

Design and Simulation Analysis of 12.4 kWp Grid Connected Photovoltaic system by using PVSYST Software



B. Kailash Krishna Prasad, K. Prahlada Reddy, K. Rajesh, P. Viswanath Reddy

Abstract: The grid connected photovoltaic based systems are gaining popularity day by day, since it is considered to be as a reliable and eco friendly system. This paper mainly discusses about the design aspects of a grid connection based solar photovoltaic system. As a part of design, a 12.4kWp photovoltaic array nominal power generation at standard temperature conditions has been considered and simulated the same in PVSYST software environment. The paper throws light on various aspects like developing sankey diagram of the power output losses, examining the performance ratio and its energy output of photovoltaic plant which is to be installed, investigating the performance of a selected photovoltaic module, fixing of tilt angle, plotting of power and temperature distribution related curves through software simulation. This paper also shows the recommendations pertaining to connection of modules in a string mode and shown the power sizing curve of inverter output.

Keywords: Performance ratio, Photovoltaic, PVSYST, Sankey Diagram, Temperature distribution, Tilt angle.

I. INTRODUCTION

The power generation through solar photovoltaic (PV) systems has been gaining enormous popularity now a day because of rise in energy demands and its direct energy conversion capability from light energy to electrical energy. The grid connected PV system is having many advantages in both reducing the complexity of the design and cost view point as well. The other advantage of the grid connected system is that, a bidirectional net metering shall be employed so that, the meter reads both the power consumption from the

utility and also note the amount of power actually fed to the grid. Thereby, the power bills will cut down drastically because this type of system will facilitate a good opportunity to sell power to the Electricity board. The standalone PV system requires an additional battery backup for storage facility which thereby enhances the overall cost investment.

There exist several softwares to simulate and design the solar PV systems namely: PVSYST, PVGIS, Helioscope, Arc GIS, Google Sketch up, SolarMAT, HOMER and so on. Among the aforementioned softwares, PVSYST is little bit easier to analyze and design. Helioscope is also considered to be a good option in order to design a solar PV system, but it is cloud computing based platform and commercially very expensive. Google Sketch up is mainly used to design 3D pictures of PV system installations. The advantage of PVSYST is that, it gives us the information about the power output, sankey diagram representation describing about the various losses in the system output, generates report for future investigations and user friendly environment.

Anand Mohan *et.al* mainly focused on the development of photovoltaic power system in Himachal Pradesh area and explained about the economical aspects involved in the installation of the power plant. Also, the authors illustrated about the load analysis considering the power vitality [1].

C. P. Kandasamy *et.al* elucidated about the solar potential assessment using PVsyst software for the prevailing geographical conditions in southern parts of Tamil Nadu state. The performance of 1000 kWp grid connected photovoltaic system has been considered for simulation study. The aspects like energy production and other cost parameters were discussed in the paper [2].

Nallapaneni Manoj Kumar *et.al* explained about the 100kWp grid connected system which is suitable for catering the needs of electrical power supply for an academic institution [3].

Paras Karki *et.al* focused on comparing the performance aspects of grid connected systems installed in the areas of Kathmandu and Berlin [4].

The authors in [5] focused on the aspects of design and installation of grid based PV system in Madan Mohan Malaviya University of Technology which is located in Gorakhpur, India.

The authors in [6] illustrated about the importance of HOMER and SolarMAT softwares in designing the hybrid based PV systems. They also explained about design criteria of solar PV systems by representing the CO₂ emission levels.

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II. ABOUT PVSYST

The PVSYST is a better simulation tool which facilitates various options like designing a grid connected PV system, standalone PV system,

Small scale energy production for pumping applications and only DC power production. Depending upon the requirement, the user can select a particular design area and mitigate for solution. The software also provides an opportunity to have a preliminary design for marketing and promotion of PV system installations to the consumers. The Detailed design is for solar installers and it can generate the results such that, based on the simulation results one can initiate the process of setting up a solar PV plant.

III. DESIGN METHODOLOGY

The steps involved in simulation design are illustrated in the form of flow chart below:

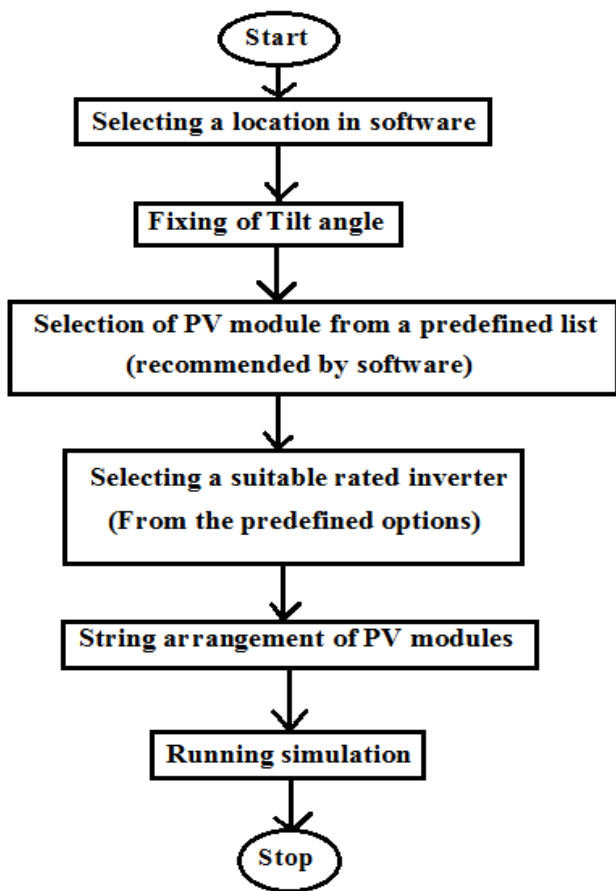


Fig. 1 Flow chart of design procedure

The various steps involved in designing the grid connected solar PV system in simulating platform are explained below in detail in a user friendly manner.

A. Specifying the geographical site parameters

Consider an area where we need to install a PV based power plant. The most important aspect is to select the geographical area and should be linked with any data source like NASA-SSE satellite data which is specified by software. The following table depicts the geographical site parameters of Vishakhapatnam region in Andhra Pradesh which is predefined by software itself. This data could be considered as reference data for any area in Andhra Pradesh. The

advantage of the PVSYST is that, after selecting the region of installation, the software itself will link the latitude and longitude data which are taken from NASA-SSE satellite station automatically.

Table- I: Monthly geographical conditions

Month	Geographical site parameters		
	Horizontal global irradiation (kWh/sq.m. month)	Horizontal diffuse irradiation (kWh/sq.m. month)	Temperature (°C)
JAN	169.9	61.1	25.9
FEB	163.5	57.7	26.3
MAR	180.1	67.9	26.7
APR	171.0	62.1	26.9
MAY	167.1	58.9	26.5
JUN	165.0	51.9	24.8
JUL	170.2	55.2	23.6
AUG	172.1	61.4	23.4
SEP	175.5	63.3	24.1
OCT	174.8	65.7	25.0
NOV	162.0	60.6	25.6
DEC	164.3	60.5	25.8

B. Block diagram of grid connected PV system

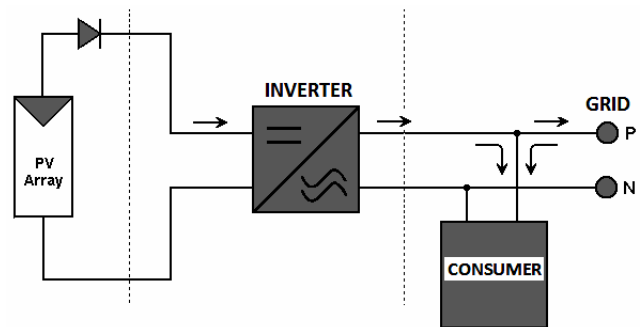


Fig. 2 Grid connected PV system schematic representation

C. Fixing of Tilt and Azimuth angle

The Tilt angle can be modified depending upon the place of installation and also to maximize the yield of solar energy. The Tilt angle is kept around 10 degrees. Azimuth angle is specified as zero in simulation.

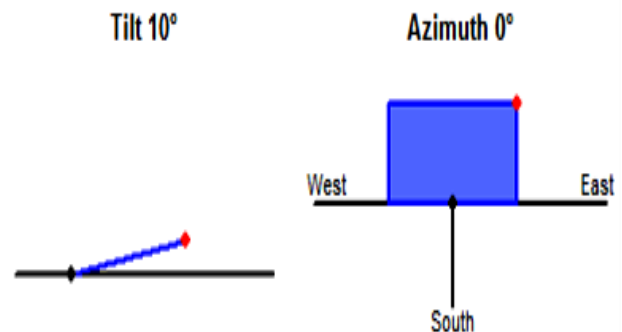


Fig. 3 Tilt and azimuth angle fixation

The performance curve of Tilt angle and plane orientation is shown below in Fig. 3 and Fig. 4 respectively.

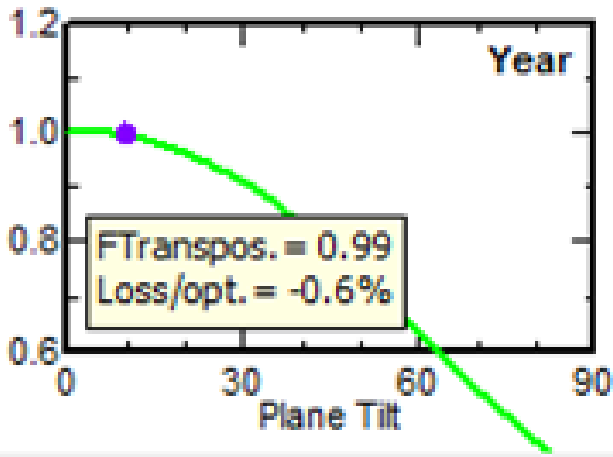


Fig. 4 Tilt angle performance curve

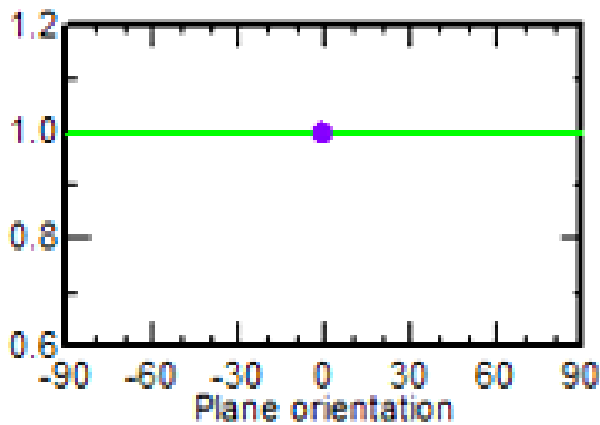


Fig. 5 Plane orientation

D. Selecting a suitable PV module:

Depending upon the economic viability option, ageing factor and performance criteria, a PV module could be chosen among the available list which is predefined in the software. Longi Solar LR6-60 BP 295 M Bifacial PV model has been selected for simulation to obtain better performance output.

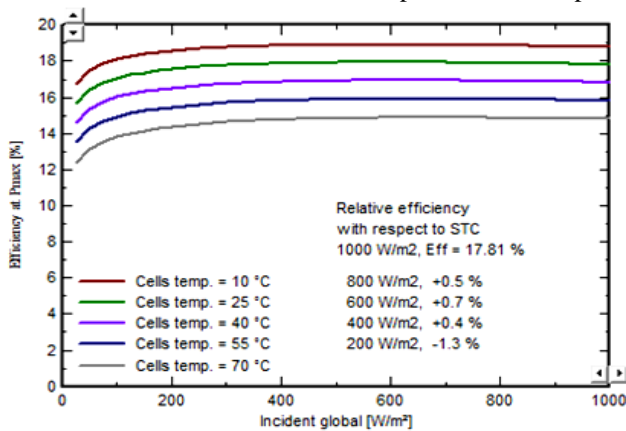


Fig. 6 Optimized Longi Solar PV module curves

Table- II: PV model values

Longi solar model parameters at Tref = 25 °C	
SHUNT RESISTANCE (Rsh)	600 ohm
SERIES RESISTANCE (Rs)	0.304 ohm
NOMINAL POWER (STC)	295Wp
SHORT CIRCUIT CURRENT (Isc)	9.68 A
OPEN CIRCUIT VOLTAGE (Voc)	39.90 V
CURRENT AT MPP (Impp)	9.110 A
VOLTAGE AT MPP (Vmpp)	32.40 V

E. Selecting a suitable Inverter:

An inverter can also be selected from the options specified by the software and the technical feasibilities of available inverters could be examined. Canadian Solar Inc 600kW Inverter has been chosen for simulation purpose.

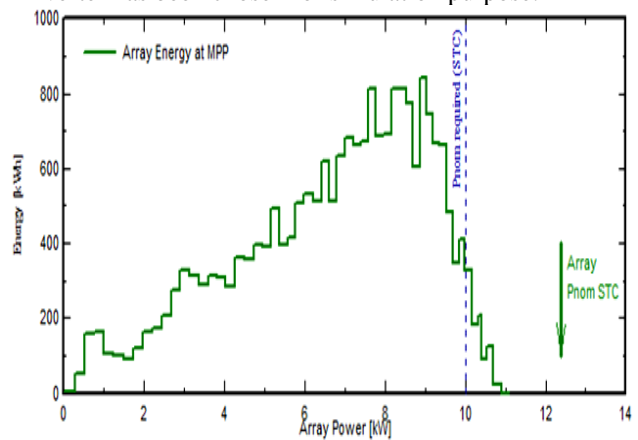


Fig. 7 Power sizing of inverter output

The array voltage sizing can also be depicted as follows:

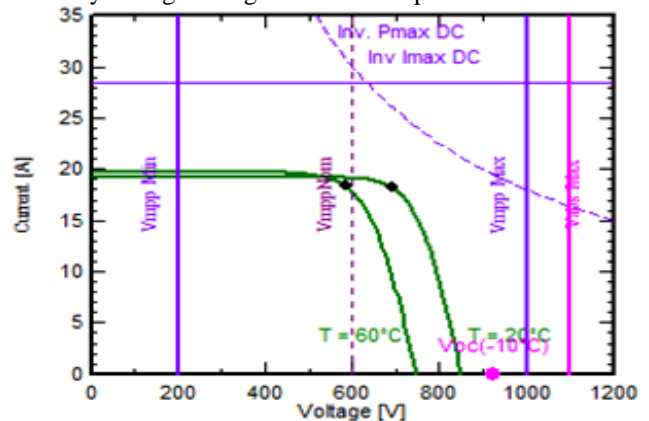


Fig. 8 PV array voltage sizing

F. Number of modules and string arrangement:

The software also suggests us about the optimal string assessment of PV modules. According to this case study, the software recommended 21 modules in series and there should exist 2 strings in parallel for getting optimized power output.

IV. SIMULATION RESULTS AND DISCUSSIONS

After undergoing the design procedure mentioned above, the model should be simulated and the inferences can be analyzed for assessing the plant efficiency.

Detailed simulation has been performed and obtained various outputs which are represented below for better understanding of the plant installed.

The various results such as daily input/output plots, sankey diagram representation of losses, horizon line drawing plot of location chosen, performance ratio data plot, daily energy output plot including the incident variations, array temperature distribution during running conditions, array power distribution plot, normalized productions including the loss changes, plot examining about the sun azimuth and incidence angle are presented below respectively.

A. Daily input / output diagram

The following plot shows the daily variations in the input/output profiles of energy injected into the grid (kWh/day) and the global incidence on the plane (kWh/m²/day).

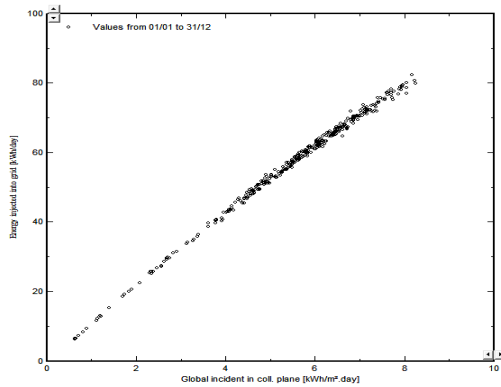


Fig. 9 Energy injected to grid versus global incident plot.

B. Sankey diagram of losses:

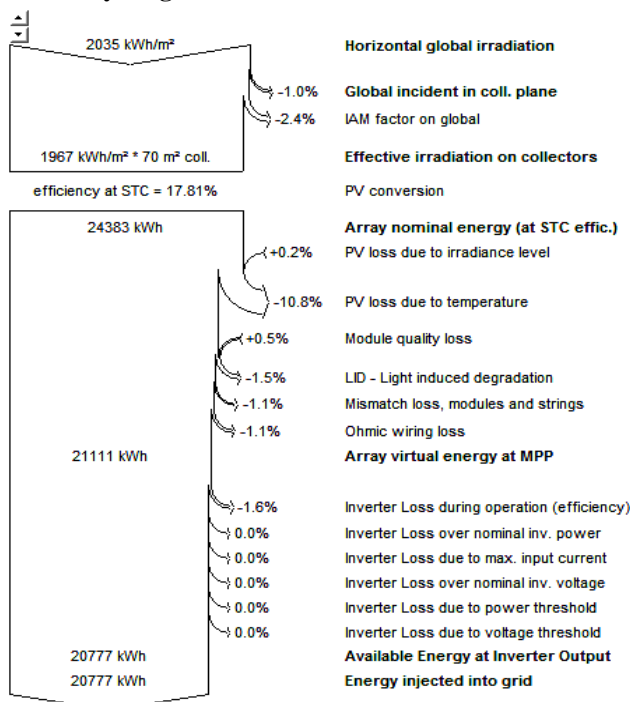


Fig. 10 Sankey diagram simulation outcome

The above diagram represents the energy input and the energy output including step by step loss analysis.

Sankey diagram is a very useful tool to examine the plant efficiency. A total of 20,777 kWh is the energy injected into the grid as shown in the simulated figure. Array nominal energy is estimated as 24,383 kWh. So, a difference of 3,606kWh is the total losses of the system.

C. Horizon line drawing:

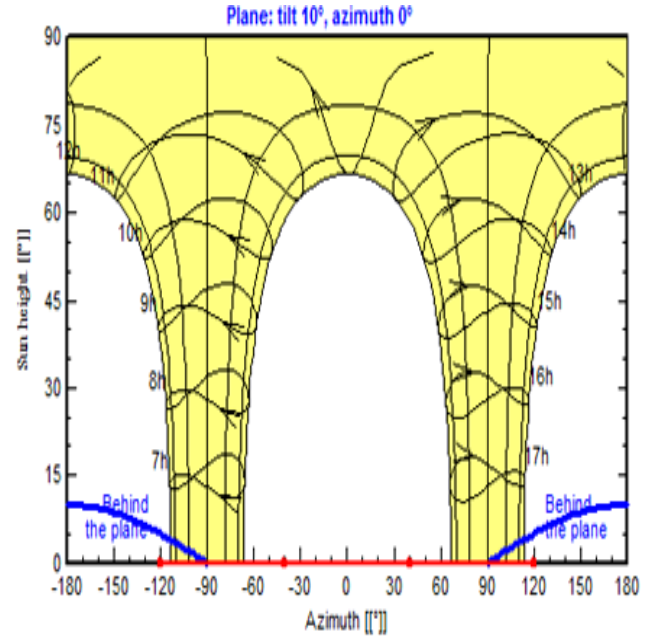


Fig. 11 Horizon (for shadings) line diagram

D. Performance ratio:

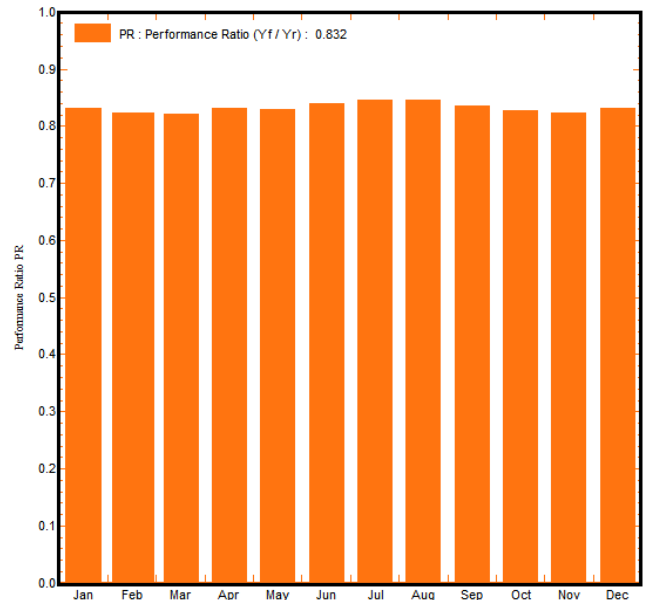


Fig. 12 Performance ratio curve analysis

E. Daily energy output plot:

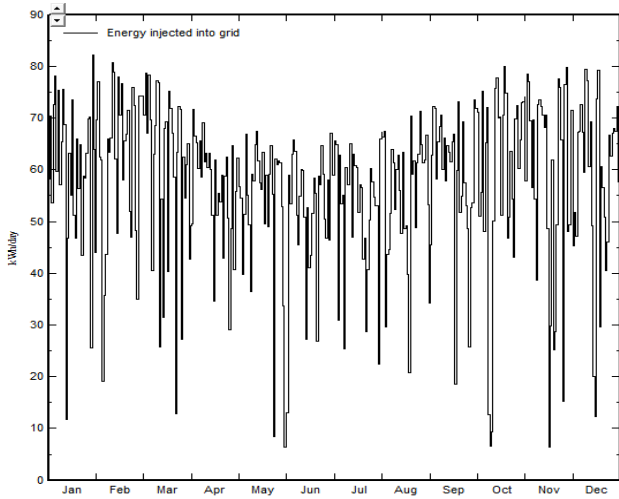


Fig. 13 Daily energy response variations

F. PV array temperature distribution:

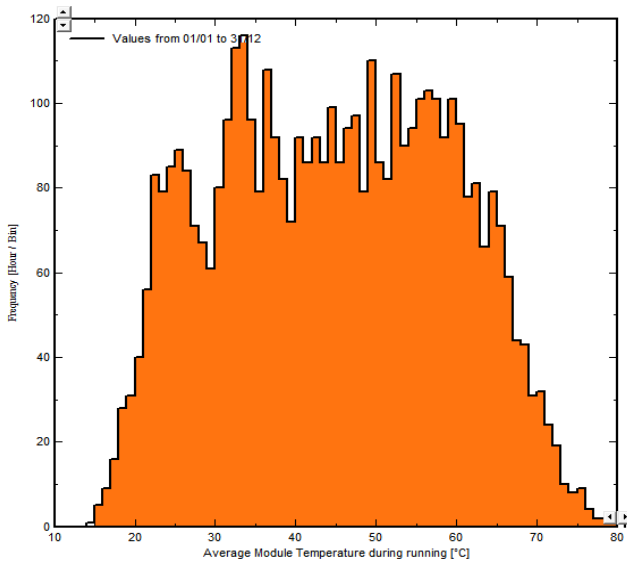


Fig. 14 Temperature distribution of array

G. PV array power distribution:

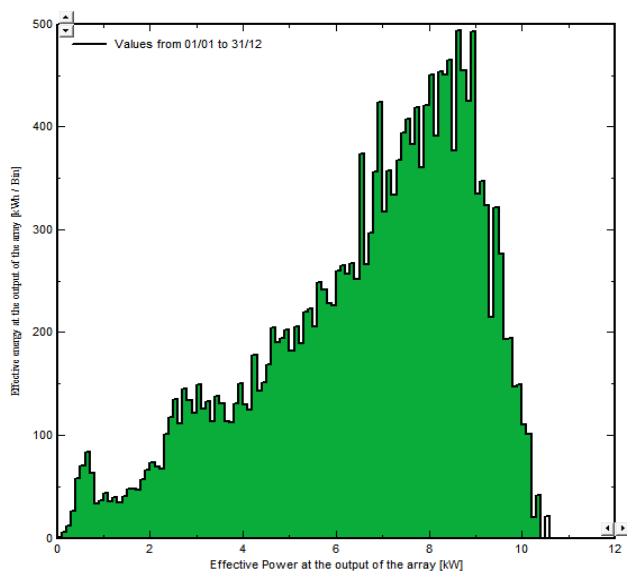


Fig. 15 power distribution of array

H. Sun incidence angle plot including its azimuth:

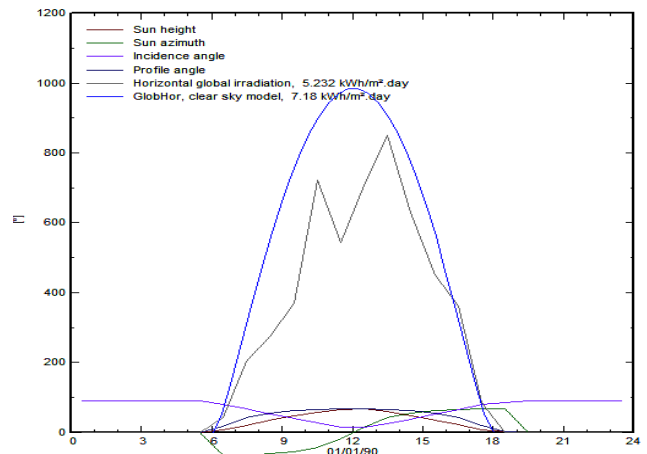


Fig. 16 Incidence plot of sun

I. Normalized power production (per installed kWp):

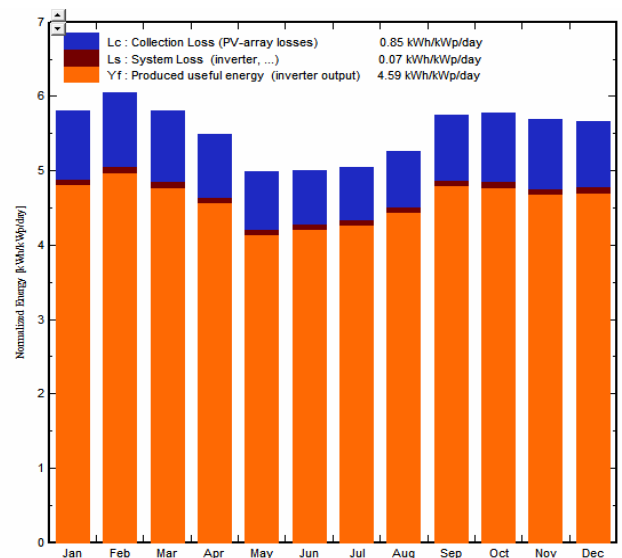


Fig. 17 Normalized power plot

J. Energy use and user's needs:

The following data has been obtained from simulation results which shows clearly about the energy fed to the grid and the corresponding performance ratio (PR) value. The PR value obtained through simulation is 0.832 on an average basis which is considered as a good value and thus it further recommends installation of the solar power plant without any hesitations.

Table- III: Simulated results of Energy supplied to Grid

Month	Month wise simulated data of Energy fed to grid	
	<i>E_Grid (kWh)</i>	<i>PR</i>
JAN	1850	0.830
FEB	1726	0.823
MAR	1835	0.822
APR	1698	0.832

MAY	1590	.829
JUN	1565	0.841
JUL	1639	0.846
AUG	1707	0.845
SEP	1785	0.836
OCT	1834	0.827
NOV	1740	0.823
DEC	1808	0.832

V. CONCLUSION

This paper significantly emphasized on simulating a 12.4kWp solar based Photovoltaic power plant and explained the design procedure to mitigate the issues related to selection of PV modules, inverter power sizing, location selection, strings arrangement etc. one can keep this paper as a reference tool to investigate the installation aspects of grid connected systems. This paper serves as a better guide for the beginners and solar practitioners, who are interested in installing a solar energy based grid connected photovoltaic system and also can estimate various losses in the system accurately with the help of PVSYST software. The major advantage of PVSYST is that, one can generate the complete installation report and examine the power output and losses in the plant.

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