Techno Economic Simulation of 1 MWp Grid Connected Solar PV System at Jaipur for Different Manufactuirng Technology

Vijay Singh, Anil Boyal

***Abstract**: Production and loss prediction play an important role in the effective planning and operation of solar photovoltaic systems. The performance of a solar PV system depends on the geographical location, system design, horizon and orientation of the solar panels in a given system. Professionals can use a variety of forecasting tools to effectively plan and predict grid connections and standalone solar PV systems. In this paper, we have developed an equivalent mathematical model for 1MWp grid-connected solar PV systems that have been developed and installed for Jaipur. With the help of the PV Syst design tool, performance parameters, yield and loss have been predicted for the equivalent model. Monthly earnings and losses as well as annual gains and losses have been synthesized. For the performance evaluation of the forecast data, we compared the techno economic simulation for different manufacturing technologies. Thin film, Ploy Crystalline and Mono Crystalline based systems have been developed. Predicted data can be used as an important tool for analyzing location and seasonal specific losses. Conducted research will be helpful in calculating area specific impact on selection of manufacturing technology of panels as well as its impact on active area of installed system.*

***Keywords**: Yield Forecasting, Loss Forecasting, PVsyst, Performance Ratio, Grid Connected Solar PV*

I. INTRODUCTION

India is in the early stages of a major transformation, bringing new opportunities. 1.3 billion people in the country are active in many areas in international affairs. The energy sector is growing rapidly, but will face India's modernization and economic growth, further accelerating the pace of the challenge, especially taking into account the policy focus of India's manufacturing base. In recent years, power generation has increased dramatically, but has been affected by the precarious financial situation of local distribution companies, distribution networks and industry losses. India's hydropower and wind power installed capacity of 250,000 kilowatts, up to 23 million kilowatts, but almost did not play its huge potential for renewable energy. However, India is currently very high in this area, and by 2022 (excluding large hydropower) the goal is to increase from the current 37 GW capacity significantly to more than 100 GW. Solar power generation is a key factor in government expansion plans [1] The performance of solar PV systems is highly dependent on geography and system design. Therefore, in order to develop efficient systems, we need efficient design and forecasting tools.PVSyst is a multi-purpose tool for optimizing and planning grid and independent solar photovoltaic system design and installation.

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In the upcoming part, we have progressively implemented an equivalent simulation model of the 100 KWp system installed at the University of the island to predict and evaluate the performance of the power plant. [2,3]

II. PV SYSTEM

The solar PV system consists of photovoltaic arrays, inverters and other balancing system components such as mounting systems, charging controllers, cables, power transformers and suitable energy storage systems. The choice of components depends on the system and has been selected separately for each item. Figure 1.1 shows a schematic diagram of a grid-connected PV system. [4]

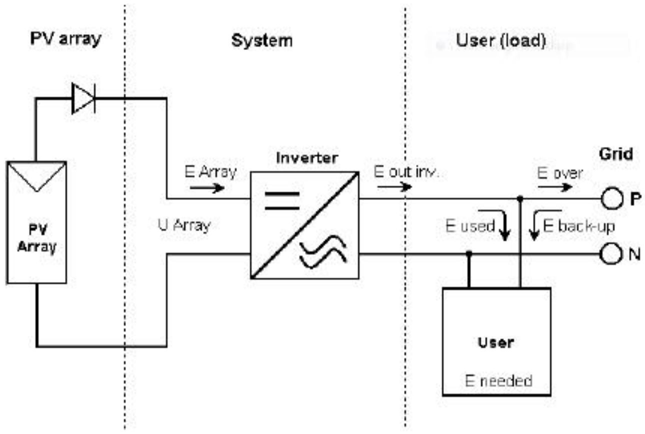

Fig.1.1 Grid Connected Solar PV System

In order to convert the direct current generated by the solar array into alternating current. There are many inverters on the market that are based on a battery connection system or a network topology-based system. Compatibility with solar arrays and optimized dimensions are major concerns for efficient system design in solar photovoltaic systems. The power and rated frequency of the frequency converter must be based on the system design. Other components of the grid connection system include mounting brackets, switches, cables, connectors and system monitoring components. It should be noted that the use of DC cables must be small because of its high ohmic losses and high cost. The central inverter also requires the use of matrix and inverter fuses to protect the voltage overload between the junction boxes themselves as infinite energy storage, which can provide excess energy to the grid. [5,6]

III. SYSTEM COMPONENTS

The research work has been carried out on 100 kWp grid connected solar photovolatic system installed at Poornima University at Jaipur.

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Major building blocks of installed solar photovoltaic system can be classified as follows.

- Solar Panel
- Inverter
- Geographical location and Horizon
- Orientation

Solar Panel Specifications-Solar modules related to system design and installation are manufactured by TATA POWER under the designation Tata-BP 235. We have simulated similar system for three different manufacturing technolgy which are explained in table 1..

Fig.1.2 Snapshot of Installed Solar PV Plant

Table-1Description of Solar Panel

S.No.	Manufacturing Technology	Model Name	Power Rating
1.	Poly Crystalline	Tata-BP 235	235 W
2.	Mono Crystalline	SPR 300N (Sun Power)	300 W
3.	Thin Film	BSM Si Plus(BOSCH)	130 W

Inverter Specifications-Invereter incorporated in the given system is of Power One make with model number PVI-Central-500-TL. Inverters are connected in string topology with each having rated power of 500 KVA.. There are two inverters connected in string topology with the photovoltaic array.

Table 2- Description of Inverter

Model	PVI-Central-500-TL.
NumberofInverter	02
$V_{DC(Max)}$	1000V
$I_{DC(Max)}$	1100A
$V_{DC(MPP)}$	465-900V
I_{SC}	43A
Power Rating	25kVA
$I_{AC(Max)}$	900A

Fig.1.3 Snapshot of DC Distribution Box

Location, Orientation and Horizon-Linear shading with fixed tilt of 26 ^{0} orientation has been opted for the system.The photovoltaic system has been set up at Jaipur (Rajasthan) which have latitude and longitude of 26.9124° N, 75.7873° E respectively and altittude of 431m above sea level . Time zone is selected as per Indian Standard Time (IST). [9]In the next section the step by step integration of mathematical equivalent model of given grid connected system in PV Syst is discussed.

IV. DESIGN OF SYSTEM IN PV SYST

We synthesized the mathematical equivalence of the installed power plant in PVSyst by synthesizing Jaipur's synthetic meta-documents. Subsequent steps involve mathematical modeling of solar panels, inverters and orientations. Designed to install the power plant in PV-Syst, a commercial tool for the design and installation of a wide range of solar photovoltaic systems. Here we describe the step-by-step process of our PV plant design mathematical modeling and software design as follows.

Synthesis of Irradiation data-The irradiation data were obtained from NASA-SSE satellite data,release 6 as well as Meteonorm saatelite release.The obtained Irradiation data consitituted values of syntheticaly generated hourly values of ambient temperature, diffused, beam and global irradiation of Jaipur for span of one year as plotted in figure 1.4. These data were saved in PVSyst for creating new geographical site.[5.2]

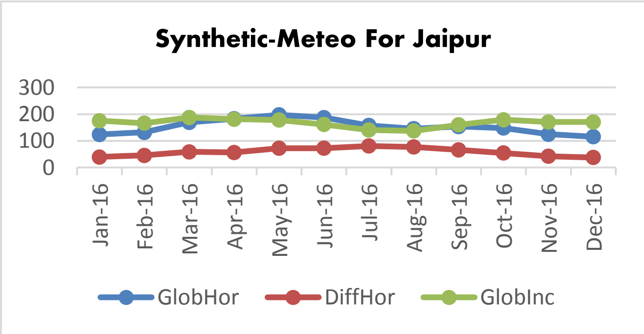

Fig.1.4 Synthetic Generted Meteo Data for Jaipur

System design using datasheet-Using the TATA Power, Sun Power and Bosch'spanel data sheet, the equivalent mathematical model of the solar panels has been obtained in the PV-Syst user-defined library. These models are used to create a 1MWp system for the proposed PV plant. Using the Power One manufacturer's data sheet, the equivalent mathematical model of the inverter is designed in the PV-Syst user-defined library. These inverters were used to create a 1MWp system for the proposed PV plant. This process can be understood by the analysis in Figure 1.5, which is a snapshot of the PV-Syst system design tool created for the proposed system. [4]

Orientation and Horizon- Taken into account the fixed inclination of 26 degrees with zero azimuth angle present in the installed power plant.

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Follow these directions to create an equivalent mathematical model and equivalent real-time simulation of the current system in PV-Syst. Figure 1.6 illustrates the optimization of the tilt and tilt angles of the tilt angle in the PV-Syst of the proposed system.

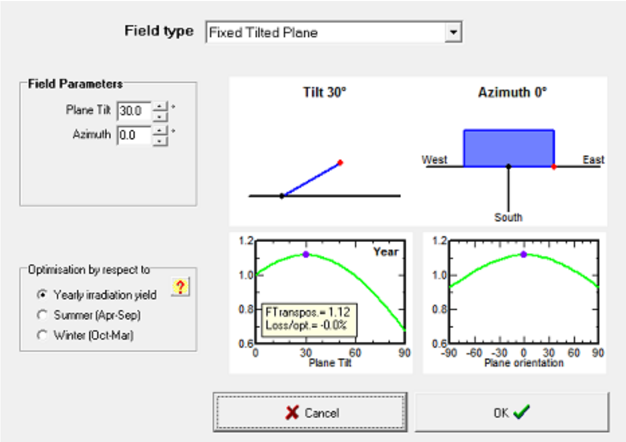

Fig.1.5 Orientation and Tilt Optimization for System

***Interconnection of Invereter and Array*-**There are two 500 kW frequency converters to achieve the equivalent simulation model of the installation system. Figure 1.7 illustrates the interconnection of the inverter and the panel in the series topology, and finally the connection to the grid to connect to the two-way network [8] The inverter is used to convert DC to AC voltage, each inverter 500kW power and three-phase output frequency of 50HZ. "The module used in the plant is a PV module made of polysilicon. The physical dimensions of the module are: frame length: 1667 mm, frame width: 1000 mm, frame thickness: 33 mm.

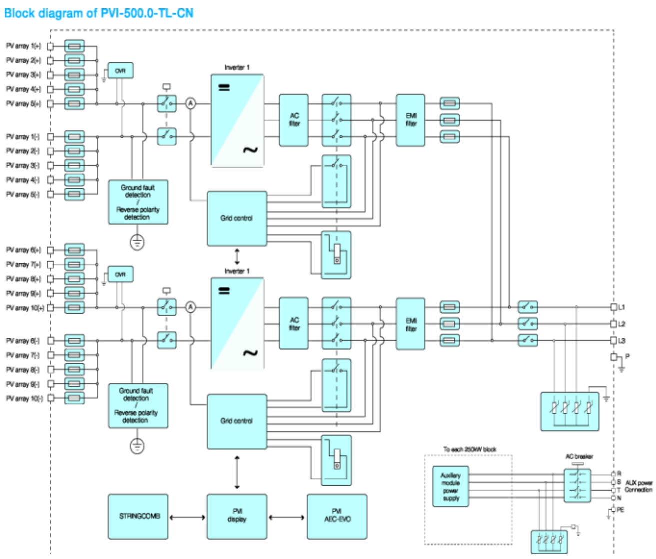

Fig.1.6 Inteconnection of Inverters in String Topology

V. SIMULATION USING PVSYST

The overall simulation has been carried out on PV-SYST 5.74. Simulation results for proposed 1 MWp system can be divided into following categories-

- Yield Forecasting/Simulation
- Losses Simulation
- Performance Ratio
- Generation by Inverters
- Design and Simulation of Dependence of Manufacturing Technology

These simulation is carried out first on monthly basis in order to obtain result of forecasted value for a complete year.Similarly simulation was done for the same designed system on daily basis so as to formulate forecasted result

Yield Simulation-The yearly reference and final yield has been simulated using pv syst software for proposed system. The plot of yield has been characterized as normalized poroduction and main results.The unit of reference and final yield is in hours per day.

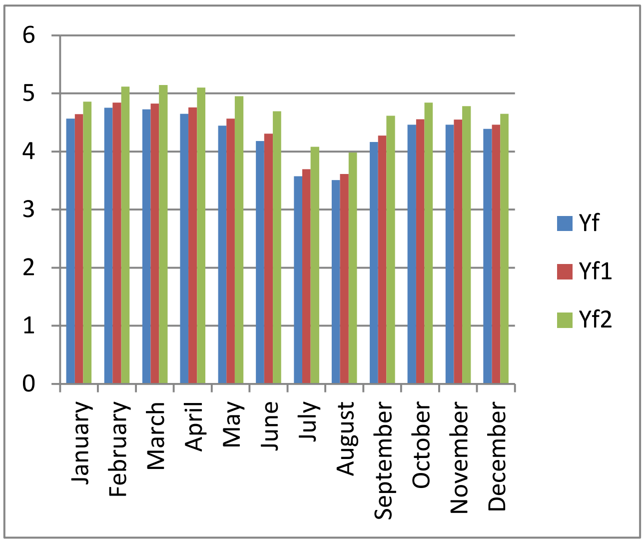

Fig. 1.7. Monthly yield forecasting for a complete year

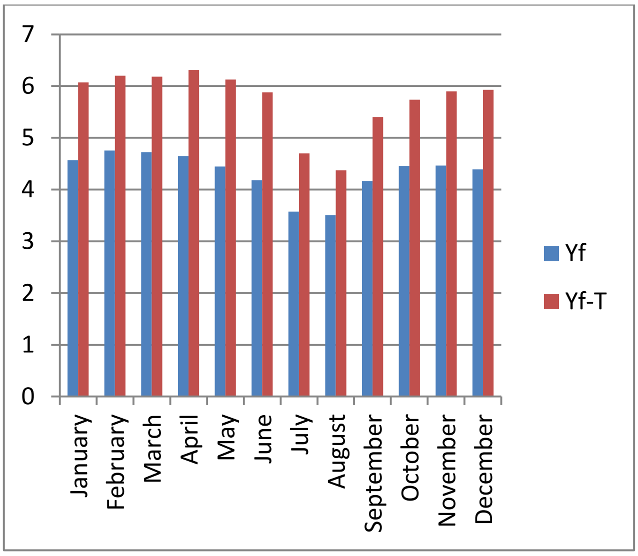

Fig. 1.8. Monthly yield forecasting for a complete year with tracking

Losses Simulation-Using PV-SYST loss diagram for complete year was obtained in which spectral losses as well as module and inverer based losses can be classified and calculated. Loss diagram is useful in classification and calcultion of losses as well as to understand effect of parametric variation and system components on losses present in proposed system.

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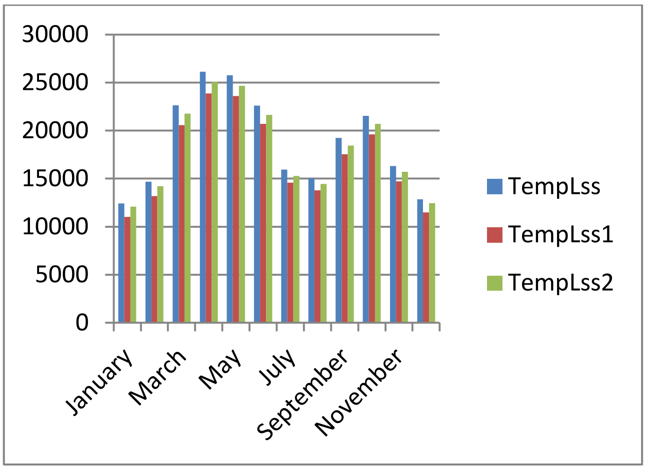

Fig.1.9 Loss Diagram of SPV Plant for April Month

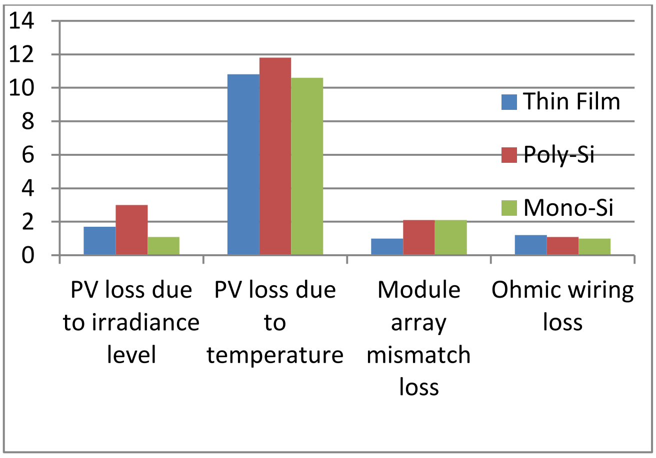

Fig. 1.10 Loss diagram of SPV Plant for One Year

Performance Ratio-Performance ratio is defined as ratio of final yield to refernce yield which is given in Fig. 6.7 for a complete year.

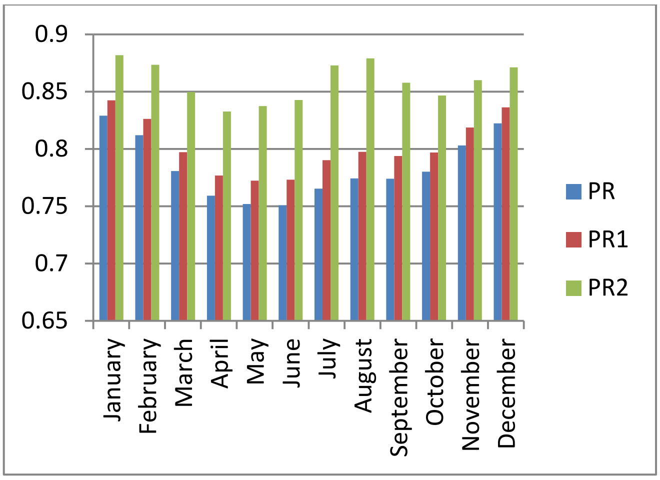

Fig. 1.11 Forecasting of Performance Ratio for a Year

Generation Forecasting-Using PV syst forecasted values of yearly generation is calculated on basis of kWh/Month. We have also simulated forecasted value of generated power by Solar PV plant for April month calculated on the basis of kWh/day. The results are shown in figure 1.14 and figure 1.15.

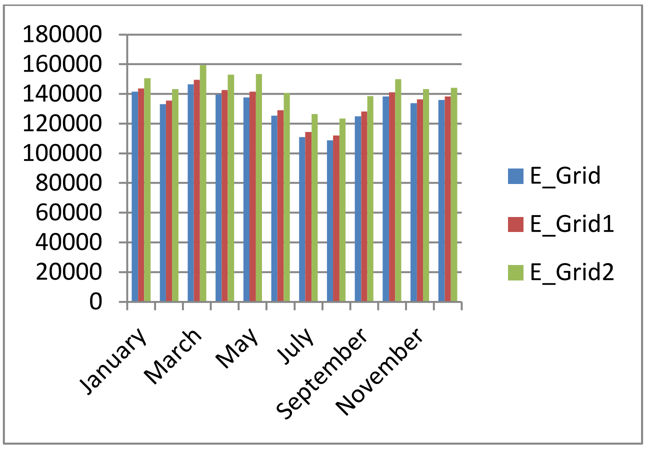

Fig. 1.12 Forecasting of Performance Ratio for a Year

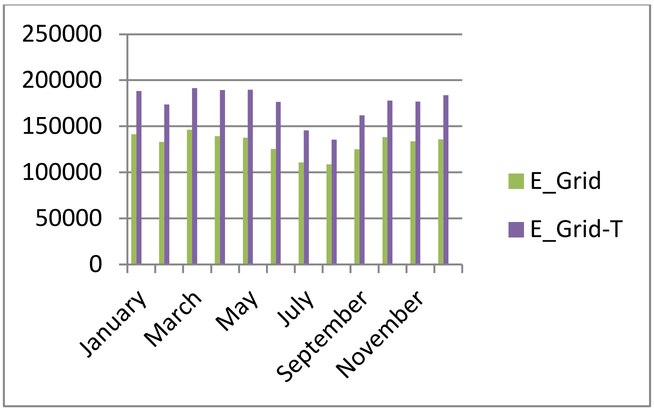

Fig. 1.13 Forecasting of Performance Ratio for a Year

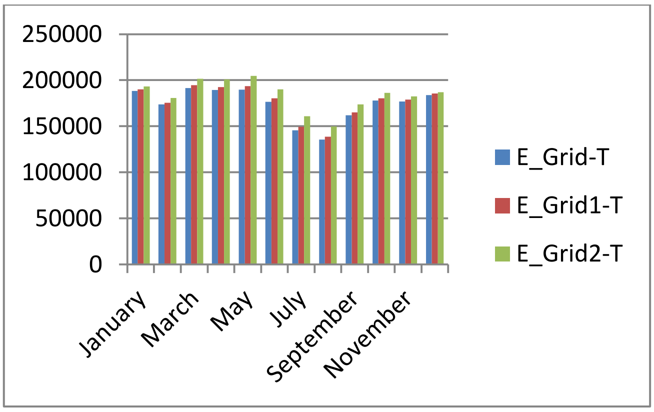

Fig. 1.14 Forecasting of Performance Ratio for a Year

The value of forecasted values obtained from simulation of equivalent mathematical model is formulated for comparison and analysis with the actual recorded data which is explained in next section. Comparison with actual recorded data can be used to access the accuracy of forecasted model as well as for optimum planning and economic analysis of installed system.

VI. RESULTS

Simulated as well as experimental results of performance assessment, yield forecasting and loss forecasting for installed grid connected solar photovoltaic, system at Poornima university have been obtained, The results obtained from forecasting simulation have been summarized in tabular form. Table 6.1 explains the result obtain for four parameters from simulation

Table 3- Summary of Simulation/Forecasting

Name of Parameters	Yearly Average Forecasted Value	Average Forecasted Value (April)
PR	**0.79**	**0.773**
Reference Yield	**7.28**	**8.26**
Final Yield	**5.81**	**6.385**
Energy Output for Inverter (KWH)	**176682.33**	**191534**

Table 4- Summary of Recorded Data

Manufacturing Technology	Price/Wp	Generation /Yearly	Generation Cost
Poly- Silicon	38	2081 MWH/Year	5.50/unit
Mono-Silicon	45	2125 MWH/Year	6.11/Unit
Thin Film	30	2211 MWH/Year	4.38/unit

To obtain the performance of forecasted model parameters from recorded data logger is compared with the forecasted value of PV-Syst. Table 5 explains the deviation in forecasted and actual recorded value .

Table 5- Summary of Recorded Data

Manufacturing Technology	Area	Model Number	Panel Efficiency
Poly- Silicon	7093 m2	TATA-BP	16.15
Mono-Silicon	5435 m2	Sun Power	20.46
Thin Film	10997 m2	Bosch	9.69

Table 6- Summary of Recorded Data

Parameters / Year	2013	2014	2015	Average	PV-Syst
Einj_grid(MWh)	1551	1641	1541	1578	1576
Maximum generation (MWh)	Mar-164	Mar-161	Apr-154	160	146
Minimum generation (MWh)	Aug-88	Jan-109	Jan-116	104	108
Performance ratio (%)	74.2	78.2	76.2	76.2	78.34
Cumulative utilization factor	17.7	18.7	17.5	17.9	4.38
Array yield (YA) kWh/kWp/day	4.2	4.4	4.2	4.3	4.38
Reference yield (Yr) kWh/kWp/day	5.6	5.7	5.6	5.6	5.51
Final yield (Yf) kWh/kWp/day	4.1	4.4	3.8	4.1	4.32
Array losses (Lc) kWh/kWp/day	1.4	1.2	1.3	1.3	1.1
System losses (Ls) kWh/kWp/day	0.05	0.03	0.45	0.17	0.06

VII. CONCLUSION

In this paper For the efficient utilization of solar energy, it is essential to implement efficient mathematical model, design and installation process as well as forecasting techniques for planning and reliability.In our research work carried out we have addressed these problems and successfully developed each of the problem with the help of relevant software. We have implemented 1 MW solar power plant model in PV-Syst for Phagi Jaipur.It was evident that thin film module based system showes better performace at reduced cost of production but area required is compratively large due to less efficient system. Comparative analysis with real data proved that the prediction accuracy was 6 % for the PV Syst based simulation system.

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