Performance and Evolution of Grid Connected To 5MW Solar Photovoltaic Plant in Shivanasamudra

Manukumar D.M.[1], Ganesha T.[2], Mallikarjunayya C. Math[3]
Department of Thermal Power Engineering[1, 2, 3,]
VTU PG Centre, Mysore/ VTU Belgaum Karnataka India[1, 2, 3]
Email: gowdadmk@gmail.com[1], ganeshtnaik88@gmail.com[2],
mcmath1018@yahoo.com[3],

Abstract-The depletion of fossil fuel resources on a worldwide basis has necessitated an urgent search for alternative energy sources to meet up the present day demands. Solar energy being a clean, inexhaustible and environment-friendly potential resource among all renewable energy options. But in the demand the combination of solar and conventional conversion units are now being implemented as Grid connected energy systems. The objective of this paper is to determine the performance of grid connected to 5MW solar photovoltaic plant and developed a system based on the potential estimations made for a chosen area of 100m². The specifications of equipment are provided based on the availability of the component in India. Annual energy generation by proposed Grid connected SPV power plant is calculated. present scenario, there is a need of continuous supply of energy, which cannot be full filled by alone wind energy system or solar photovoltaic system due to seasonal and periodic variations. Therefore, in order to satisfy the load

Keywords: Solar energy, Grid connected SPV system. Solar radiation Photovoltaic, Diurnal variation, daily energy output, and monthly energy output, , yearly energy output.

1. INTRODUCTION

Renewable energy is generally defined as energy that comes from resources which are continually replenished on a human timescale such as sunlight, wind, rain, geothermal tides and waves. Grid-connected solar Photovoltaic (SPV) systems that involve the direct conversion of sunlight into electricity which is fed directly into the electricity grid as shown in fig 2. This will be a very good way to boost the existing electricity production capacity in the country, which is mainly from hydro and thermal sources. This will contribute positively to the worsening energy situation in the country. Solar energy, being a renewable source, will also provide energy without pollutants and greenhouse gas emissions. This can go a long way to help mitigate the adverse effect of global warming as well as contribute to sustainable energy development. While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development [1].

Photovoltaic's offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that converted light energy directly into electricity. It is anticipated that photovoltaic systems will experience an enormous increase in the decades to come. However, a successful integration of solar energy technologies into the existing energy structure depends on a detailed knowledge of the solar resource. But it is essential to state the amount of literature on solar energy, the solar energy system and PV grid connected system is enormous. Grid interconnection of photovoltaic (PV) power generation system has the advantage of more effective utilization of generated power. However, the technical requirements from both the utility power system grid side and the PV system side need to be satisfied to ensure the safety of the PV installer and the reliability of the utility grid. For this survey have gone through different books, journals and papers to get its keen knowledge [2].

1.1TYPES OF SOLAR PHOTOVOLTAIC POWER SYSTEM

The PV systems are designed to supply power to electrical loads. The load may be of DC or AC type and depending on the application, the load may require power during the daytime only or during the night time only or even for 24 hours a day. Since a PV panel generates power only during sunshine hours, some energy storage arrangement is required to power the load during the non-sunshine hours. This energy storage is usually accomplished through batteries. During the non-shine hours the load may also be powered by auxiliary power sources such as diesel generator, wind generator or by connecting the PV system to the grid or some combination of these auxiliary sources as shown in fig. 1. Here preferring grid connected solar PV system only.[3]

PV systems can be broadly divided into the following three categories as shown in fig 1.

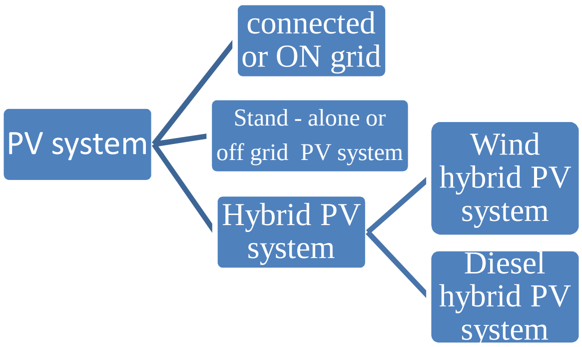

Fig. 1 Classification of photovoltaic system

1.2 GRID-CONNECTED PHOTOVOLTAIC POWER SYSTEM

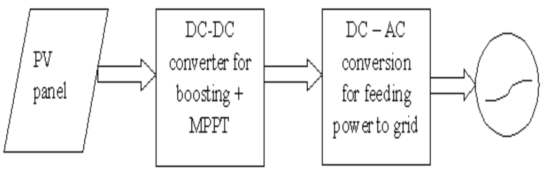

Fig. 2 Schematic diagram of grid connected solar PV system

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers are power systems energized by photovoltaic panels which are connected to the utility grid. Grid-connected photovoltaic power systems consist of Photovoltaic panels, MPPT, solar inverters, power conditioning units and grid connection equipment as shown in fig.1 these systems seldom have batteries. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load to the utility grid.[3]

Residential grid-connected photovoltaic power systems which have a capacity less than 10 kilowatts can't meet the load of most consumers. They can feed excess power to the grid, which in this case acts as a battery for the system. The feedback is done through a meter to monitor power transferred. This is called net metering. Photovoltaic wattage may be less than average consumption. In that case the consumer will continue to purchase grid energy lesser amount than previously. If photovoltaic wattage substantially exceeds average consumption, the energy produced by the panels will be much in excess of the demand. In this case, the excess power can yield revenue by selling it to the grid. Depending on their agreement with their local grid energy company, the consumer only needs to pay the cost of electricity consumed less the value of electricity generated. This will be a negative number if more electricity is generated than consumed.

1.3 TYPES OF PHOTOVOLTAIC'S CELLS

There are essentially two types of PV technology, crystalline and thin-film. Crystalline can again be broken down into two types [4]

- Monocrystalline Cells
- Polycrystalline Cells
- Thin film

2. OBJECTIVES

The objectives of this work is to estimate the performance and evolution of grid connected to 5MW solar PV plant using PVSYST software in Shivanasamudraat Mandya district of Karnataka. Performance ratio of 5MW solar plant in Shivanasamudra, rating of plant for 100 m^2 area, annual energy generation from 5MW grid connected solar photovoltaic (SPV) system, some theoretical causes for the losses and suggest some methods which can reduce the losses and improves the overall efficiency of the plant.

3. METHODOLOGY

1. **Supervisory Control and Data Acquisition (SCADA) system:**are used to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining and transportation. These systems encompass the transfer of data between a SCADA central host computer and a number of Remote Terminal Units.
2. **PVSYST software:** It is a PC software package for the study, sizing, simulation and it is appropriate for grid-connected, stand-alone, pumping and DC-grid systems. Data analysis, directed for architects, engineers and researchers, enduring quite beneficial tools for academics.

4. RESULTS AND DISCUSIONS

Table 1. Solar radiation data on hourly basis in March month.

Sl. No.	Time	ModulTemp (°C)	AmbientTemp (°C)	Wind Speed km/h	Radiation W/m²
1	7:00	30	24	4.3	315
2	8:00	31	26	4	320
3	9:00	35	26.5	6.2	380
4	10:00	46	28.9	3	415
5	11:00	48	30	6	720
6	12:00	56	30.5	7	880
7	13:00	57	31.2	8.2	920
8	14:00	51	30.7	4.6	912
9	15:00	46	31	2.2	630
10	16:00	44	31	3.6	615
11	17:00	37	31	6.8	280
12	18:00	30	30	8.4	30.8

3.1 Diurnal variations

The detailed daily and monthly average peak solar radiation was recorded in the SCADA system. The exact values of radiations were listed in the Table 6.6. For the corresponding daily and monthly average peak solar radiation in kWh/m^2 has shown in Fig. 6.5. And has Plot between peak solar radiation available in kWh/m² and for different months.

Table 2. Month and daily average solar radiation data in kWh/m².

Sl no	Month	Monthly average peak Solar radiation in kWh/m²	Daily average peak solar radiation in kWh/m²
1	Sept 2013	130.873	4.362
2	Oct 2013	147.340	4.753
3	Nov 2013	155.329	5.178
4	Dec 2013	180.665	5.830
5	Jan 2014	190.579	6.150
6	Feb 2014	166.140	5.934
7	Mar 2014	197.322	6.365

3.2 Target and actual generation for the year of 2013 – 2014

After obtaining all the days and months of solar energy generation data from the SCADA system, the ratio of actual generation and target generation gives the performance ratio of this plant. The target energy can be estimated from STC is 8322MW$_p$h (19% capacity utilization factor).

Target annual energy is
= (5 MW$_p$×24 h×365×0.19 = 8322 MW$_p$h)

The target annual energy is 8322MW$_p$h (for 25 acres area), it can be divided by 365 days gives the daily average target energy generation is 22.8 MW$_p$h. Total number of days in that respective months is multiplied with the daily target energy gives the target generation of that corresponding month as shown in Table 3.

Sl no	Month	Target power(t) [MW$_p$h]	Actual power (a) [MWh]	Performance ratio PR=(a/t)×100
1	Sep-2013	684	568.8	83.16%
2	Oct-2013	706.8	531.5	75.20%
3	Nov-2013	684	528.3	77.24%
4	Dec-2013	706.8	599.9	84.88%
5	Jan -2014	706.8	634.2	89.73%
6	Feb-2014	638.4	571.4	89.50%
7	Mar-2014	706.8	635.1	89.86%
		4833.6	**4069.2**	**84.18%**
				15.82%

Table 3 Performance table

Table 3 shows March month shows the highest solar energy generation because of higher solar potential and cleaning of the panels. The November month shows the lowest solar energy generation due to over deposited dust on the panels and lower solar potential. But in the January and March months shows higher performance ratio because of geographical location and time variations, an increase of PR accordingly increases the final yield value.

Table 4. Daily and monthly energy generation data from SCADA system.

No.	Date	March month Daily energy Output (MWh)	September month Daily energy Output (MWh)	October month Daily energy Output(MWh)	November month daily energy output MWh	December month daily energy output MWh	January month daily energy output MWh	February month daily energy output MWh
1	1/3/2014	17	20.9	17.4	21	15.1	18.4	21.8
2	2/3/2014	21.3	22.6	11.5	20.1	15	20.2	22.6
3	3/3/2014	21.8	20.7	18.9	18.8	15.7	21.5	21.5
4	4/3/2014	21.1	18.4	26.6	11.2	20	21.2	19.9
5	5/3/2014	21.2	18	21.3	15.1	20.5	19.8	20.3
6	6/3/2014	20.8	17.9	21.9	19.4	17.5	20.6	21.3
7	7/3/2014	20.5	15.4	19.1	22.8	15.5	20.9	22.1
8	8/3/2014	20.9	11.3	17.7	20.8	18.2	21.2	18.3
9	9/3/2014	19.6	10.6	13.9	22.4	20.9	21.8	21.2
10	10/3/2014	20.3	19	21.9	23.1	21.1	19.8	21.8
11	11/3/2014	19.3	12.8	22	19.1	20.3	20.4	21.4
12	12/3/2014	19.6	16.9	20.1	15.9	12.9	21.3	23.3
13	13/3/2014	19.6	17.7	16.1	13.8	6.6	22	22.3
14	14/3/2014	19.3	18.7	15.8	16.1	13.2	21.4	20.8
15	15/3/2014	19	23.5	11	21.8	21.1	21.9	19.5
16	16/3/2014	21	17.1	15.9	7.1	23	18.4	17.7
17	17/3/2014	20.1	13.5	18.1	12.3	22.4	16.1	24.8
18	18/3/2014	19.4	17.9	18.1	15.4	20.9	21.1	16.9
19	19/3/2014	20.3	17	15.3	22.5	21.9	20.6	16.6
20	20/3/2014	21.6	13.6	12.4	20.5	22.2	16.9	17.8
21	21/3/2014	21.3	19.7	12.3	19.5	21.5	22.1	21.2
22	22/3/2014	21.6	22.7	11.1	19.6	22.4	19.5	18.5
23	23/3/2014	21.3	25	10.2	13.5	22.9	20.2	19.8
24	24/3/2014	21.2	24.5	8.5	14.2	15.4	19.6	20.3
25	25/3/2014	20.1	23.6	15.8	15.7	20.7	21.4	15.7
26	26/3/2014	20.2	27.6	19.3	17.8	23.2	21.9	20.6
27	27/3/2014	20.6	24.9	20.2	16.4	22.3	20.4	22.1
28	28/3/2014	21.8	19.3	15.8	18.9	21	21.3	21.3
29	29/3/2014	21.4	19.1	20.8	14.1	20.3	20.6	
30	30/3/2014	21.6	18.9	22	19.4	22.5	21.2	
31	31/3/2014	20.3		20.5		23.7	20.5	
	Total	**635.1**	**568.8**	**531.5**	**528.3**	**599.9**	**634.2**	**571.4**

3.5 Annual energy yield

The average yearly energy output in the table 5 are calculated by multiplying average monthly energy output with total number of months 12. The daily energy output also calculated for various months as shown in 2nd column. Monthly energy output is calculated by multiplying the number of days in that month with the daily energy output as shown in 3rd column. Kilowatt-hour (kWh) means (1,000) one thousand watts acting over a period of one hour. The kWh is a unit of energy. 1kWh=3600 kJ.

The minimum annual targeted energy is 8322 $MW_p h$, but due to seasonal, periodic variations and from the dust deposited on the panel surfaces causes lower energy than the targeted energy.

Table 5 Average annual energy yield in MWh.

Months	Daily average energy output [MWh]	Monthly Energy Output [MWh]	Average monthly Energy output [MWh]	Average yearly energy output [MWh]
Sep	18.96	568.8	581.31	6975.72 MWh
Oct	17.14	531.5		
Nov	17.61	528.3		
Dec	19.35	599.9		
Jan	20.45	634.2		
Feb	20.40	571.4		
Mar	20.48	635.1		
Total	**20.40**	**4069.2**		

3.6 Peak variation and possible plant rating

Onthe earth surface the climatic condition vary from site to site. By that the plant rate will always depend on the solar peak radiations. The Table 6.19 shows the peak value of solar potential.

Table 6.19 shows the average peak solar radiation for different months is 166.8926kWh/m². Already assume that for 100 m² area are available for radiation of solar power plant. From this data the average peak solar radiation for the different months can be calculated. So the possible plant rating can be calculated by multiplying average peak solar radiation value 166.8926 kWh/m² with the consider area 100 m², finally get 4.63590 kW. So predicted plant rating in kW is 5 kilo watts [5kW].

Table 6. Plant rating for 100m² area.

Month	Monthly Average peak radiation output kWh/m²	Average peak radiation Output kWh/m²	Average peak for 100 m² area kW	Possible plant rating kW
Sep -13	130.873	166.8926	$\frac{166.8926 \times 100}{3600}$ 4.63590 kW	**5 kW**
Oct -13	147.340			
Nov -13	155.329			
Dec -13	180.665			
Jan -14	190.579			
Feb -14	166.140			
Mar -14	197.322			
Total	**1168.248**			

It is observed that from the table 6, performance ratio depends on the factors like solar irradiation, the optimum angle of tilt, air temperature, design parameters, quality of modules, efficiency of inverter etc. The results have been obtained based on the above parameters using SCADA system.

Performance ratio (PR) is calculated by using this equation, which is shown in given below

$$PR = \frac{\text{Actual reading of plant output MWh}}{\text{Calculated theoratical plant output in MWh}}$$

$$PR = \frac{4069.2}{4833.6} * 100 = 84.18\%$$

4. CONCLUSION

The performance of plant can be analyzed by considering the monocrystalline and polycrystalline panels, performance ratio and other condition such as solar irradiance, wind, speed, module temperature of the plant. It can verify the overall system performance by considering array conversion efficiency, cable loss, transmission losses using the simulation software PVSYST.

- The performance ratio of the 5MW solar photovoltaic plant is 84.18%. The PR of all the seven months average value gives the overall performance of the plant.
- Rating of plant for 100 m² area is 4.63590 kW.
- Annual energy generation by proposed grid connected SPV power plant is 6975.72 MWh.
- The losses in the site can be theoretically analyzed are Cable Losses, Energy loss due to

Grid Failure, Defects and Defective Parts, Effect of Module Temperature and Wind Speed, Energy losses due to dust deposits and etc...

- Suggestions made in order to reduce the losses and improve the overall efficiency of the plant were minimizing of system failures, Tripping of inverters, improved design/installation of equipment's, failures should be rectified as early as possible to avoid down time of the plant and plant should be cleaned frequently and maintained properly for improving the better performance.

Solar photovoltaic potential generation during the period from September 2013 to March 2014 is assessed in Shivanasamudra, Mandya district of Karnataka. It is found the March month gives 635.1 MWh which is maximum monthly energy output out of seven months. Because of its higher solar potential and cleaning of panels at that month. The month of November produced the lowest solar energy 528.3 MWh. Monthly and yearly outputs were calculated. By taking the monthly peaks, the average peak output is calculated from where an estimate of the possible plant rating is made. Finally the performance of the plant is 84.18% which is found to be satisfactory.

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