Simulation and Performance Analysis of 100kWp Grid Connected Solar Photovoltaic Plant Using PVSyst Software

Pratik K. Mochi
Assistant Professor, Department of Electrical Engineering
C.S. Patel Institute of Technology, CHARUSAT University
Changa, Gujarat, INDIA
pratikmochi.ee@charusat.ac.in

***Abstract*— Solar photovoltaic is one of the emerging renewable energy technologies as its grid integration is one of the best way to increase the electrical energy potential of the nation and to fulfill the energy needs. For the simulation and performance analysis of grid connected photovoltaic system, PVSyst software provides very good platform in order to facilitate yield estimation and future expansion of power plant. In the same regards, this work presents simulation of 100kWp grid connected solar PV power plant situated at Charusat University, Gujarat, INDIA. In the simulation, various parameters such as geographical location, solar panel tilt angle, system sizing, operating temperature, inverter efficiency, electrical losses, sun position variation, simulation duration etc. are taken into consideration. A simulation has been done for year 2015 and power generation per month is compared with actual power generation of power plant. The simulation results obtained for one day and one month are also compared with actual power generation to analyze the variation and uncertainty of photovoltaic power generation. In addition to results, a detailed power flow diagram is obtained indicating all system losses and output power. The simulation results are matched with actual results of the plant. As a future work, a survey is to be done for calculation of rooftop space in other buildings for further expansion of power plant and simulation based study will be done to estimate power generation.**

Keywords*— *solar photovoltaic; grid integration; PVSyst simulation; renewable energy

I. Introduction

INDIA is the first in the world for designing and implementing solar powered system to run the load of an international airport located at Cochin. Solar power plants have been built across the country including Gujarat, Rajasthan, Maharashtra, Madhya Pradesh, Tamilnadu, Andhra Pradesh and other states with various schemes [1]. Presently India is 9^{th} in the world ranking with 4.963GW of installed capacity by solar photovoltaic technology [2].

For the performance assessment of solar power plant, various simulation and design tools are available. Out of these, PVSyst software is used in this study. By the simulation, the estimated power generation and cost analysis of solar power plant can be carried out for particular geographical location. This kind of study of solar photovoltaic power plant is very useful for new system and future expansion of existing system.

II. 100kWp Grid Connected Plant

The grid connected 100kWp solar photovoltaic plant under this study is located at Gujarat, INDIA. The basic components are solar pv module, module mounting structure, inverter and connection accessories like array junction box, ac distribution board with energy meter.

A. Solar Power Plant Rating

The geographical location of solar power generation plant is at latitude 22.3E and longitude 72N. The nominal system generation capacity is 100kWp at standard test condition (STC). The system gives three phase 415V, 50Hz output which is connected to nearest point of utility grid.

B. Solar Module

The photovoltaic technology used is multicrystalline solar cell with 60 cells connected in series to form one solar module. The power rating of one module is 250Wp at STC with open circuit voltage of 36.8V and short circuit current of 8.83A. A series parallel connection of modules is used for desired output power. In the system, total 20 modules are connected in series to make a single string and total 20 such kind of strings are connected in parallel. The system has total 400 solar modules.

C. Solar Module Mounting Structure

For the mounting and support of solar panels, the fabricated galvanized steel structure is used. This structure comprises of various components which are designed, managed and mounted in the place of installation to survive unfavorable weather conditions with minimum amount of maintenance. This structure provides optimum angle of inclination depending on system location. Generally optimum tilt angle for panel installation is kept equal to the latitude angle of location. In this system the tilt angle is selected to be 30 degree taking self cleaning and water runoff into consideration. Figure 1 shows the PV system at its location.

Fig. 1. Solar Photovoltaic System

D. Inverter System

The inverter used serves dual purpose of conversion from dc power to ac power and tracking of maximum power point of PV module. The inverter has MPPT voltage range of 350-800V DC, the nominal DC input power of 20.4 KW and output voltage is 415V three phase 50Hz. The nominal apparent power is 20 KVA.

E. Connection Accessories

In addition to solar modules and inverter, the connections accessories contributes important role in the system. These accessories includes array junction box, ac distribution board, PVC copper cables of different dimensions and length as per requirement, multi contact male and female cable coupler, nut, bolt, screw, socket, earthing wire and cable tie.

III. PVSYST SIMULATION TOOL

PVSyst is available freely for a 30 day trial period[3], during which period the full version is accessible. Data is included for certain stations and new data set can be created by importing data. PVSyst has a preliminary and a project design mode, and the preliminary mode can be used to get an approximate value of radiation and power output from the system. The project design mode allows for user defined losses, inverter efficiency, shading analysis and several other variables which provide a more accurate output[5]. The software has the following three main modules:

A. Preliminary design

PVSyst is a simple tool for grid, stand-alone or pumping system pre-sizing. Based on user's requirements like energy needs and "Loss of load" probability, and very few other input parameters, this provides the photovoltaic system component sizes, evaluates the daily, monthly and yearly production and performances, and performs a preliminary economic evaluation of the PV system[5].

B. Project design

This is used for performing detailed simulation in hourly values, including an easy to use expert system, which helps the user to define the PV-field and to choose the right components. This produces a complete printable Report with all parameter and main results[5].

C. Tools

This module performs the database meteorological and components management. It provides also a wide choice of general solar tools (solar geometry, meteorological on tilted planes, etc), as well as a powerful mean of importing real data measured on existing PV systems for close comparisons with simulated values[5].

IV. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

PVSyst is a user friendly photovoltaic system design and simulation tool which gives wide range of inputs for simulation and provides detailed performance characteristic of PV system in grid connected as well as standalone mode. PVSyst has a large database of meteorological data for a number of location all over the world. It also provides manual insertion of measured data for sites which are not enlisted in the software. It presents results in the form of a full report which includes specific graphs and tables. The data can be exported for use in other software. To obtain results, we have to provide some inputs to the software. Simulation variables in PVSyst are geographical location, solar insolation, inverter losses, system operating conditions.

The system parameters have been given as input in the simulation and results for different duration are recorded and compared with actual power generation. Figure 2 shows the energy production per kWp and losses for 12 months. The simulation result shows that the power generation in every month is variable in nature which is obvious.

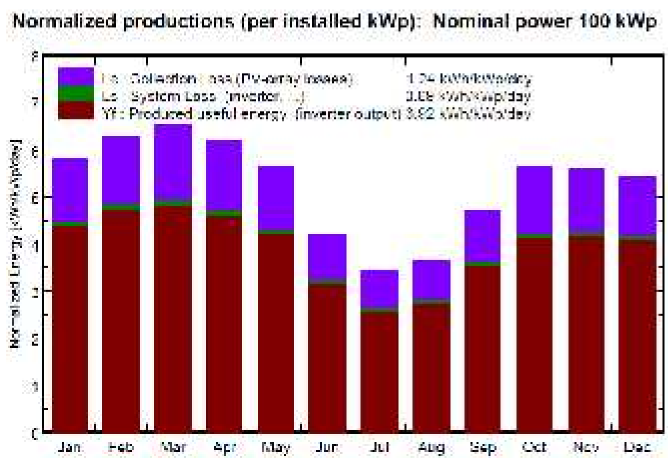

Fig. 2. Energy Production per kWp for one year

The software facilitates the simulation for one day to estimate the power generation. The simulation has been done for 29th April and the curve of power generation during whole day is shown in the figure 3. The actual power generation for the same day has also been recorded and the power generation curve is shown in figure 4. In both the results, the peak value of power is going near to 70KW in the peak sun hours. The actual power generated for the day is 745kWh which is nearly equal to the power generation estimated by simulation. Again the actual power generation of each day depends on the weather condition which can make difference with simulation result.

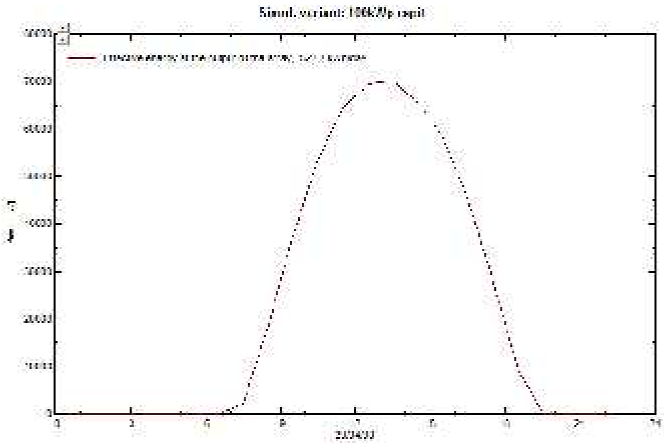

Fig. 3. Simulation result for one day

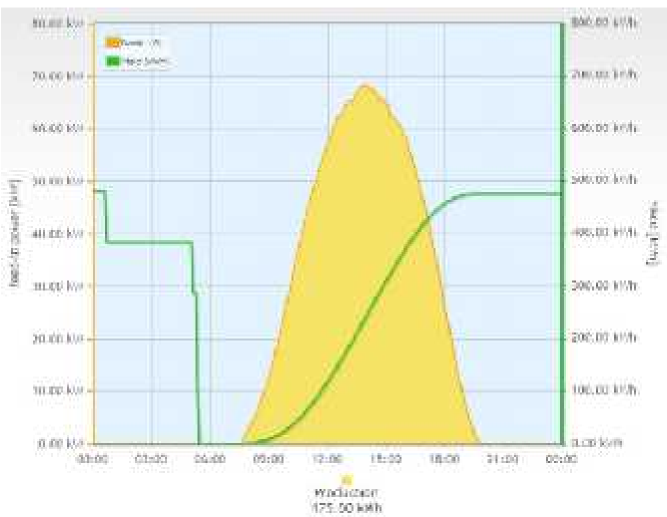

Fig. 4. Actual power generation for one day

The simulation is carried out to approximate the power generation for one month. The simulation is done for February month which includes 28 days and the power generated in each day is shown in graphical manner in figure 5.

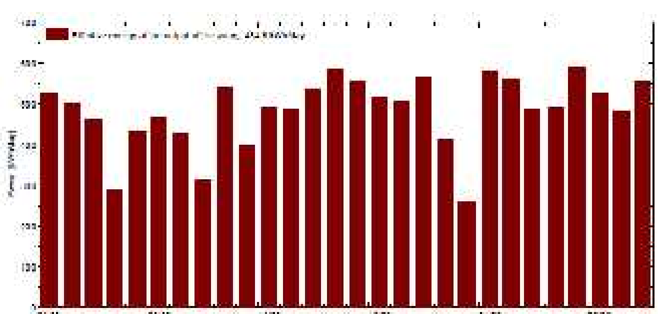

Fig. 5. Simulation result for one month

To compare the simulated results with actual power generation in same month, the actual result has been recorded as shown in table I.

TABLE I. ACTUAL POWER GENERATION IN ONE MONTH

Day	kWh	Day	kWh	Day	kWh	Day	kWh
1	365	8	505	15	449	22	458
2	368	9	492	16	361	23	550
3	422	10	483	17	288	24	512
4	450	11	469	18	396	25	382
5	419	12	455	19	386	26	465
6	441	13	489	20	345	27	498
7	470	14	318	21	352	28	372

According to the simulation, the power generation for the year 2015 is 143240 kWh. The variation in power generation by each month is shown in the table II. The actual power generated in the year 2015 is 141593 kWh. The actual power generated by each month is compared with simulation result. Thus PVSyst software provides the approach for the comparing simulation results with actual results in wide range of time period of power generation.

TABLE II. COMPARISON OF SIMULATION AND ACTUAL RESULTS

Month of Year 2015	Simulation result (kWh)	Actual power generation (kWh)
January	13586	13078
February	13279	13493
March	14969	14620
April	13819	13768
May	13027	14255
June	9446	9691
July	8040	7467
August	8541	10067
September	10545	11803
October	12822	12684
November	12556	8592
December	12611	12075
Total	**143240**	**141593**

The loss flow diagram of the system is shown in fig. 6. The Incidence Angle Modifier (IAM) refers the reduction of insolation reaching photovoltaic cell due to reflection of sun rays while passing through glass cover of pv module. These losses increase with increase in incident angle with respect to sun position [3]. For present system, these losses are 3%. The PV loss due to irradiance level refers to the decrease in module efficiency in low light conditions and it is 2.6% in this case. The system has maximum losses due to temperature that is 14.3%. The performance of solar module changes with change in temperature. The temperature coefficient of module and thermal loss factor affect this loss. The thermal loss factor is not a scientifically determined value but it is set by designers according to experience and previous estimations. A value of $20W/m^2k$ is acceptable for most systems. If modules are mounted on roof structure, the value can be set to 15. When the modules are free standing in a cool and windy location, the value can be set to 29. For crystalline silicon technology, the open circuit voltage of module drops about 0.37% for each degree Celsius increase in temperature and short circuit current increases by approximately 0.05% [4].

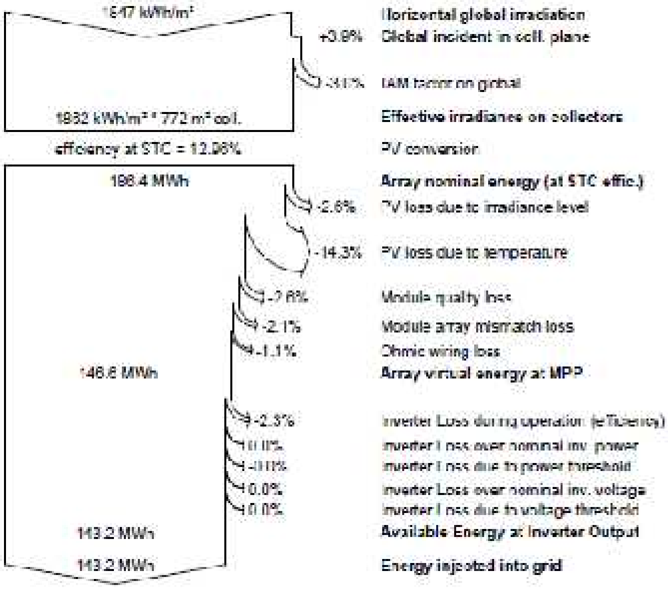

Fig. 6. System loss flow diagram

The module quality loss is 2.6% which depends on tolerance value of quality loss provided by manufacturer. It is calculated by lower tolerance plus quarter of the difference between lower and higher tolerance. The module mismatch loss is 2.1%. it is because of mismatch between modules in string. The reasons for mismatch can be different tilt angles, different types of cable connections, uneven soiling, temperature difference between modules etc [5]. The losses due to shading and soiling are neglected in this case. The rest of the losses include inverter losses, ohmic losses due to conversion from dc power to ac power and connections of cables.

V. CONCLUSION

The PVSyst software is a very good design and simulation tool for grid connected PV system that provides any range of duration of simulation for calculating estimated power generation. When comparing simulated result with actual power generation, it is found that the both results are nearly same for annual power generation. For more accurate results, the actual calculation of ohmic loss can be done and analysis of soiling loss can be carried out in actual system which demands a survey for estimating uncertainty of soiling loss and weather conditions. For the future work, the space available for installation of photovoltaic module can be calculated and power generation can be approximated for this expanded system. Furthermore the power generation can be increased by changing the tilt angle of the panel equal to latitude angle of geographical location.

ACKNOWLEDGMENT

The author would like to thank Dr. Praghnesh Bhatt, Head of Electrical Engineering department, CSPIT, CHARUSAT University, for his continues motivation. The author also thank to Prof. Chetan S. Solanki, IIT Bombay, for his valuable suggestions and help.

REFERENCES

[1] S. Deambi, “ Solar PV Power: A global perspective”, ISBN 978-81-7993-389-3, TERI Press 2012

[2] www.irena.com

[3] www.pvsyst.com

[4] G.M. Masters, “Renewable and efficient electric power systems” ISBN 0-471-28060-7, Wiley 2004

[5] Dr. B.D.Sharma, “Performance of solar power plant in India” Feb 2011.