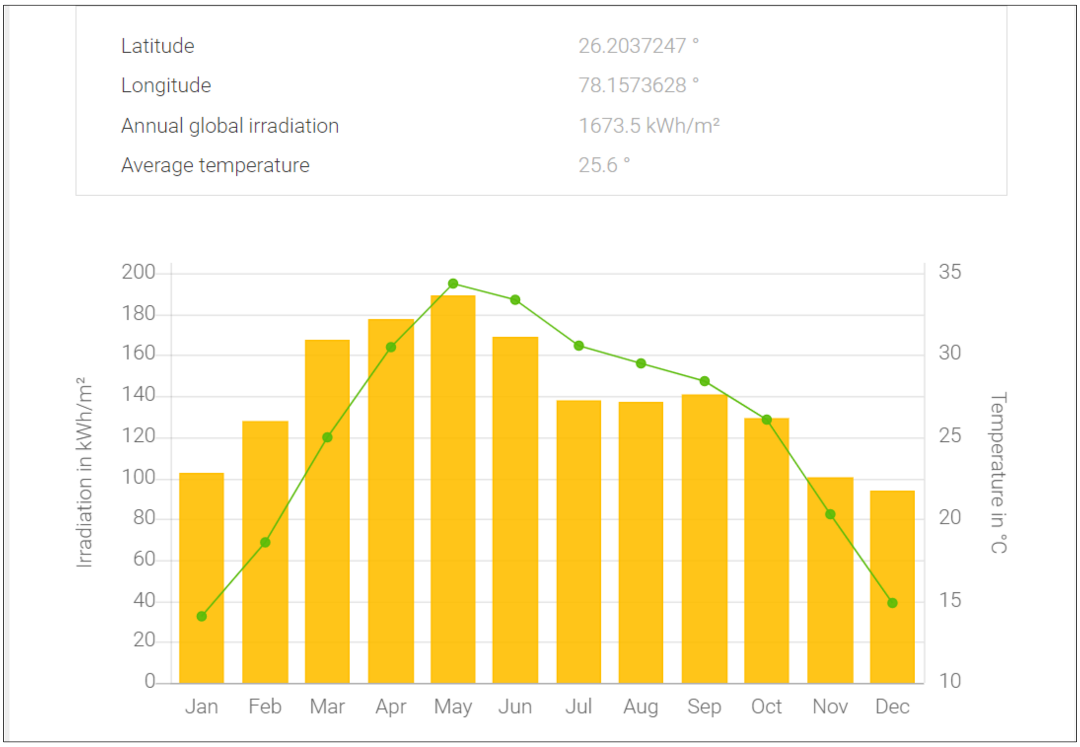


Fig.1. Annual Temperature Profile for Location

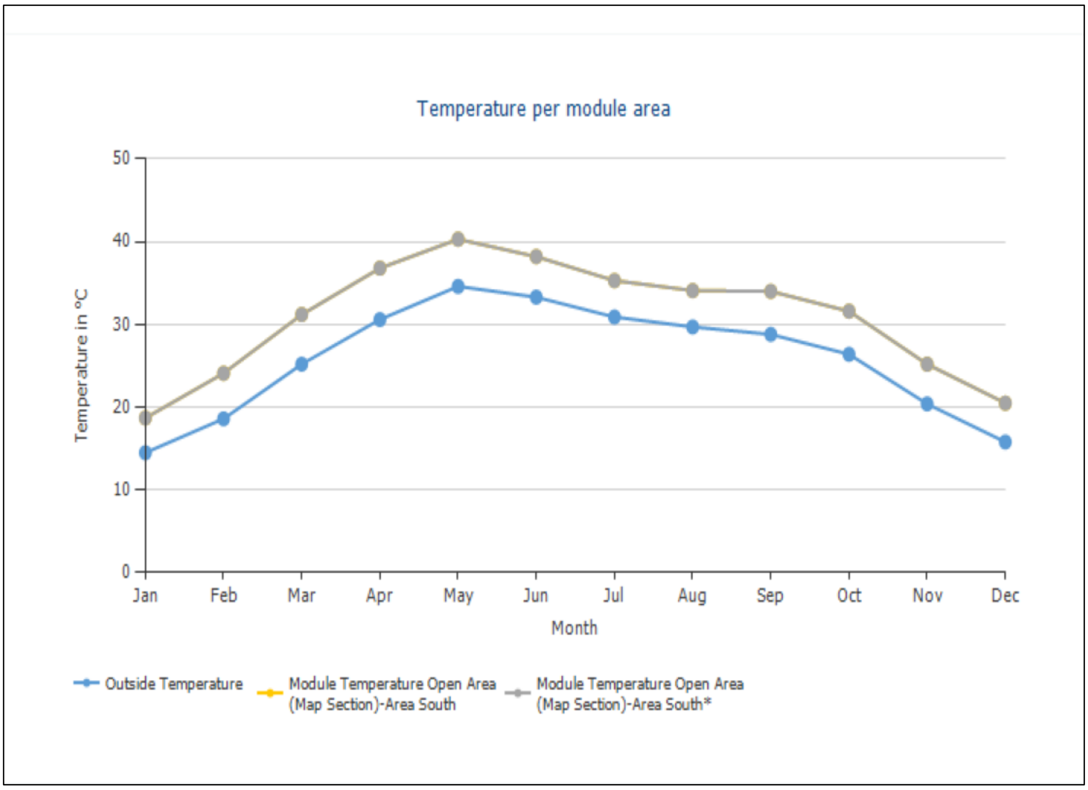


Fig. 2 Temperature Per Module Area

CHAPTER II: FEED IN DATA AND SPECIFICATIONS

The details regarding the monthly consumption of the building on which we have to setup our system is very crucial before designing a PV system. That is an Industry in Rural area of Gwalior Tehsil, Near Tighra Road, lashkar, Gwalior ,474001, Madhya Pradesh, India.

Months	**Consumptions**
January	22670
February	23529
march	29049
April	27838
May	38647
June	40828
July	35728
August	32837
September	32398
October	31344
November	28368
December	25836
Total	**369072**

Table 1. Monthly Energy Consumption

2.1 SYSTEM DESIGNING:

A large-capacity solar system had to be installed in order to meet the energy requirement given the consumption. To the right we are using a system designing tool called PV*SOL premium 2021 (R8).

PV*SOL premium 2021 (R8):

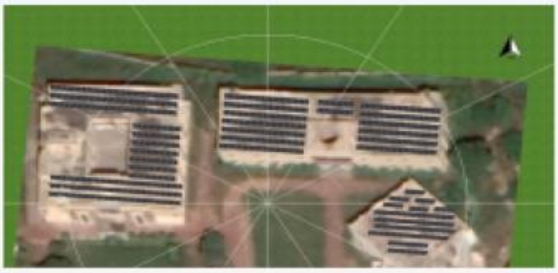
The best design tool is simulation software, which makes precise forecasts simple. By putting systems into perspective and producing expert reports, you can provide consumers the best return on their investment. The photovoltaic system performance simulation software for solar systems is known as PV*SOL® premium. For people who do not want to utilize 3D to model shading and see the landscape, it is a fully functional program. [10].

Configuration of the System:

By supplying various system parameters to our simulation tool as input. We learn that the system needs many components.

We need to build a solar photovoltaic system with a capacity of 241.2 kW for the specified energy usage. Additionally, this system needs 1342.66 m^2 of surface area for the installation of PV modules.

2.2 Data of project area and grid:



Project Data

Project Name	pv 20
Offer Number	20
Project Designer	Tapan
Start of Operation	20-01-2023

System Type, Climate and Grid

Type of System	3D, Grid-connected PV Syst...
Climate Data	GWALIOR (IN-AFB), IND
Time step of simulat...	1 min
AC Mains	230 V, 3-phase, cos φ = 1
Maximum Feed-in P...	No

Consumption

Total Consumption	369072 kWh
Load Peak	56.7 kW
Resolution of the data	1 h

3D Design	
Total Power	241.2 kWp
Module Area	Open Area (Map Section)-A...
Module Data	REC300TP2M
Manufacturer	REC Solar
Number of PV Modu...	525
PV Generator Output	157.5 kWp
Inclination	30°
Orientation	185°
Installation Type	Mounted - Open Space
Module Area	Open Area (Map Section)-A...
Module Data	REC300TP2M
Manufacturer	REC Solar
Number of PV Modu...	279
PV Generator Output	83.7 kWp
Inclination	30°
Orientation	185°
Installation Type	Mounted - Open Space
Configuration	
Total Power	222 kW
Sizing Factor	108.6 %

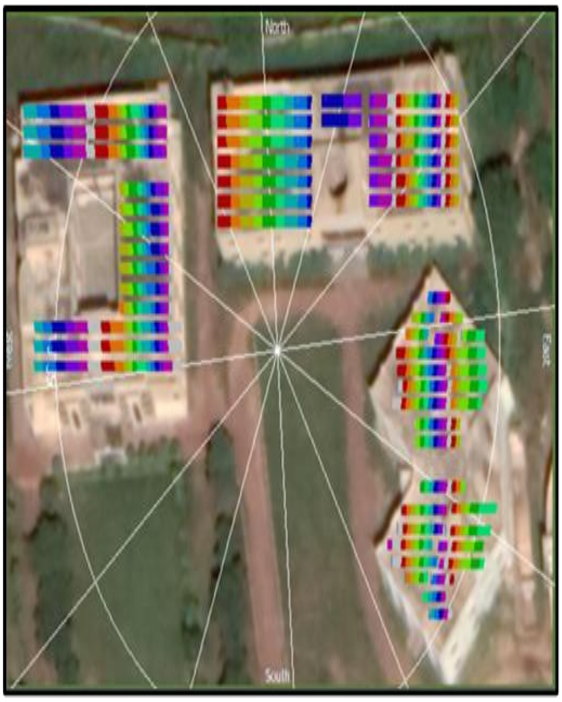


Fig. 3(A) System Planning with 3D visualization

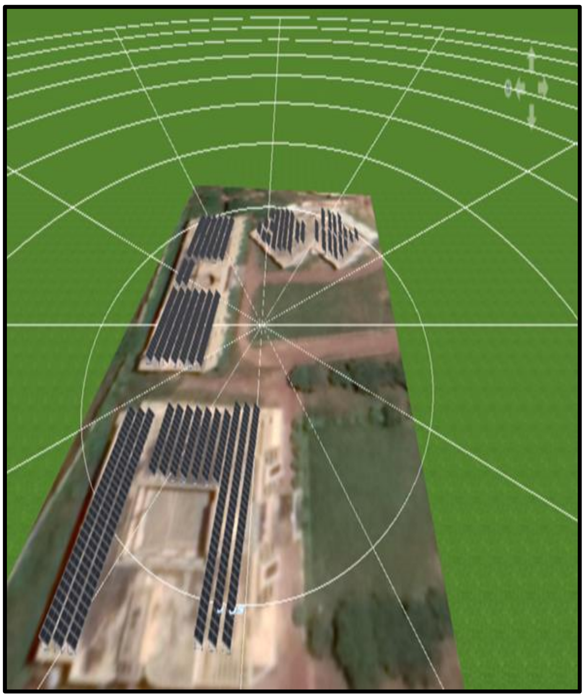


Fig. 3(B) System Planning with 3D visualization

There is total 804 modules which are mounted in two rooftop buildings one is having 525 module and there are 279 PV module in the other building of an Industry are positioned in solar to generate energy. There are 24 inverters connected in the necessary configuration to regulate and deliver this generated power.

CHAPTER III: Methodology

3.1 Circuit Designing

In this system, we have used modules of REC Solar which model number REC300TP2M having capacity of 300 W and the Inverters of Solinteg with model number MHT-10K-40 having capacity of 10KW and Samsung SDI. co. ltd. All in one series 8.

There is total 804 PV modules are positioned in a solar field to generate energy. There are 24 inverters connected in the necessary configuration to regulate and deliver this generated power.

In this a single line circuit schematic for the suggested setup. For setup the system, we have used modules of REC Solar which model number REC300TP2M and Inverters of Solinteg and Samsung SDI which model is MHT-10K-40 and All in One Series 8 respectively.

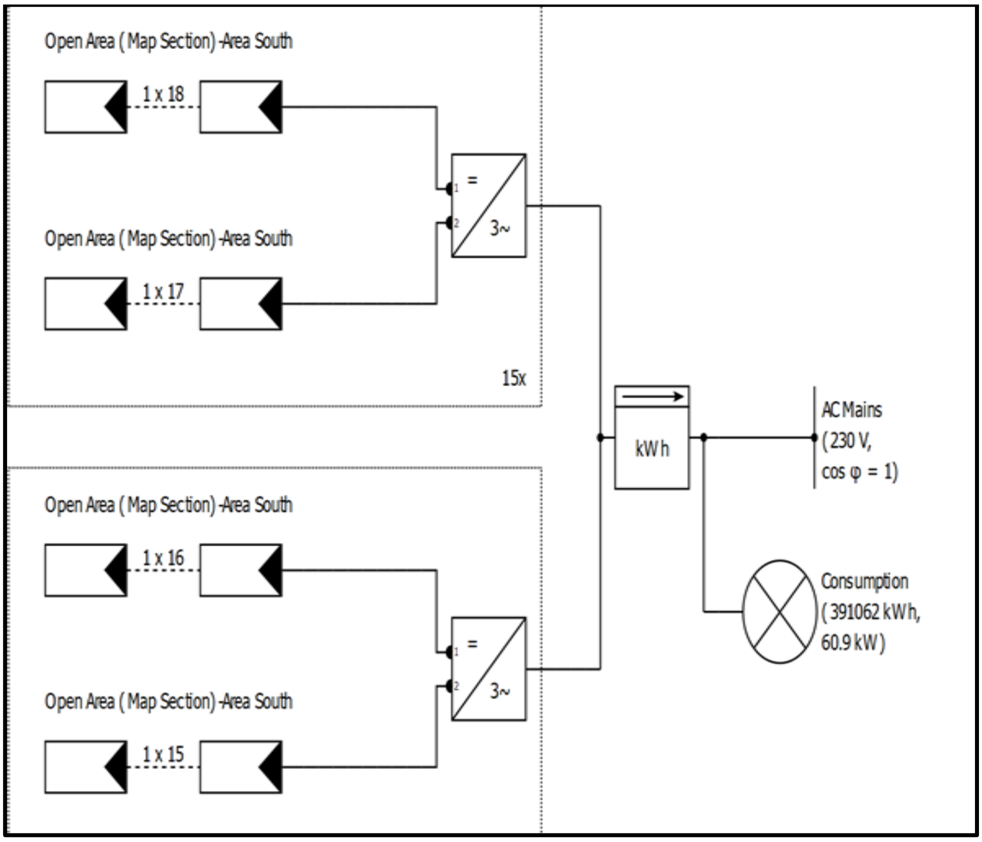


Fig. 4 Block diagram of a solar PV system that is connected to the grid.

3.2 Array Designing:

In arrangement of the solar PV module system, we use two module area of an industry for the research we had mounted REC solar REC300TP2M ,525 PV module mounted in 876.74 m^2 surface area by which we got 157.50kwp as an output and with same manufacturer we mounted 279 PV module in the second module area which had provided 83.7 kWp as an output. In both the module area the inclination is 30^o and orientation is 185^o mounted open space rooftop area. So total 804 PV module is mounted on the rooftop which provides 241.2 kWp and for this we use 24 inverters ,15 is of solinteg MHT-10K-40 and 9 is from Samsung SDI and the area receives roughly 1870 kwh/m2 of total global irradiation every year.

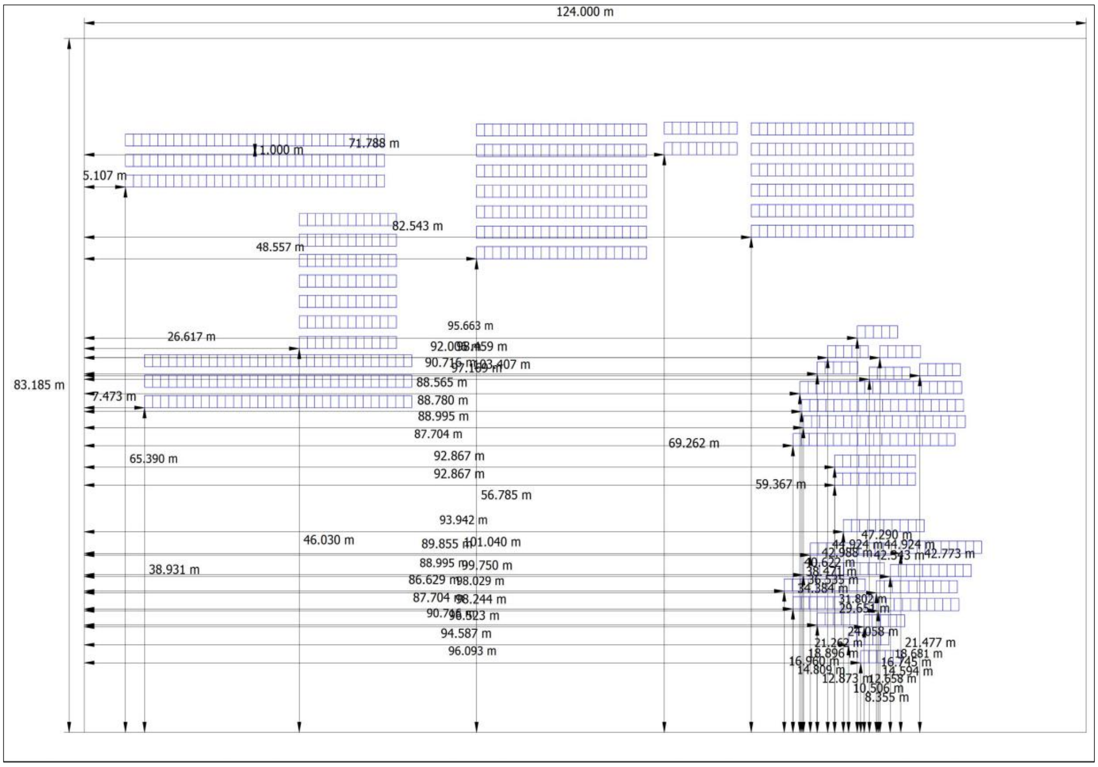


Fig. 5 Array Designing of PV System

3.3 PV energy During Observation Period:

As per company module of REC solar the degradation module of the solar system in the observation period in which the remaining output is 83% after 25 Years.

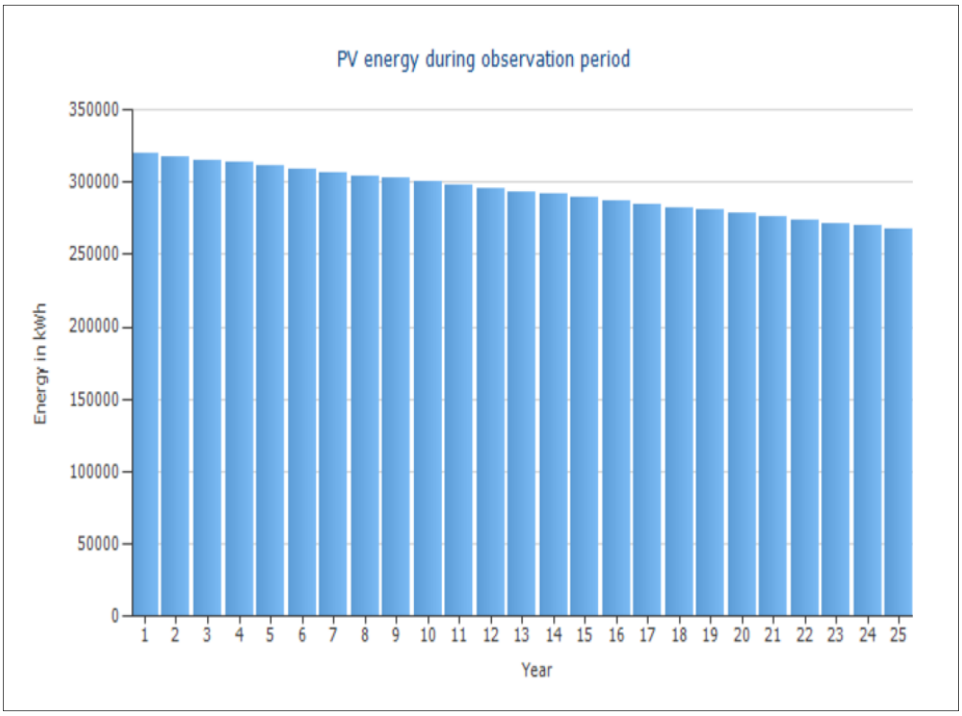


Fig. 6 PV energy During Observation Period

3.4 Losses:

There are Different types of losses that occur in a photovoltaic system. There is approximately 10% total losses that occur in this system in which Shading loss is 2%, Reflection loss is 1.2%, Irradiation loss is 0.8%, Spectral loss is 1%, Cable loss is 1.5%, losses due to array mismatch is 0.5% , and Inverter loss is approximately 3%. most losses are with design issues, while none of them are stable so they vary according to temperature, weather, and load conditions.

CHAPTER IV: Simulation Result

Our simulation tool produces various outcomes for various sections of our solar photovoltaic system after compiling all the input parameters. These are associated with system performance, yearly production prediction, performance ratio, etc. In addition to these, the PV*SOL also calculates other financial outcomes, which are covered individually in the next section.

4.1 SYSTEM PERFORMANCE:

The output of the system after executing a simulation using PV*SOL is displayed in Table 2(A). A 241.2kW solar system that is adequate for the utility location was obtained from this simulation. And this system can produce 3,20,980 units annually, which is enough to meet the demand for all the machinery of an Industry.

4.2 SYSTEM OUTPUT PARAMETERS :

PV System –

PV Generator Output	241.2 kWp
Spec. Annual Yield	1326.71 kWh/kWp
Performance Ratio (PR)	75.34 %
Yield Reduction	14.7 %
Pv Generator Energy (AC Grid)	320,980 kWh/Year
CO_2 Emission avoided	1,50,401 kg/Year

Table 2(A). System output parameters

Appliances –

Appliances	369,072 kWh/Year
Standby Consumption	978 kwh/Year
Total Consumption	370,050 kWh/Year
Energy From Grid	49,069.7 kWh
Solar Fraction	86.7 %

Table 2(B). System output parameters

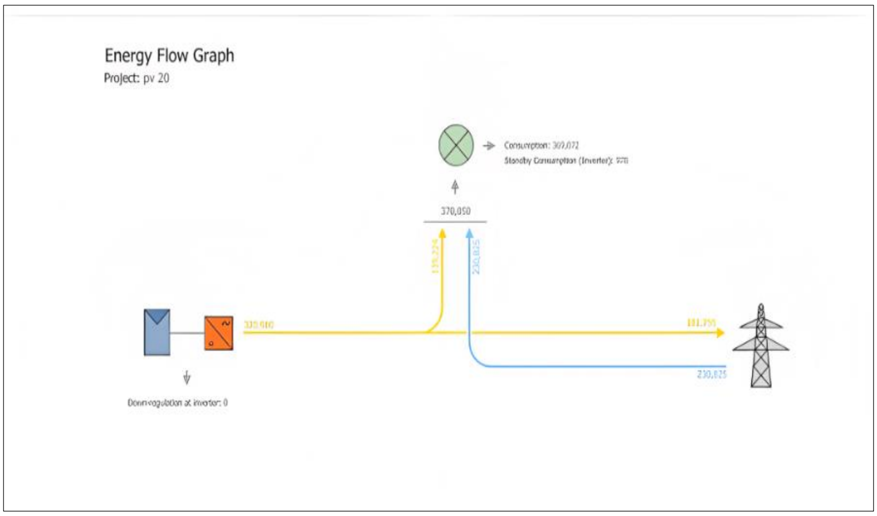


Fig. 7. Energy flow Graph.

Fig.7 represents the Flow of energy from sourse to consuming device it also called the energy floe chart which is used to illustrate a flow of the energy or transforming visual force combined with quantity.

4.3 Production Forecast & PR (Per Inverter Performance Ratio):

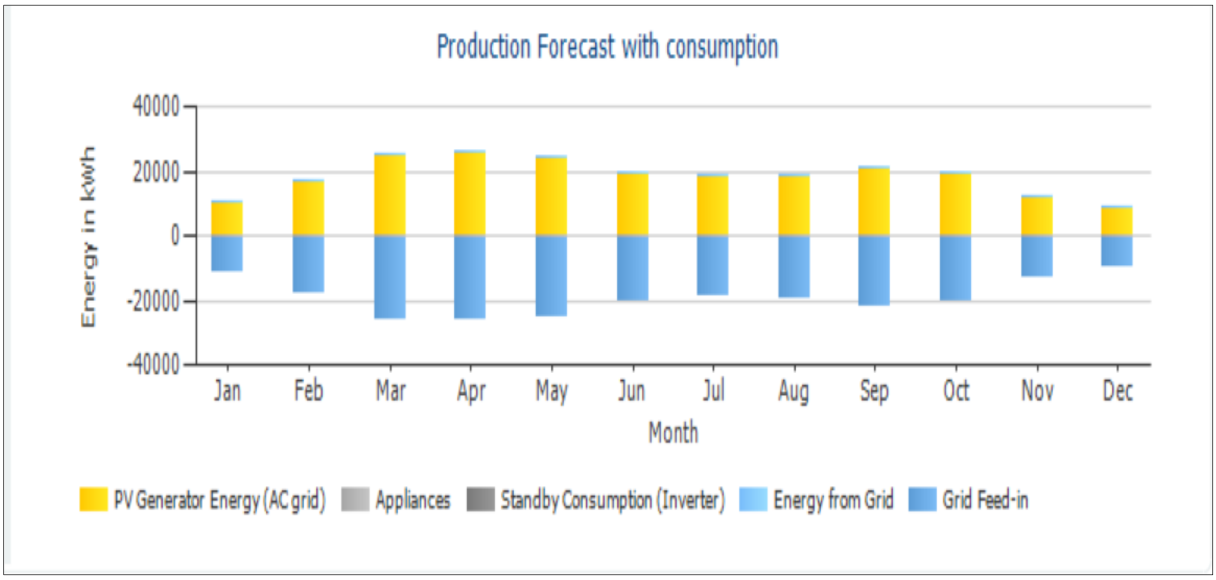


Fig. 8. Production Forecast With consumption.

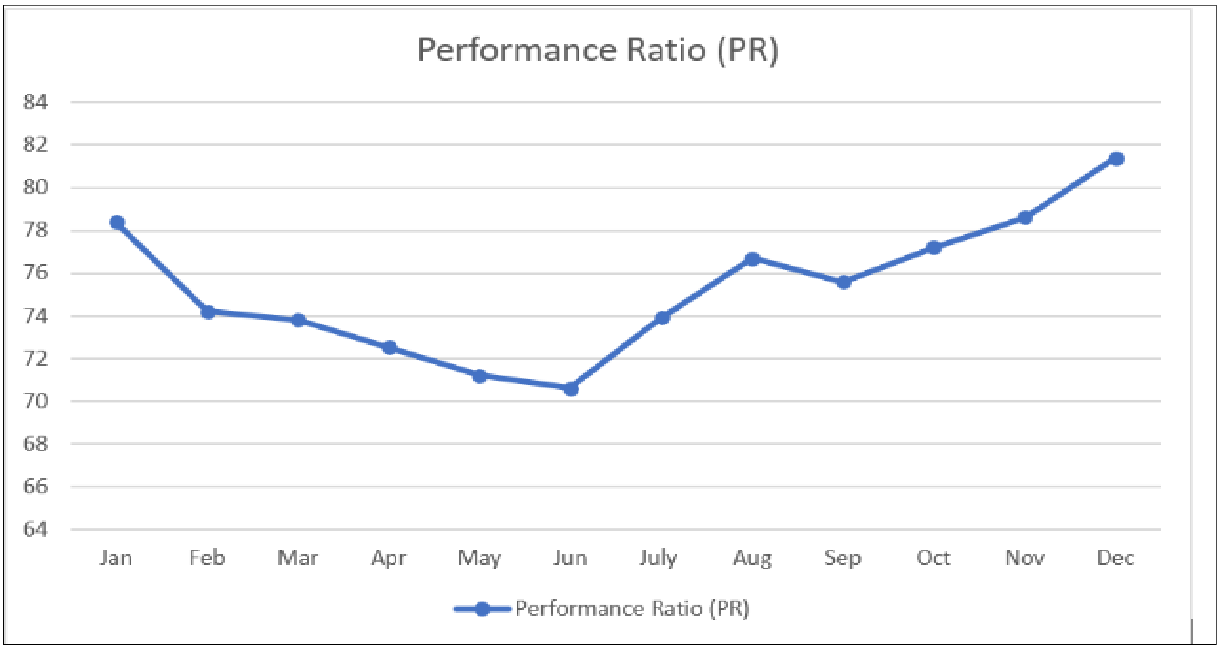


Fig. 9 Performance Ratio (PR)

4.4 Irradiance per Module Area:

Power per unit area is the unit used to measure solar light. Fig. 9 represents the graph of energy in kWh/m2 for each month of the year.

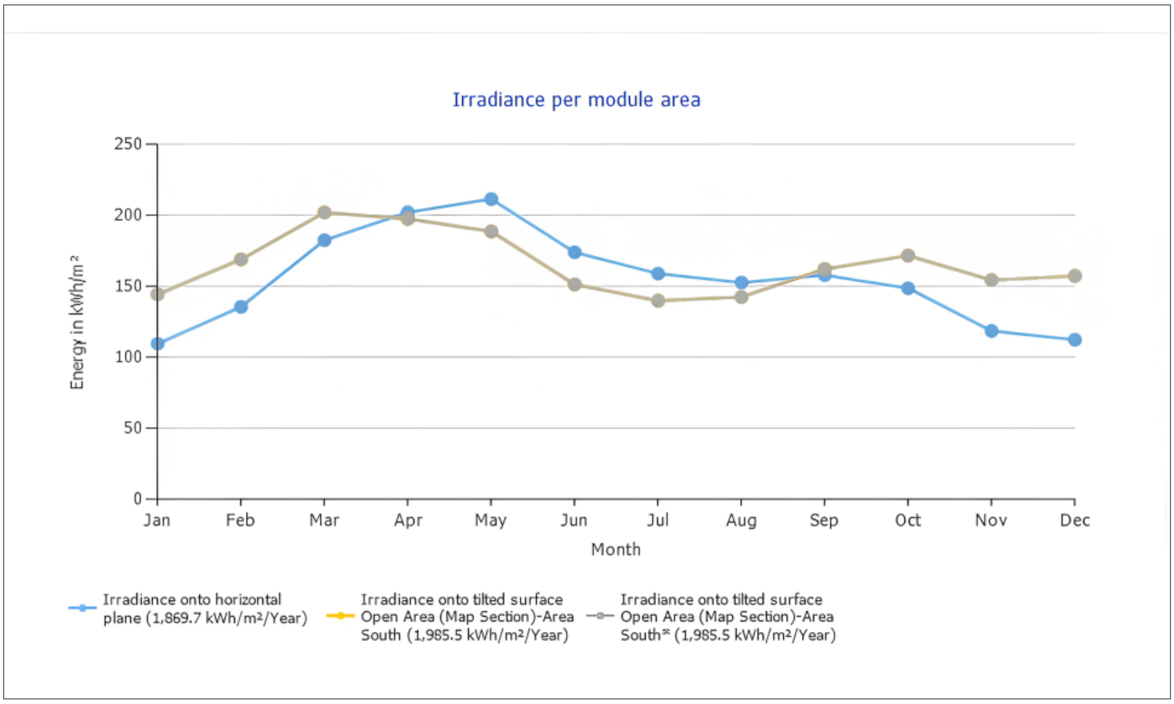


Fig. 10 Irradiance per Module Area

CHAPTER V: Financial Analysis:

For a thorough review of the system, financial analysis is required. Any system cannot be considered feasible without conducting a financial analysis. As a result, it is a crucial factor in this entire investigation.

Output Result-

PV Generator Energy (AC Grid)	320,980 kWh/Year
Output of PV Generator	241.2 kWp
Period of Assessment	25 Years
Price of electricity (Net-metering)	6.74 ₹/kWh
Return on assets	16.28 %
Accrued Cash Flow	10,42,659.50 ₹
Amortization Period	6.3 Years

Table 3. Output Result

5.1 Energy Cost Saving:

Fig. (11) represents the electricity cost saving graph where the fall in the amount of electricity cost is clearly seen after the installation of PV system. The reduction in the electricity cost shows that there will be a high amount of saving in terms of electricity cost which will make the system economical.

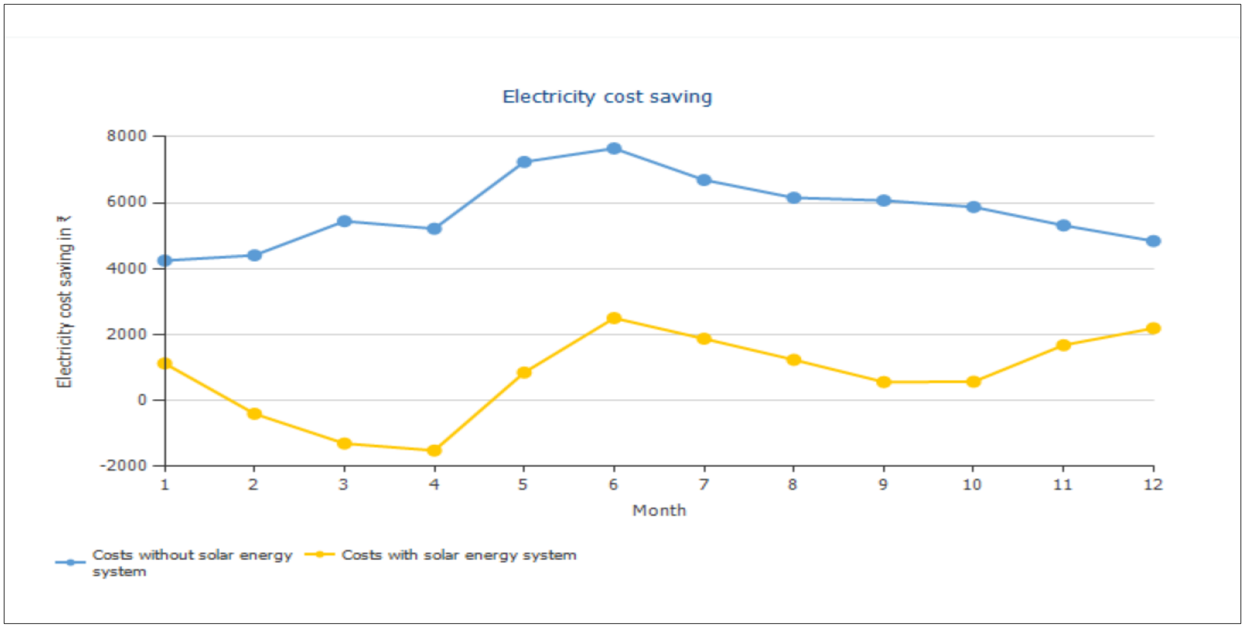


Fig. 11 Electricity Cost Saving.

5.2 Development of Energy Costs:

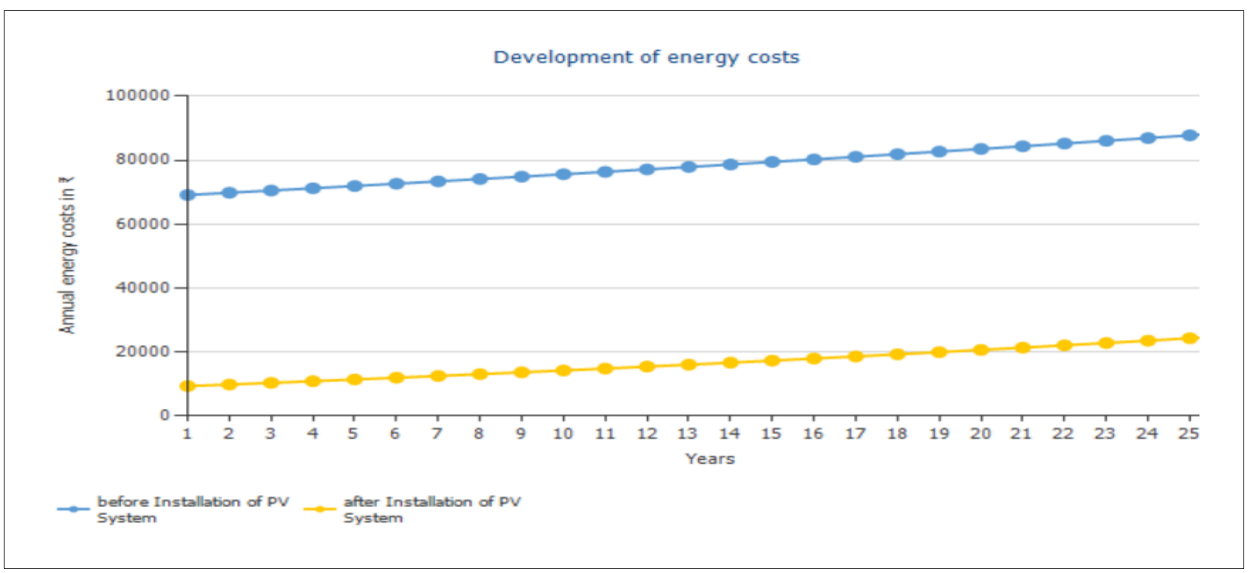


Fig. 12 Development of Energy Costs

As like Fig (11), Fig (12) represents the Deduction in annual energy cost, it shows the development of energy costs in increasing time yearly but after the installation of PV system there shall be similar development in the cost but it will be much economical then before the installation of the PV system.

5.3 Accrued Cash Flow:

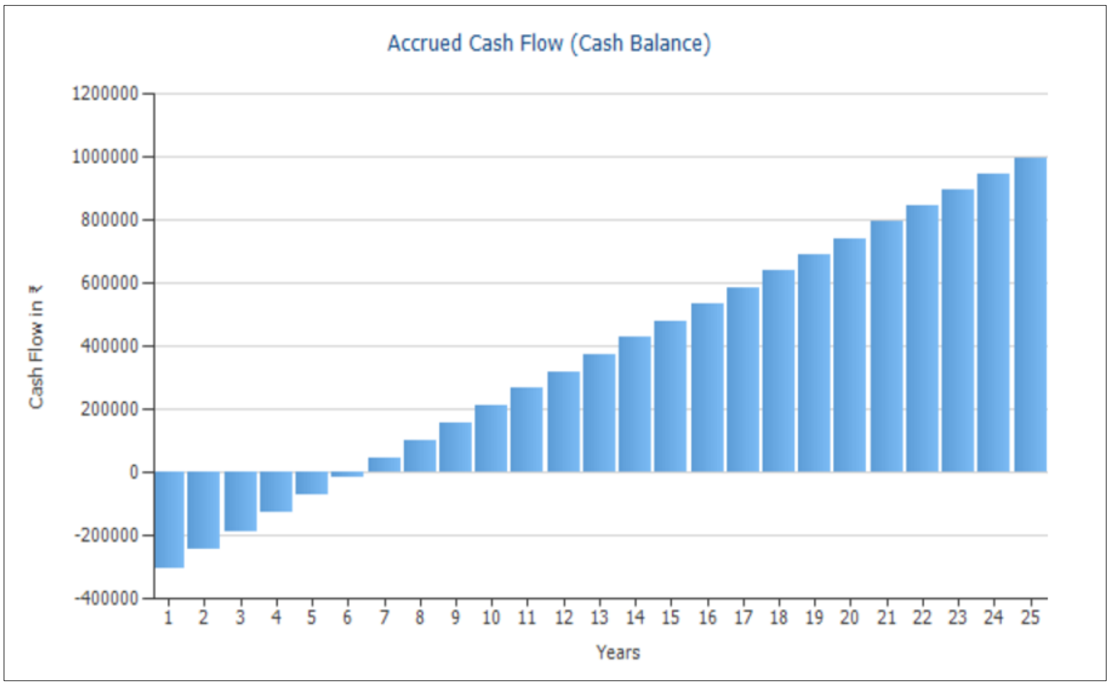


Fig. 13 Accrued Cash Flow.

The grid-connected PV system's financial analysis was determined using the PV*SOL program. Figure (13) depicts how the PV system built at the site meets demand and generates a profit 6.3 years after the installation Period.

CHAPTER V: CONCLUSION

The site for this photovoltaic solar system's 241.2 kW capacity has been researched. And as a result of the research study, we have come to certain results that support the profitability, viability, and utility of our system in the given context. This system produces 3,20,980 units annually, which is very close to the amount of utility used. The assets' annual rate of return is 16.28%. When using conventional energy, the yearly CO_2 emission can be cut down to 1,50,401 kg/year. Therefore, one of the most quantifiable criteria for the acceptability of renewable energy is included here. The system's average performance ratio is 75.34%, and its annual yield is 1326.71 kWh/kWp. This system has a payback period of about 6.3 years. Utilising solar energy enables people significantly reduce their energy use and eliminates dependency. For many consumers, the drop in electricity costs is a huge comfort as shown in this study Users receive the highest returns on investments which will generate more job opportunity in future. The study's conclusion is that PV*SOL Premium Simulation Tool may also be utilised as a tool for system design.

References

1. PV magazine: india.com/2023/01/03/solar-in-2023. (2023, Feb. 22) (2023).

2. Ankit Varshney, Abu Tariq: “Simulink Model of Solar Array for Photo-voltaic Power Generation System”, International Journal of Electronic and Electrical Engineering, Volume 7, Number 2 (2014), pp. 115-122 (2014).

3. M.E. Ahmad, S. Mekhilef,: "Design and Implementation of a Multi-Level Three-Phase Inverter with Less Switches and Low Output Voltage Distortation, “Journal of Power Electronics, vol. 9, pp. 594-604, 2009 (2009).

4. Dubey, K., Shah, M. T.: Design and simulation of Solar PV system. 2016 International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT). (2016).

5. Kumar, N. M., Subathra, M. S. P., & Moses, J. E.: On-Grid Solar Photovoltaic System: Components, Design Considerations, and Case Study. 2018 4th International Conference on Electrical Energy Systems (ICEES). doi:10.1109/icees.2018.8442403. (2018).

6. I. A. Odigwe, C.I. Nnadi, A.F.Agbetuyi, A..Awelewa and F.E.Idachaba.: “Development of a software solution for solar-PV power systems sizing and monitoring,” International Journal of Renewable Energy Research I.A. Odigwe et al.Vol.3, No. 3., (2013)

7. J. Uwibambe : “Design of photovoltaic system for rural electrification in rwanda,” University of Agder, Faculty of Engineering and Science Department of Renewable Energy, 2017. “PDCA12-70 data sheet,” Opto Speed SA, Mezzovico, Switzerland. (2017).

8. Sharma, R., Gidwani, L.: Grid connected solar PV system design and calculation by using PV∗SOL premium simulation tool for campus hostels of RTU Kota. 2017 International Conference on Circuit, Power and Computing Technologies (ICCPCT). (2017).

9. M. Kavitha et al.: "Energy Forecasting of Grid Connected Roof Mounted Solar PV Using PV*SOL," 2021 International Conference on Innovative Computing, Intelligent Communication and Smart Electrical Systems (ICSES), Chennai, India, 2021. (2021) .
10. PV*Sol: (2023, Jan.25) https://pvsol-online.valentin-software.com. (202

GLOSSARY

Solar Photovoltaic - An electric power system that uses photovoltaics to provide usable solar electricity is known as a photovoltaic system, often known as a PV system or solar power system. It is made up of a combination of several parts, such as solar panels that take in and convert sunlight into power, solar inverters that change the output from direct to alternating current, mounting hardware, wiring, and other electrical components needed to make up a functional system. It might also have an integrated battery and a solar tracking system to enhance the device's overall performance.

Solar Irradiance - The power delivered by the Sun in the form of electromagnetic radiation in the measuring device's wavelength range per unit of surface area is known as solar irradiance. Watts per square metre (W/m2) is the SI unit used to measure solar irradiation. In order to report the radiant energy released into the environment (joule per square metre, J/m2) over a specific time period, solar irradiance is frequently integrated across that time period. The terms solar irradiance, solar exposure, solar insolation, and insolation are all used to describe this combined solar irradiance.

Grid Connected PV - Grid-connected PV systems contain solar panels that can meet all or a portion of their power requirements during the day while remaining wired into the local electrical grid at night. PV systems fueled by solar energy can occasionally create more electricity than is required or used, particularly during the long, hot summer months. In the majority of grid-connected PV systems, the excess or extra electricity is either stored in batteries or sent back into the electrical grid network. The PV solar panels or array are electrically linked or "tied" to the local mains power grid, which feeds electrical energy back into the grid, in a grid connected PV system, also known as a "grid-tied" or "on-grid" solar system.

System Designing - PV arrays need to be mounted on a solid, long-lasting structure that can hold them up and endure corrosion, wind, rain, and hail for many years. These structures tilt the PV array at a fixed angle that depends on the local latitude, the structure's orientation, and the necessary electrical load. Modules in the northern hemisphere are aimed due south and slanted at an inclination equivalent to the local latitude to produce the highest annual energy output. Currently, rack mounting is the most popular technique since it is reliable, adaptable, and simple to build and install. Methods that are more complex and less expensive are always being created.

Financial analysis - Electrical, and mechanical work, the BESS, SCADA, consultancy services, land removal, and physical and pricing contingencies are all included in capital costs. Price contingencies and financial expenses, however, are not included in the FIRR calculation. O&M costs include photovoltaic, inverter, and BESS O&M as well as the annual replacement of 60 solar panels, the replacement of six inverters every five years, the cost of the land lease, the cost of insurance (which amounts to 0.3% of revenues), and other charges. The research treats the BESS as a capital expenditure rather than an expense because it will be replaced every ten years.

To determine the project's financial viability, the weighted average cost of capital (WACC) and the FIRR are compared. A 25-year analysis of the project is conducted, excluding the building phase. Zero is taken as the residual value.

PV*SOL Premium - The best design tool is simulation software, which makes precise forecasts simple. By putting systems into perspective and producing expert reports, you can provide consumers the best return on their investment. The photovoltaic system performance simulation software for solar systems is known as PV*SOL® premium. For people who do not want to utilize 3D to model shading and see the landscape, it is a fully functional program.

Payback Period- The time it will take for the savings from your solar panels to equal the cost you paid for them is referred to as the payback period for solar panels. Understanding the correlation between your electricity usage, overall system cost, solar tax credits and rebates, energy production, additional incentives, and the cost of electricity will help you calculate your solar payback. Unfortunately, there is no predetermined solution for the typical solar panel payback period due to these connected elements.

BIBLIOGRAPHY

Appendix