Performance Evaluation of Grid-connected Solar Photovoltaic plant using PVSYST Software

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***Abstract*— Electricity is an essential part of our way of life. Most of the electricity is currently provided from the conventional thermal or hydro power stations. With the growing concern about the greenhouse gas emission and other environmental issues the renewable energy technologies such as photovoltaic cells are increasingly being recommended for electricity production. In this paper, the simulation of a grid-connected solar photovoltaic system is presented with the use of the computer software package Pvsyst and their performance was evaluated. The performance ratio and the various types of power losses (temperature, internal network, power electronics) are calculated. From the results, the viability of installing 1 MW solar photo voltaic (PV) power plant is discussed at geographical location shapur, Gujarat**

***Index Terms*— Electricity, Grid connected solar PV system, Photovoltaic cells, PVsyst software, Gujarat.**

1. INTRODUCTION

A photovoltaic (PV) system consists of a PV array, battery and elements for power conditioning. The PV system converts solar energy into dc power. If ac loads are used means, the system requires inverter to convert dc into ac. There are two types in PV system such as grid connected and standalone. Grid connected photovoltaic systems feed electricity directly to the electrical network, operating parallel to the conventional energy source. Grid-connected systems generate clean electricity near the point of use, without the transmission and distribution losses or the need for the batteries. Its performance depends on the local climate, orientation and inclination of the PV array, and inverter performance. Whereas, a stand-alone system involves no interaction with a utility grid, the generated power is directly connected to the load. In case the PV array does not directly supply a load, a storage device is needed [1]. Mostly this is a battery, the battery bank stores energy when the power supplied by the PV modules exceeds load demand and releases it backs when the PV supply is insufficient. This standalone PV power generation will be used in the home for the electrification purpose [2]. A wide variety of tools exist for the analysis and dimensioning of both Grid connected and stand-alone photovoltaic systems. System designers and installers use simpler tools for sizing the PV system. Mostly scientists and engineers typically use more involved simulation tools for optimization. Software tools related to photovoltaic systems can be classified into pre-feasibility analysis, sizing, and simulation. PVsyst is a dedicated PC software package for PV systems. The software was developed by the University of Geneva. It integrates pre-feasibility, sizing and simulation support for PV systems. After defined the location and loads, the user selects the different components from a product database and the software automatically calculates the size of the system. The solar data at 0.5° latitude and longitude resolution are available in PVsyst Software [3, 4]. Financial analysis can also be performed. Economic feasibility and viability of implementing PV solar energy in the State of Kuwait was found that the energy resources used in producing traditional electricity was saved and the cost of CO2 emissions was also saved [5]. In this work, the simulations are performed by using PVsyst 5.41. By comparing the energy production, performance ratio, efficiency and cost, the optimal location for installing 1MW grid connected solar PV power plant in the shapur village in Gujarat are discussed. The graphs and tables that will depict in the later portion of the paper had been generated while doing the simulation.

2. GEOGRAPHICAL CONDITION AND LOCATION OF SHAPUR VILLAGE AT GUJARAT

The project site is located at Latitude 21°28.835' N and Longitude 70°22.254'E.

Table 1 Monthly Meteo Values

Definition of a geographical site

Geographical Site

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Situation	Latitude 21.5°N	Longitude 70.4°E	
Time defined as	Legal Time Time zone UT+5.5	Altitude 40 m	

Monthly Meteo Values Source Meteonorm 6.1

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
Hor. global	5.03	5.87	6.77	7.30	7.39	5.89	4.52	4.24	5.29	5.73	5.06	4.65	5.64	kWh/m².day
Hor. diffuse	0.96	1.22	1.54	1.93	2.39	3.16	2.93	2.93	2.55	1.57	1.25	1.08	1.96	kWh/m².day
Extraterrestrial	7.29	8.42	9.57	10.52	10.96	11.06	10.99	10.67	9.92	8.80	7.59	6.94	9.40	kWh/m².day
Clearness Index	0.690	0.698	0.708	0.695	0.675	0.532	0.411	0.397	0.533	0.651	0.667	0.670	0.600	
Amb. temper.	21.0	22.7	26.2	28.8	30.7	30.8	29.1	27.8	27.8	28.2	26.1	22.7	26.8	°C
Wind velocity	2.2	2.4	2.8	3.2	4.2	4.9	5.7	4.6	2.9	1.9	1.7	1.9	3.2	m/s

In PVsyst location of geographical site was selected so from meteonorm monthly meteo values for whole year are generated as shown in table 1

3. GRID CONNECTED SOLAR PV SYSTEM

1 MW grid connected solar PV power plant is installing the energy production, economic feasibility of the place of shapur village at Gujarat using PVsyst Software. Figure 1 shows the proposed model of the grid connected PV system. The following tables, figures are given for shapur site only.

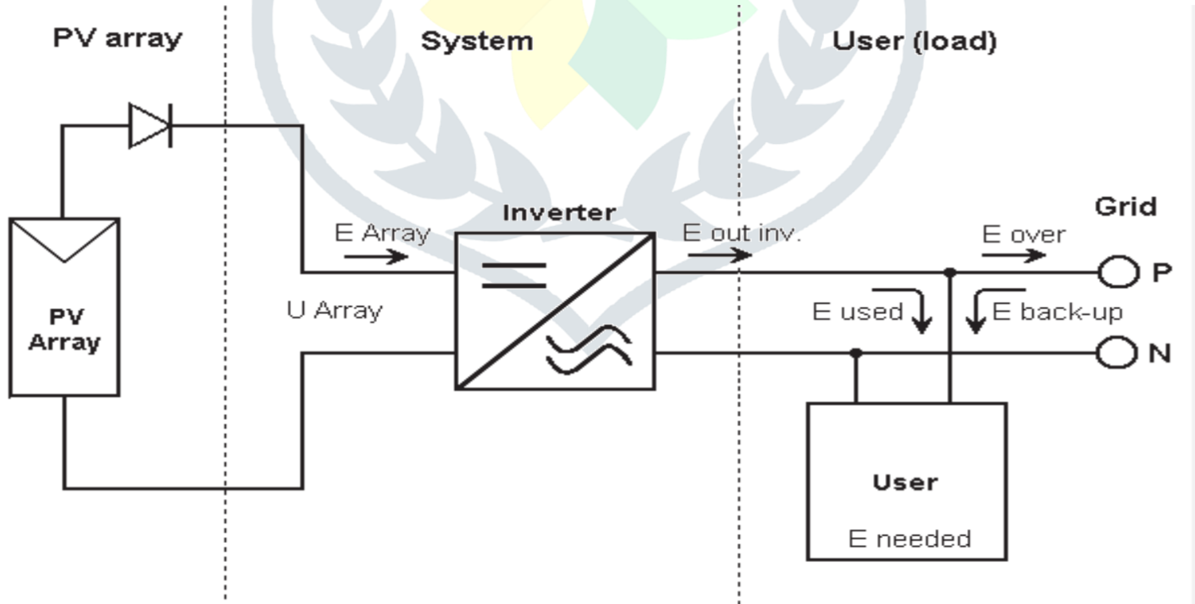

Figure 1 Grid connected PV system

Fig 2 shows the inclination and orientation for the solar panel for shapur site. The tilt angle for PV array is kept as equal to the latitude of the corresponding location to get maximum solar
Irradiation [6, 7]. So that the optimum tilt angle for shapur (21^o 28) site is kept as 22^o.

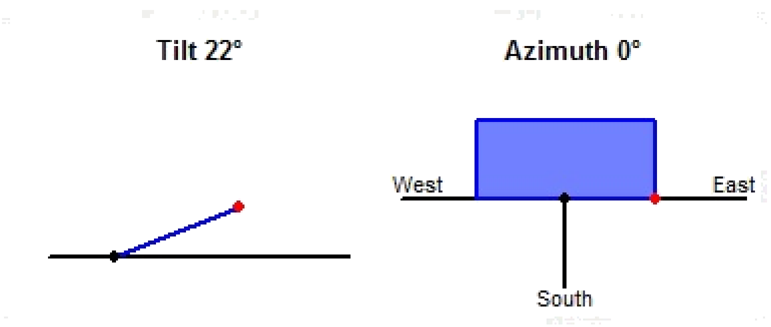

Figure 2 Orientation

4. SYSTEM DEFINING PARAMETERS

The following are the details about the Grid connected PV systems for shapur site.

Table 2 System Defining Parameters

Module type	Standard
Technology	Poly-crystalline
Nominal power	1000kWp
Load profile	Grid
PV module	280 Wp , 30V
Inverter	250KW , 300-850V ,50Hz

5. PERFORMANCE ANALYSIS

This research work is totally based on the PVSYST software. We have used this software for modeling purpose. All the figures, tables are depicted here in the paper are generated during the simulation process for shapur site only. As this paper represents the computational modeling so we just present the simulation results only rather than the description.

Table 3 Energy Injected to the Grid

	E_Grid kWh
January	127094
February	122912
March	134800
April	139891
May	134194
June	101078
July	94589
August	99854
September	96730
October	123542
November	123150
December	119146
Year	1416980

Table 3 shows that the energy uses of the shapur site. It depicts the monthly average energy injected into the grid in kWh. The maximum energy injected into the grid at the month of April as 139891 kWh. The minimum energy injected into the grid at the month of July as 94589 kWh. The total energy injected into the grid is 1416980 kWh/year.

Table 4 Normalized Performance Coefficients

	Yr kWh/m².day	Lc	Ya kWh/kWp/d	Ls	Yf kWh/kWp/d	Lcr	Lsr	PR
January	159.87	0.966	0.01	0.092	4.10	0.187	0.018	0.795
February	158.78	1.186	0.01	0.095	4.39	0.209	0.017	0.774
March	177.95	1.297	0.01	0.096	4.35	0.226	0.017	0.757
April	189.12	1.535	0.01	0.107	4.66	0.244	0.017	0.740
May	179.05	1.348	0.01	0.099	4.33	0.233	0.017	0.749
June	132.97	0.982	0.00	0.082	3.37	0.222	0.018	0.760
July	125.02	0.904	0.00	0.078	3.05	0.224	0.019	0.756
August	132.32	0.964	0.00	0.084	3.22	0.226	0.020	0.754
September	128.09	0.967	0.00	0.079	3.22	0.226	0.018	0.755
October	163.08	1.181	0.01	0.095	3.98	0.225	0.018	0.757
November	159.76	1.130	0.01	0.091	4.10	0.212	0.017	0.771
December	149.47	0.894	0.00	0.085	3.84	0.185	0.018	0.797
Year	1855.49	1.112	0.01	0.090	3.88	0.219	0.018	0.764

Performance ratio (PR) is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r) [8]. Table 4 shows the performance ratio of Grid connected system for shapur site. The yearly average performance ratio is 0.764.

Table 5 Meteo and Incident Energy

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb Inc kWh/m²	DifS/GI
January	129.0	54.00	19.70	0.0	159.9	58.17	0.939	0.364
February	137.0	54.99	22.90	0.0	158.8	57.43	0.998	0.362
March	168.0	72.01	27.10	0.0	178.0	72.10	1.223	0.405
April	192.0	74.00	29.80	0.0	189.1	71.66	1.398	0.379
May	194.0	83.01	29.70	0.0	179.0	78.23	1.413	0.437
June	145.0	81.00	29.60	0.0	133.0	76.59	1.056	0.576
July	135.0	81.01	29.10	0.0	125.0	76.83	0.983	0.615
August	138.0	80.01	28.80	0.0	132.3	76.75	1.005	0.580
September	126.0	71.99	29.00	0.0	128.1	70.45	0.917	0.550
October	147.0	66.01	27.90	0.0	163.1	67.32	1.070	0.413
November	132.0	53.01	24.70	0.0	159.8	56.44	0.961	0.353
December	119.0	51.01	20.40	0.0	149.5	55.08	0.866	0.368
Year	1762.0	822.04	26.57	0.0	1855.5	817.05	12.830	0.440

Table 5 shows the meteorological and incident energy of the PV system. The global horizontal irradiation (GlobHor) is 1762.0 kWh/m^2/year. The horizontal diffuse irradiation (DiffHor) is 822.04 kWh/m^2. The overall global incident energy on the collector plane is 1855.5 kWh/m^2.

Table 6 shows the detailed monthly average system losses in kWh. Module quality loss (Mod Qual) is 802.14 kWh/year. Module mismatch loss (Mis Loss) is 32055 kWh/year. Ohmic wiring loss (Ohm Loss) is 15476 kWh/ year. Array virtual energy at Maximum Power Point (MPP), EArrMPP is 1450306 kWh/Year. Total Inverter loss is 33326 kWh/year.

Table 6 Detailed system Losses

	ModQual kWh	MisLoss kWh	OhmLoss kWh	EArrMPP kWh	InvLoss kWh
January	71.60	2861	1383	129947	2853
February	69.33	2771	1440	125585	2674
March	76.19	3045	1634	137788	2988
April	79.26	3168	1804	143142	3251
May	76.07	3040	1499	137346	3153
June	57.41	2294	888	103580	2502
July	53.85	2152	822	97078	2489
August	56.81	2270	954	102477	2623
September	54.95	2196	950	99153	2423
October	70.01	2798	1437	126535	2993
November	69.51	2778	1438	125880	2729
December	67.13	2683	1228	121794	2647
Year	802.14	32055	15476	1450306	33326

Table 7 shows the balances and main results of Grid connected PV system. Yearly global horizontal irradiation is 1762.0 kWh/m^2. The yearly global incident energy on the collector plane is 1855.5 kWh/m^2. Energy available at the output of the PV array is 1449870 kWh. The energy injected into the grid is 1416980 kWh. The EffArrR is the efficiency of the PV array/rough area and the yearly average efficiency is 11.27 %. The yearly average efficiency of the system is 11.02 %. The average ambient temperature is 26.57^o C.

Table 7 Balances and Main Results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	129.0	19.70	159.9	155.2	129941	127094	11.73	11.47
February	137.0	22.90	158.8	154.4	125585	122912	11.41	11.17
March	168.0	27.10	178.0	172.9	137774	134800	11.17	10.93
April	192.0	29.80	189.1	183.4	143095	139891	10.92	10.67
May	194.0	29.70	179.0	172.9	137270	134194	11.06	10.81
June	145.0	29.60	133.0	128.2	103525	101078	11.23	10.97
July	135.0	29.10	125.0	120.5	97003	94589	11.19	10.92
August	138.0	28.80	132.3	127.8	102446	99854	11.17	10.89
September	126.0	29.00	128.1	123.8	99097	96730	11.16	10.90
October	147.0	27.90	163.1	158.5	126476	123542	11.19	10.93
November	132.0	24.70	159.8	155.4	125870	123150	11.37	11.12
December	119.0	20.40	149.5	145.2	121787	119146	11.76	11.50
Year	1762.0	26.57	1855.5	1798.1	1449870	1416980	11.27	11.02

Fig. 3 represents the Performance Ratio of the Incident energy for the entire month of the year graphically. The average Performance ratio is 0.764.

Fig. 4 represents the overall system loss diagram for shapur site. The horizontal global irradiation is 1762kWh/m2.The effective irradiation on the collector plane is 1798kWh/m^2. Then the PV cell converts solar energy into electrical energy. After PV conversion, array nominal energy is 1816636 kWh.The efficiency of PV array is 14.60% at Standard Test Condition (STC). Array virtual energy obtained is 1450306kWh.After the inverter loss, the available energy at the inverter output is 1416980kWh. So the energy injected into the grid is 1416980kWh.

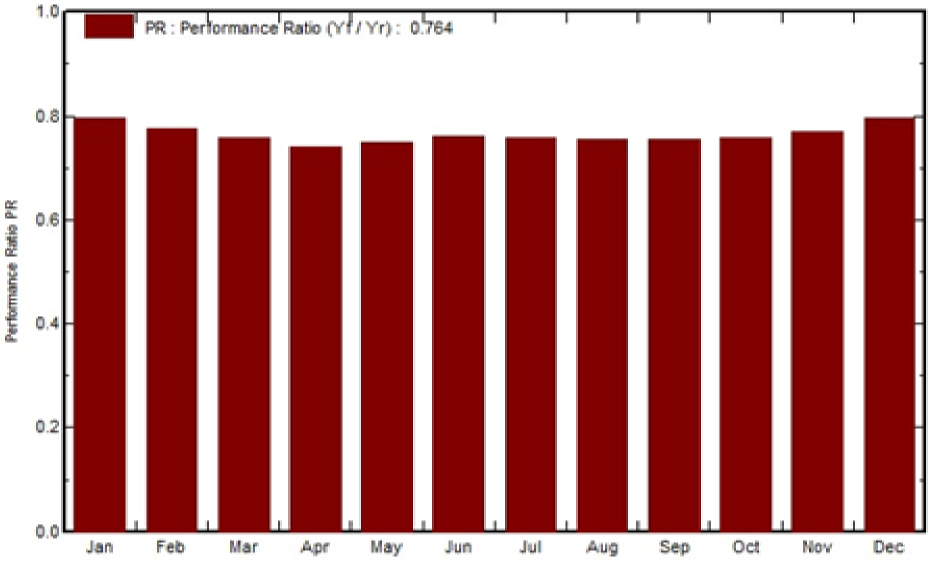

Figure 3 Performance Ratio

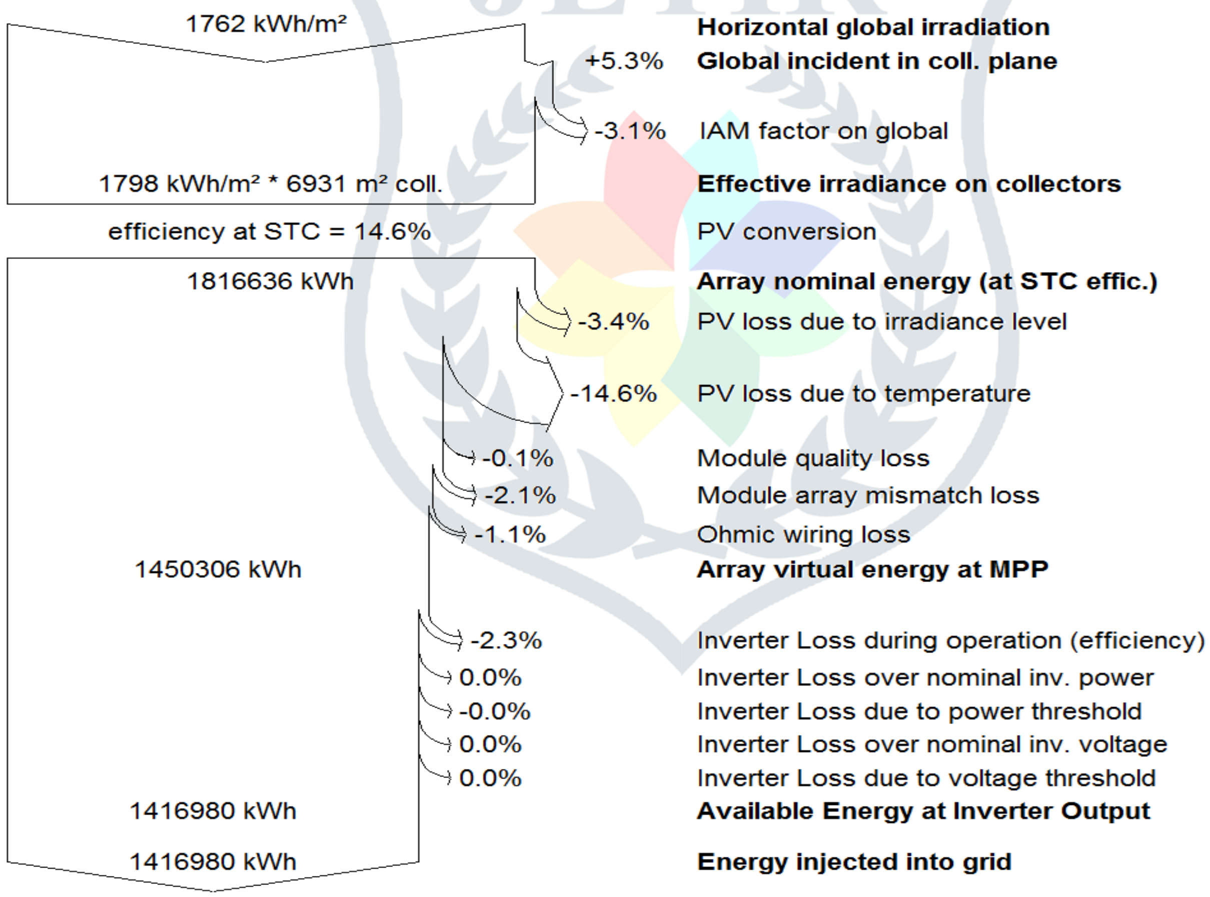

Figure 4 System Loss Diagram

7. CONCLUSION

In this work, efficient PV system is designed for grid connected environment using PVsyst software. For Grid connected PV system, the viability of installing 1 MW plant in shapur village at Gujarat is considered. The maximum solar irradiation is achieved at a tilt angle of 22^{o} (for shapur) which is nearly equal to the latitude of that location (21^{o} 28) and no shading effect is considered. For 1MW Grid connected solar PV system Energy injected to grid is 1416980kWh and The performance ratio is 0.764 and the various power losses are calculated.

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