Journal of Science and Technology
ISSN: 2456-5660 Volume 06, Issue 02, March-April 2021
www.jst.org.in *DOI: https://doi.org/10.46243/jst.2021.v6.i2.pp79-86*

Design Optimization and Simulation of a Solar Grid Connected Photovoltaic System for a Residential House in West Central Maharashtra

Aditya Arvind Yadav[1], Niranjan Oturkar[2], Ketki Suryakant Deshmane[3]
[1]*(M. Tech (Energy Technology), Department of Technology, Shivaji University, Kolhapur, Maharashtra, India)*
[2,3]*(M. Tech (Energy Technology), School of Energy Studies, SPPU, Pune, Maharashtra, India)*
[1]*Corresponding Author: adiyadav821@gmail.com*

To Cite this Article
Aditya Arvind Yadav, Niranjan Oturkar, Ketki Suryakant Deshmane, "Design Optimization and Simulation of a Solar Grid Connected Photovoltaic System for a Residential House in West Central Maharashtra", Journal of Science and Technology, Vol. 06, Issue 02, March-April 2021, pp79-86

Article Info
Received: 22-10-2020 Revised: 02-02-2021 Accepted: 11-02-2021 Published: 12-02-2021

Abstract: *The present work focuses on design of a grid connected solar Photovoltaic system for a typical house using dynamic simulation software PVSYST. The PVSYST is a state-of-art dynamic simulation software used for designing of solar PV system i.e., grid tied and stand-alone system. The major steps involved in the designing of any Solar Photovoltaic system is analysis of electrical appliances consumption, electricity bill analysis and estimation of solar radiation data at the proposed site. The PVSYST software enables the user to select the Solar PV module, inverter, batteries, and other accessories through the list of templates available in software. The performance parameters like normalized energy, performance ratio, daily input-output and system output power distribution are displayed in the final simulated report.*

The case study simulated in the PVSYST software is located for one of the apartment in Aparna Housing Society, Tanaji Nagar Pimpri Chinchwad, Pune, Maharashtra, India. The produced useful energy for proposed system is 4.74 kWh/kWp/day with performance ratio of 79.60%. As far as losses from the system are considered it is about system losses comprises of 0.15 kWh/kWp/day and collection losses is 1.07 kWh/kWp/day respectively.
Key Word*: Grid connected, Solar Photovoltaic system, PVSyst, Performance Ratio, Solar Energy*

I. Introduction

India is one of the fastest developing country with large number of energy consumer in the world. Generally, electricity generated in India is through non-renewable energy sources. India relies on coal power plants, 76% of electricity is generated by coal power plants. Hydro power plants, nuclear power plants and natural gas power plants also contribute in total electricity generation in India.The energy consumption in India is increasing annually with increase in consumption of coal, import of coal and decrease in reserves of coal. Due to increasing energy consumption burning of coal for electricity generation will increase the environmental impact such as global warming, acid rain etc. India largely imports coal and oil from other countries increasing import bills on our economy and making dependent on others. So, to decrease the environmental impacts and increase energy security India needs to switch to alternative renewable energy sources.India has set an ambitious plan to increase generation of power from renewable energy sources by 40% till 2030. In fact, Indian government has predicted that the country will have installed renewable energy capacity of 44% by 2027.

The earth receives nearly 1.8 × 1017 W of total incoming solar radiation at the top of the atmosphere at the top of the atmosphere. The total solar power reception on the land area in India is about 5000 trillion kWh per year. India receives nearly about 250 to 300 clear sunny days. The average solar radiations incident is in the range of 4 to 7 kWh per m2. Thus, sun provides unlimited supply of energy. The availability of abundant solar energy, available terrace space are the main parameters that can be considered while designing a solar photovoltaic system [1].

II. Study Region

The simulated project is located at the one of the apartments situated at Aparna Housing Society,Tanajinagar, Pimpri Chinchwad, Pune, Maharashtra state, India. The GPS coordinates of the location are 18°37'35.5"N 73°47'14.8"E. The study region selected because maximum number of societies in this region have free space on terrace which can be used for solar photovoltaic system installation. The average solar radiation in this area is 4.88 kW-hr/m2/day which is enough to fulfil the electricity demand of a typical house. Generally, the electricity supplied to this region is generated through non renewable energy sources. So, installation of solar photovoltaic system will help to decrease pollution through non-conventional power plants to certain extent.

Figure no. 1: GPS Location of proposed system

III. Material and Methods

There are two types of solar photovoltaic system grid connected and standalone. In grid connected system the electricity generated by photovoltaic system is feed directly into electric grid/network. The grid connected system does not require batteries for storage of electricity. Whereas in standalone system batteries are required as electricity is directly supplied to load not to the grid. The amount of electricity generated through solar photovoltaic system depends on local solar radiations.[2]

The steps involved in the designing of a solar photovoltaic system for any typical load is as follows: -

1. Analysis of electric bills for minimum 2 years.
2. Analysis of actual electrical equipment's and its usage per hour.
3. Analysis of local solar radiations at the site where solar PV system is to be installed.
4. Simulating the site location on PVSYST Software.
5. Deciding which system is benefited for the site.

Electricity Bills Analysis

The electricity supplied to the apartment is by Grid Connected Maharashtra State Electricity Board i.e., single phase 230 V; 60 Hz respectively. The detailed yearly bills for year 2019 and 2020 are as follows: -

Table no. 1: Electricity Bill analysis for year 2019

S. No	Month	Units Consumed	Bill Amount (in INR)
1	January	295	2560
2	February	248	2150
3	March	381	3800
4	April	553	6060
5	May	549	6220

6	June	611	7150
7	July	390	3810
8	August	330	2980
9	September	321	1830
10	October	283	2400
11	November	321	2880
12	December	309	2890
Average		382.58	-

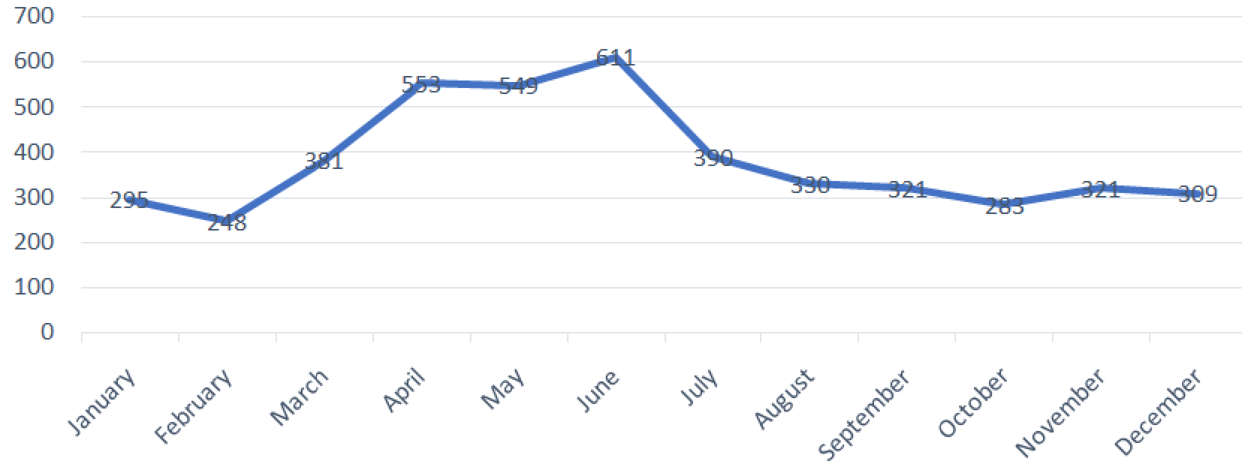

Figure no. 2: Electricity units consumption in year 2019

Similarly, the electricity consumption bill for year 2020 was also analyzed. The details of the electricity bills for year 2020 are as given below:

Table no. 2: Electricity Bill analysis for year 2019

S. No	Month	Units Consumed	Bill Amount (in INR)
1	January	310	2859
2	February	232	2059
3	March	186	1621
4	April	243	2169
5	May	456	4482
6	June	448	4658
7	July	295	2660
8	August	238	2060
9	September	237	2070
10	October	237	2080
11	November	286	2580
12	December	309	2890
Average		289.75	-

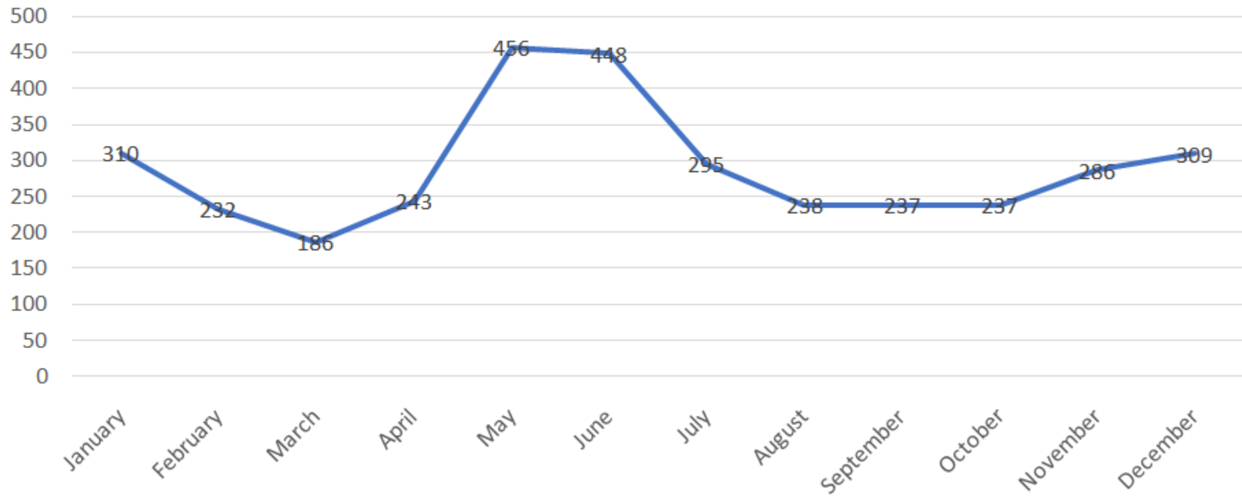

Figure no. 3: Electricity units consumption in year 2020

Electrical Equipments Analysis

The next step in the analysis is to analyse is analysing the actual electrical equipment usage per hour. The appliances used in the house are fans, LED tube, Air conditioner, Refrigerator, Washing machine, Oven, Food processor, Television, Computer and LED Bulb etc. The ratings, time of operation and units consumed per day are as shown in table below: -

Table no. 3: Analysis of Electrical Appliances

S. No	Electrical Appliances Specifications	Ratings (kW)	Time of operations (Hours)	Electricity Consumption per day (kW)
1	Fan (Bedroom 1)	0.07	10	0.7
2	Fan (Living Room)	0.07	9	0.63
3	Fan (Bedroom 2)	0.07	8	0.56
4	LED Tube (Bedroom 1)	0.02	5	0.1
5	LED Tube (Living Room)	0.02	5	0.1
6	LED Tube (Kitchen)	0.02	5	0.1
7	LED Tube (Bedroom 2)	0.02	4	0.08
8	LED Tube (Hall)	0.02	5	0.1
9	Air Conditioner	1.926	4	7.704
10	Refrigerator	0.252	24	2
11	Washing Machine	0.07	0.8	0.056
12	Oven	1.86	0.08	0.1488
13	Food Processor	0.7	0.16	0.112
14	TV	0.18	3	0.54
15	Computer	0.1	2	0.2
16	LED Bulb 1	0.009	0.5	0.0045
17	LED Bulb 2	0.009	0.5	0.0045
18	LED Bulb 3	0.009	0.5	0.0045
Total				13.443

IV. Result and Discussion

PVSYST Version 7.1.1

PVsyst is the dedicated simulation software for PV system. It was developed by University of Virginia. It helps in calculating pre-feasibility, sizing and simulation support for PV system. It automatically calculates the sizing of the PV system through the inputs given like longitude and latitude of the location, specification of the load and selection of components through product database. Financial analysis is also calculated through this software. The details of Grid connected system are as below: [3]-[5]

Grid Connected System

The PV Model characteristics for a designed grid connected system are as given below in table:

Table no. 4: PV system characteristics for grid connected system

S. No	Characteristics	Output
1	Manufacturer and Model	Generic (Monocrystalline 300Wp and 60 Cells)
2	Unit Nominal Power	300 Wp
3	Total Number of PV Modules	37 Units (37 strings ×1 Series)
4	At operating condition	
	Pmpp	9.99kWp
	U mpp	28 V
	I mpp	351 A
5	Nominal (STC)	11 kWp
6	Module area	60.2 m2
7	Cell area	52.6 m2

The Inverter characteristics for the designed grid connected PV system are as follows:

Table no. 5: PV system characteristics for grid connected system

S. No	Characteristics	Output
1	Manufacturer and Model	Generic (IQ7-60× 240)
2	Unit Nominal Power	0.240 kWac
3	Total Number of Inverters	36 Units
4	At operating condition	
5	Operating Voltage	16-37 V
6	Maximum Power	0.250 kWac
7	Pnom ratio	1.28(DC:AC)
	Total power	8.6 kWac

A. Normalized Energy

The normalized energy bar chart for each month in a year resembles various losses i.e. collection loss (Lc); System loss (Ls); and Produced useful energy (Yf) respectively. Following graph shows the details of normalized energy in kWh/kWp/day at study location.

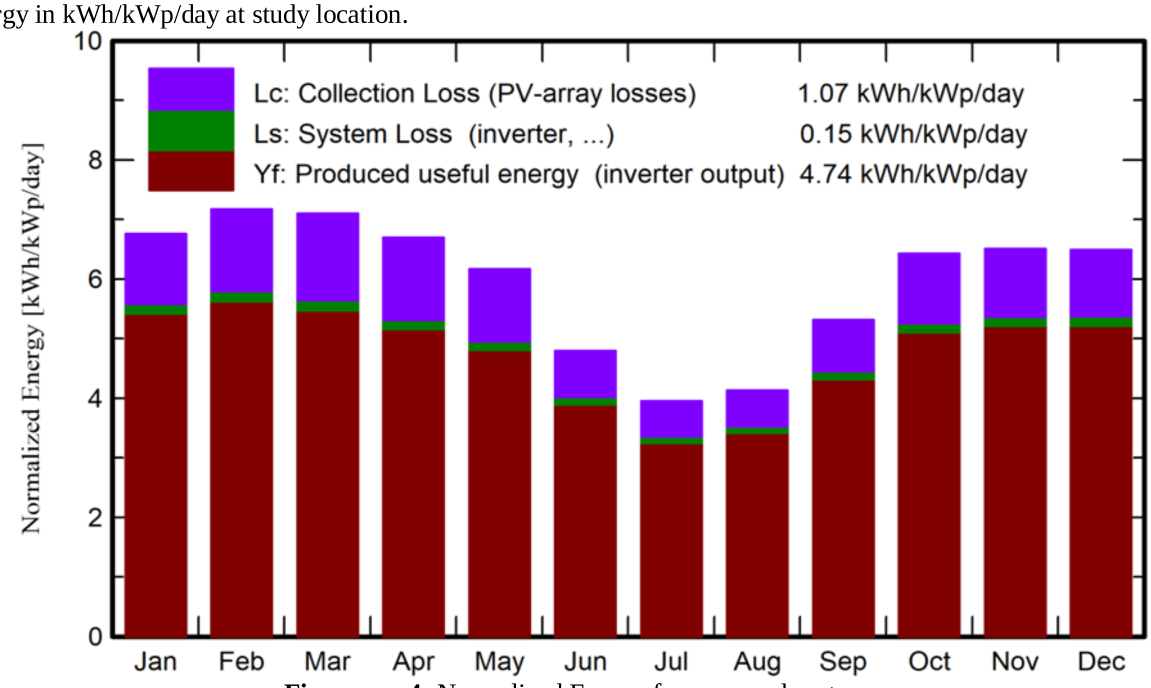

Figure no. 4: Normalized Energy for proposed system.

B. Performance ratio

The Performance ratio describes the relationship between actual and theoretical energy outputs of simulated PV system. The performance ratio (PR) obtained was 79.6% respectively.

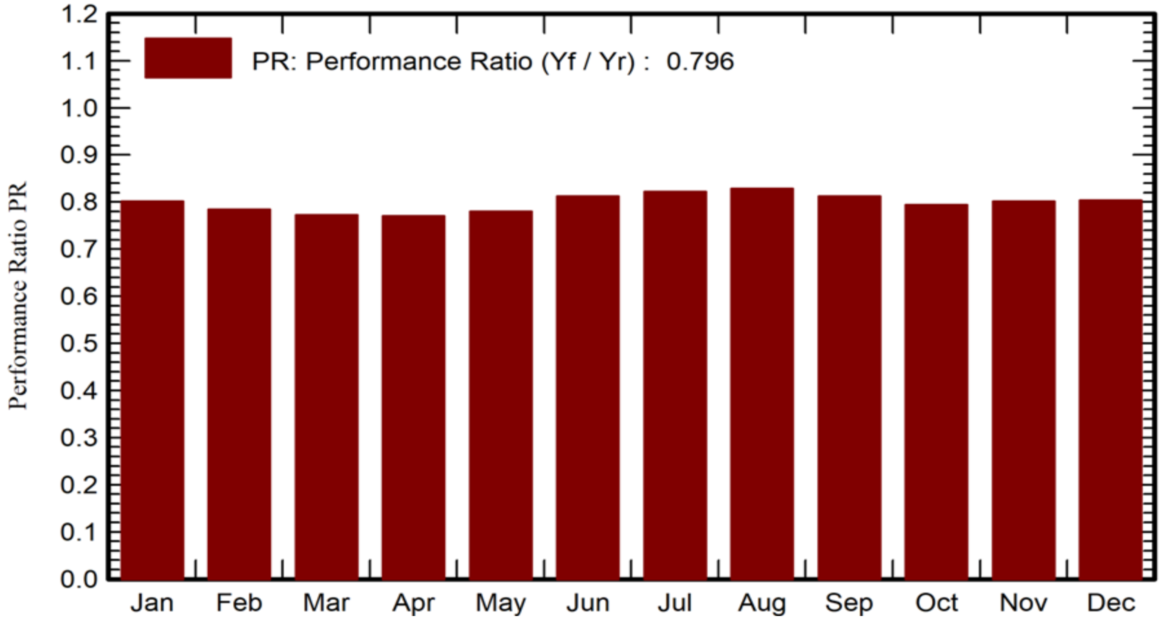

Figure no. 5: Performance Ratio for proposed system.

C. Daily Input-Output Diagram

The detail input output diagram is the relationship between global incident radiation to energy injected to the grid in kWh per day. The details of the daily input-output curve is as shown below:

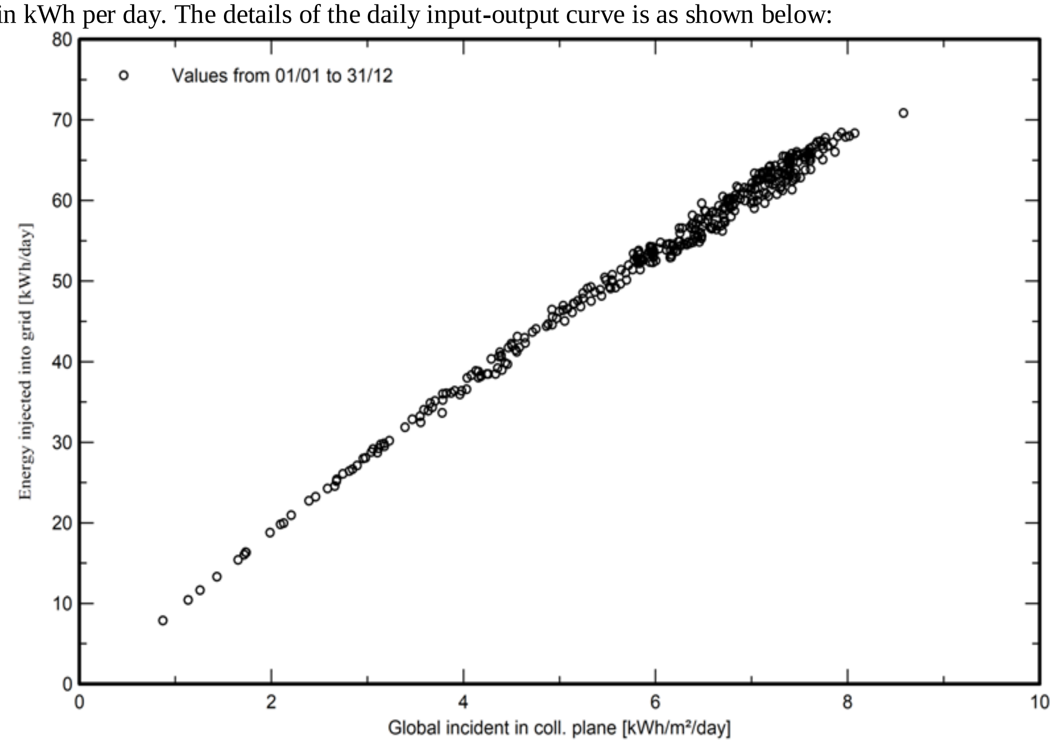

Figure no. 6: Daily input-output for proposed system.

D. System Output Power Distribution

The detail input output diagram is the relationship between power injected into the grid to the energy injected into the grid in kWh per Bin respectively. The details of System Output Power Distribution curve is as shown below:

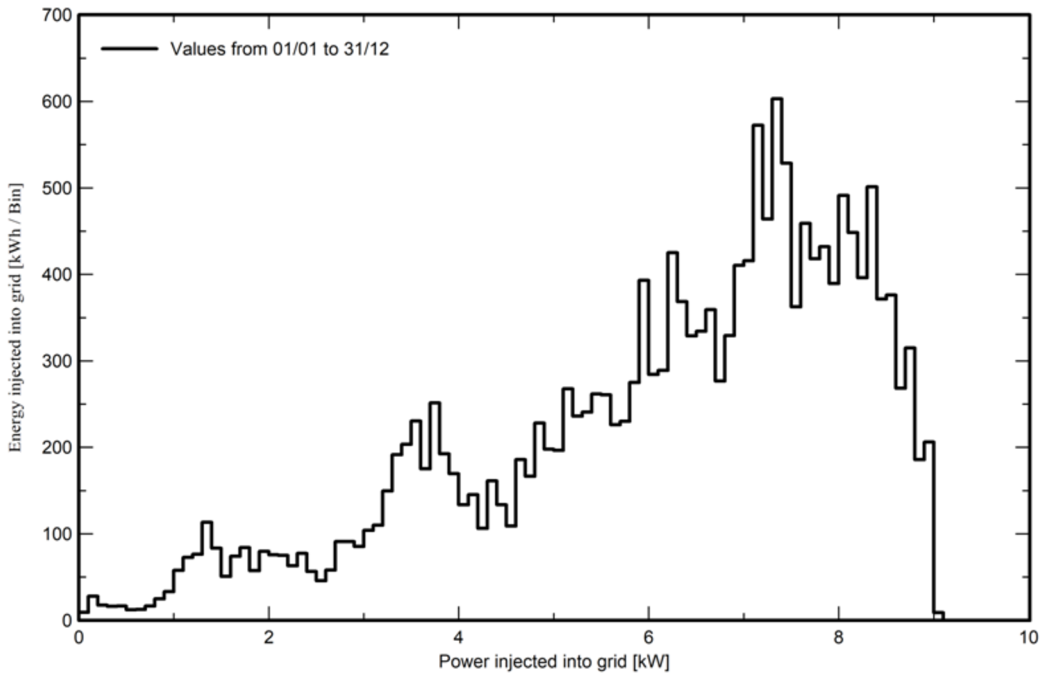

Figure no. 6: System output power distribution for proposed system

E. Balances and Main Result

Table no. 5: Balances and main result

S. No	Month	Global Horizn Irradiation (kWh/m²)	Horizontal diffuse irradiation (kWh/m²)	Amb Temperature (°C)	Global incin. On coll. Plane (kWh/m²)	Eff. Global correction (kWh/m²)	Eff. Energy at O/P of array (Mwh)	Energy injet. Into grid (Mwh)	Perfo.Ratio
1	January	157.3	42.72	20.34	209.5	207.0	1.922	1.865	0.802
2	February	165.7	42.16	22.85	200.9	198.4	1.803	1.749	0.784
3	March	204.4	55.16	26.71	220.0	216.1	1.944	1.885	0.772
4	April	210.9	67.81	29.41	200.8	196.5	1.771	1.718	0.771
5	May	223.3	71.02	29.45	191.2	185.9	1.706	1.655	0.780
6	June	171.9	87.14	26.26	143.9	139.3	1.340	1.298	0.812
7	July	142.8	79.75	24.97	122.4	118.7	1.156	1.118	0.822
8	August	139.0	88.84	24.11	128.0	124.5	1.216	1.177	0.828
9	September	159.7	78.15	24.50	159.4	155.8	1.483	1.438	0.813
10	October	173.8	63.18	24.96	199.3	196.0	1.811	1.757	0.794
11	November	153.0	47.08	22.15	195.2	192.6	1.789	1.736	0.801
12	December	148.4	40.34	20.13	201.3	199.0	1.851	1.796	0.804
Total		2050.3	763.35	24.66	2172.1	2129.9	19.79	19.19	0.796

V. Conclusion

The PVSYST is a state-of-art dynamic simulation software used for designing of solar PV system i.e., grid tied and stand-alone system. The proposed system is simulated in PVSYST software is located for one of the apartment in Aparna Housing Society, Tanaji Nagar Pimpri Chinchwad, Pune, Maharashtra, India. The simulated system has a normalized energy i.e., produced useful energy about 4.74 kWh/kWp/day and performance ratio of about 79.60% respectively. The losses by the system are system losses which comprises of 0.15 kWh/kWp/day and collection losses of 1.07 kWh/kWp/day respectively. The electrical consumption per day is about 13.44 kW, whereas the produced useful energy is 4.74 kW per day which is be easily utilized by the grid connected solar PV system. The number of monocrystalline Solar PV panels required are 37 Units (37 strings ×1 Series). The module area required is 60.2 m2 and cell area required is 52.6 m^2.

References

[1]. Ketki M, Deshmane S, Yadav AA, Ingawale SM et.al; Wind data Estimation of Kolhapur district using Improved Hybrid Optimization by Genetic Algorithms (iHOGA) and NASA Prediction of Worldwide Energy Resources (NASA Power). International Research Journal of Engineering and Technology; 2020; 7(3): 2530–2538.

[2]. Aditya Arvind Yadav, Akshay Vijay Yadav, Dr. Jaydeep Bagi and Mr. Pravin A Prabhu et.al; Design of a Solar Modified Greenhouse Prototype. Journal of Science and Technology; 2021; 06(01): 118-125.

[3]. Aditya Arvind Yadav, Shrikant Madan Ingawale, P A Prabhu et.al; Energy Consumption Assessment of Grain Drying Industry in India. International Journal of Engineering Research and Applications; 2020; 10(12): 22-28.

[4]. ElieserTarigan, Djuwari, FitriDwiKartikasari et.al; Performance analysis of 100 kWp grid connected Si-Poly photovoltaic system using PvSyst Simulation tool. Conference and Exhibition Indonesia - New, Renewable Energy and Energy Conservation (The 3rd Indo-EBTKE ConEx 2014)Energy Procedia; 2015;65 (2015) 90 – 99.

[5]. Ahmed Alnoosani, MowffaqOreijah et.al; Design of 100MW Solar PV on-Grid Connected Power Plant Using (PVsyst) in Umm Al-Qura University. International Journal of Science and Research; 2019; 08(11): 356-363.