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# Performance Assessment of Grid Connected 1.1 MWP Solar Photo Voltaic Plant in India.

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## Abstract:

The growing and developing nations, increased demand of power and limited availability of fossil sources triggered towards a sources who is purely clean green and also available in large amount . Solar energy is becoming a key option of clean and green source of energy all over the World. Many solar plants have been installed in India with different geographical sites. Investigation on the performance of solar power plants is important and initial key for installation of plant. Knowledge about the performance analysis of solar power plants result will provide correct investment decisions for installation. In this paper we examine the various parameter which is contributing to the performance of solar power plants, such as solar panel design , temperature, radiation, inverter efficiency, degradation due to aging and other climatic conditions. In this paper, performance of 1.1 MWp solar photo voltaic plant evaluated presented with the use of the computer software package PVSyst.. The performance ratio and the various power losses (solar irradiation, different type of module loss, temperature, Module soiling, AC and DC losses, cable and wiring loss etc) are calculated .Also evaluate the performance of plant in terms of different type of plant running losses like generation loss due to grid unavailability system breakdown, inverter breakdown. The use of appropriate performance parameters facilitates the comparison of grid-connected photovoltaic (PV) systems that may differ with respect to solar panel design, modern technology and different geographic location. Five performance parameters evaluated that for overall system performance with respect to the energy generation, available solar radiation, and overall effect of system losses are the following: generation analysis, inverter loss analysis, inverter efficiency, system loss analysis and performance ratio analysis These performance parameters are discussed for their suitability in providing desired information for PV system design and performance evaluation . Also discussed are methodologies for determining system a.c. power ratings in the design phase using multipliers developed from measured performance parameters. This paper work shows the performance analysis of grid connected 1.1 MWp solar PV plant at Shivagangai dist. Tamilnadu.

*Keywords* —**Solar energy, Solar photovoltaics, Solar radiation, Solar power plant, Performance analysis**

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## I. INTRODUCTION

With an installed capacity of 145 GW, the country currently faces energy shortage of 8 percent and a peak demand shortage of 11.6 percent. India faces a significant gap between electricity demand and supply. Demand is increasing at a very rapid rate compared to the supply. it is estimated that the power generation capacity in India would have to increase to 306 GW in the next ten years which is 2.1 times the current levels. India has a large potential for renewable energy sources such as solar power, biomass and wind power. With the current installed capacity of renewable energy constituting about 7.3 percent of India's total installed generation capacity[6]. India is already the fourth largest in the world in terms of wind energy installations. India just had 2.12megawatts of grid-connected solar generation capacity. predicting expected energy production from a system is a key part of understanding system value. System energy production is a function of the system design and location, the mounting configuration, the power conversion system, and the module technology, as well as the solar resource. Even if all other variables are held constant, annual energy yield (kWh/kWp) will vary among module technologies because of differences in response to low-light levels and temperature. A number of system performance models have been developed and are in use, but little has been published on validation of these models and on the accuracy and uncertainty of their output. Probably the most difficult and the most important aspect of commissioning a PV system is evaluating whether it is performing as well as it should be. First, the expected performance needs to be determined. Then, the actual performance needs to be measured. To determine the expected performance of the PVsystem, refer to the basis of design. Assuming that the system was sizing properly in the design phase, it should meet the owner's requirement for energy production. Based on the equipment specified, estimation the monthly annual and lifetime energy output of the system[3].

## II. TECHNICAL DETAILS OF SOLAR PV PLANT

The 1.1 MW Plant is divided into 4 independent segments of 500 kW, 100 kW, and two 250 kW. Each segment is equipped with four Inverters of100, 500, 250(2) kW each and grouped together to form one LT panel. Depending on the mix of 140 & 280 WP modules, 45 to 46 PV Arrays are connected in parallel to each single Inverter, and each array consists of 24 modules connected in series. The power generated from 1.1 MW PV Plant at 0.415 kV is stepped up to 11 kV with the help of three step-up transformers and connected to existing 11 kV lines[4].

### A. TECHNICAL DATA OF SOLAR PV ARRAY

TABLE I
PV ARRAY DETAILS

| PV ARRAY DETAILS | |
|---|---|
| Type modules are used | Nex power (NT-140AX),WebelW2800(280) |
| Total number of modules | 6085 |
| Solar Cell material | Silicon |
| 1 Array | 12 In -1 out |
| No. of Arrays per Inverter | 17-500KW,3-100 KW,5-250(1)KW,5-250(2)KW |
| No. of Inverter used | 4 inverter |
| No. of module connected in per Inverter | 3573-500KW,896-250(1)KW, 896-250(2)KW 720-100KW |
| Inclination of Modules (Tilt angle) | 0deg, 15deg , 31deg |

### B. MODULE SPECIFICATION

TABLE III
PV MODULES DETAILS

| TYPE | NET POWER (140 WP) | WEBEL (280 WP) |
|---|---|---|
| Maximum Power, Pmp (W) | 140W | 280W |
| Maximum Power Voltage (Vmp) | 62.3 V | 35.5V |
| Maximum Power Current (Imp) | 2.25A | 7.94 |
| Open Circuit Voltage (Voc) | 78.4V | 44.75V |
| Short Circuit Current (Isc) | 2.59A | 8.53A |
| Module dimensions (mm) | 1.4x1.1 mm | 1.4x1.3 mm |
| Module efficiency | 9% | 15% |
| NOCT– Nominal Operating Cell Temp (°C) | 55 deg c | 45deg c |
| Weight (Kg) | 19.8 Kg | 25 Kg |
| Cell Type | µc-SI/a-SI | mono |

  

## III. METHODOLOGY FOR PERFORMANCE ANALYSIS OF SOLAR PV SYSTEM

This section describes the methodology for performance analysis of a grid connected system. In order to analyze the performance of a grid connected system the performance parameters are being developed by International Energy Agency (IEA) [12]. These performance parameters include:

1-Generation analysis
2-Inverter loss analysis
3- Inverter efficiency
4- System loss analysis
5- Performance Ratio of system

These performance parameters basically provide the overall system performance. The PV plant is fully monitored to assess its performance as per IEC standard 61724 [13].

### *A. GENERATION ANALYSIS*

The total energy in a year from this 1.1MW Solar PV Plant can be calculated by using the data in average monthly insulation in Tamilnadu. This average value of the incident solar power and its availability for utilization is assumed to have taken into account the cloudy days and the variation in the incident solar flux due to seasonal variation round the year. Also, although the daylight is recorded to be available on the average for 12 hours a day, we assume that for power generation purposes it is available for only ten hours[2]. The energy generated by each 140W panel in a year for an average of 10 hours a day is 0.14 × 1.1 × 365 = 56.21 kWh. This is possibly an over-estimation because this assumes that there are no maintenance outages. We assume that solar PV plants are robust enough to not require such outages of no more than 10 percent[7]. Discounting for this, a 100W panel is thus expected to generate a total of about 330 kWh of electrical energy in a year. Total annual electricity generated by a 10 megawatt plant would be 330 kWh × 107 = 33 GWh/ annum.

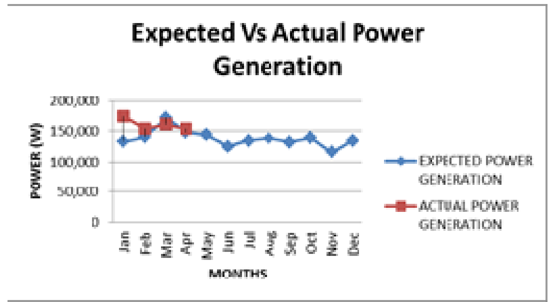


Fig. 1Expected and Real Power Generation Comparison

The Expected monthly average power generation found 166.227 Kwh. Maximum Power generates 171.67 Kwh at month of March and minimum power generation 116.376 Kwh at month of November.

### *B. INVERTER LOSS ANALYSIS*

Four numbers of pure sine wave grid connected solar inverters of capacity 500KVA, 100 KVA 250(2) kVA will be used for converting DC power into AC. Each inverter will be based on highly efficient IGBT technology with generation voltage of 415 V, three phase, 50 Hz at a rated power factor of 0.99 (lag). Inverter will be having MPPT (maximum power point tracker). The enclosure of the inverter will be of dust, vermin and water proof. The inverter will meet the other Requirements as stipulated in IEC and IEEE: 1547. The inverter will be complete with base frame, closed air circuit cooling system, LAVT (lightning arrestors and surge capacitor and voltage transformer) panel, metering and control panel, instrumentation control and safety devices and other accessories. The inverter coupled to the PV array will be suitable in all aspects for operating with grid. The inverter will be sized for the operation with input PV array power of 500, 100, 250(2) kWp. Total four inverters will be required for four PV arrays of capacity 250 kWp each. Each inverter will be sized to provide the total output energy of 1.66 million kWh.

TABLE IIIII
PV INVERTER SPECIFICATION

| SPECIFICATION | INVERTER | | |
|---|---|---|---|
| TYPE | 500KW | 250KW | 100KW |
| **Input** | | | |
| Maximum DC power | 510 KW | 259 KW | 104KW |
| Maximum dc voltage | 420 V | 320 V | 315V |
| PV voltage range at MPPT | 420-850 V | 320-600 V | 315-600 |
| **Output** | | | |
| Maximum ac power | 500KW | 250KW | 100KW |
| Nominal ac power | 500KW | 250KW | 100KW |
| Maximum efficiency | 97.9 | 96.6 | 96.6 |
| Euro efficiency | 97.3 | NA | NA |
| Weight | 2810 kg | 2404 kg | 1006 kg |

*1) EXPECTED POWER GENERATION BY INVERTER AS PER PV SYST:*

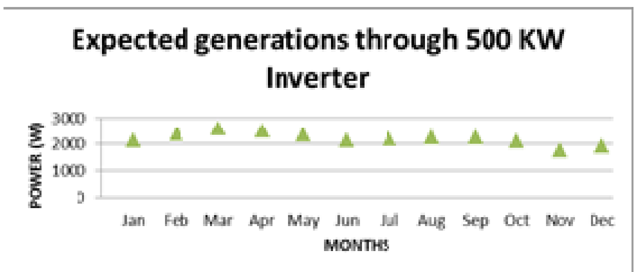


Fig. 2Expected power generation through 500 KW Inverter

Annual power generation through 500 KW inverter was found 26483 KW with maximum power generation 2579 KW at month of March and minimum power generation 1765 KW at month of November.

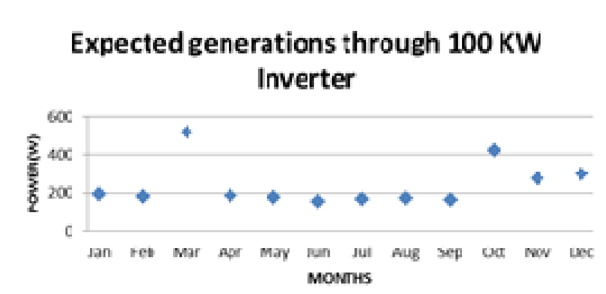


Fig. 3Expected power generation through 100 KW Inverter

Annual average power generation through 100 KW inverter was found 2918 KW with maximum power generation 519 KW at month of march and minimum power generation 275 KW at month of November.

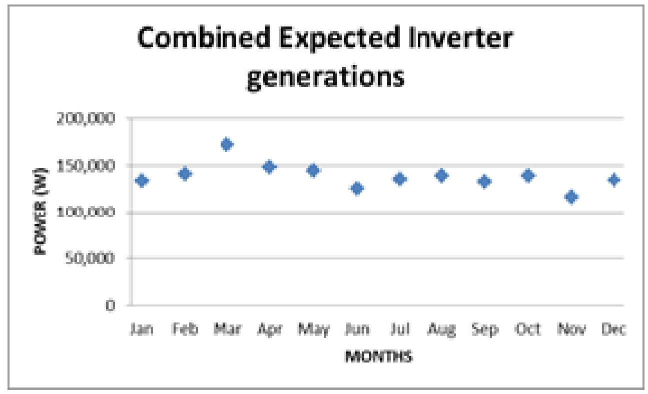


Fig. 4Combined Expected Power Generation all Inverters

Annual combined power generation through all inverters was found 166.2270 KW with maximum power generation 171.670 KW at month of march and minimum power generation 116.376 KW at month of November.

*C. INVERTER EFFICIENCY*

These inverters are grid tie inverters which are used to connect the power plant to the grid. The efficiency of an inverter has to do with how well it converts the DC voltage into AC. The currently available grid connected inverters have efficiencies of 96 to 98.5%, and hence choosing the correct inverter is crucial to the design process[8]. Most inverters are most efficient in the 30% to 90% power range. The instantaneous inverter efficiency is calculated

$$ή = \text{AC Power}/\text{DC Power}$$

Formula use for calculating input DC power

Input DC power = Solar insulation x No. of module connected with particular inverter x module area x conversion efficiency of module x conversion efficiency of inverter x no of day


Fig. 5Inverters Efficiency

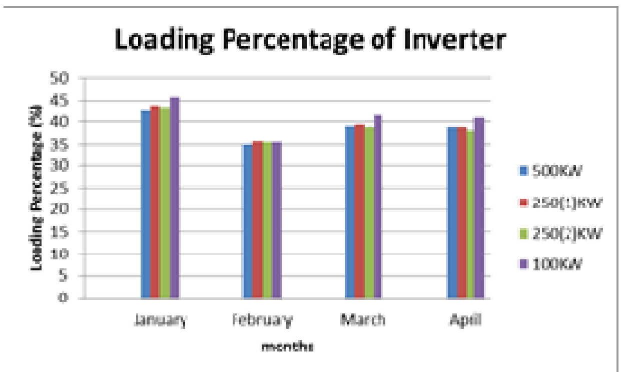


Fig. 6Inverters Loading Percentage

*D. SYSTEM LOSS ANALYSIS*

Power is also lost to resistance in the system wiring. These losses should be kept to a minimum but it is difficult to keep these losses below 1.5-2% for the system[9]. For this project the maximum cable losses has been considered 2 % resulting a reduction factor for these losses equal to 98% or 0.980.

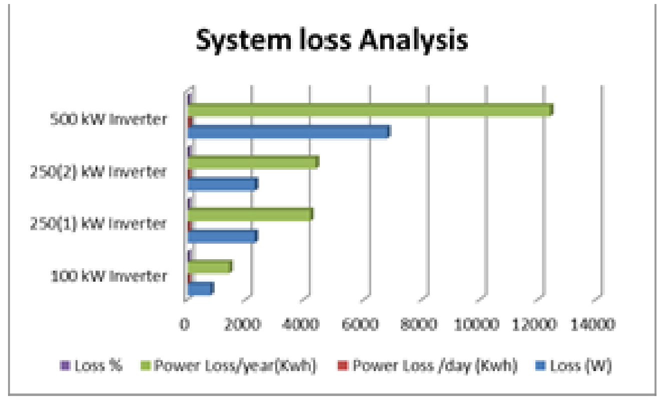


Fig. 7System Loss Analysis

*E.PERFORMANCE RATIO OF SYSTEM*

The performance ratio is one of the most important variables for evaluating the efficiency of a PV plant. Specifically, the performance ratio is the ratio of the actual and theoretically possible energy outputs[11]. It is largely independent of the orientation of a PV plant and the incident solar irradiation on the PV plant.

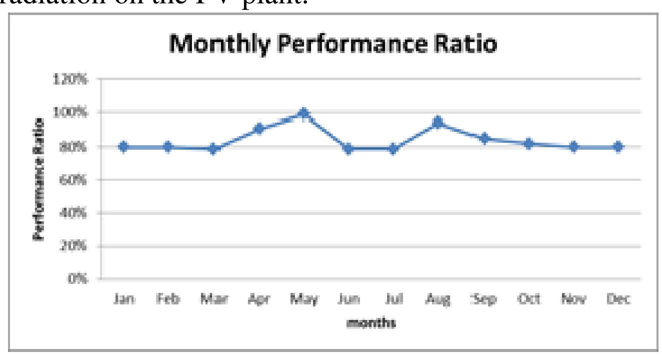


Fig. 8Monthly Performance ratios

*F. PV SYST SIMULATION*

After manual calculations the simulation was also done with the help of PVSYST software. The data input to software are module data, inverter technical specification and all the meteorological data is taken from the Meteonorm software database. PVSyst is provide sizing of solar pannel, simulation and data analysis of complete PV systems. Upon user's requirements like energy/water needs and "Loss of load" probability .this provides the PVsystem component sizes, monthly production performances, and performs a preliminary economic evaluation of the PV system[1]. Tools perform the database metrological and components management. It provides also a wide choice of general solar tools (solar geometry, Meteo on tilted planes, etc), as well as a powerful mean of importing real data. In PVSyst simulation the data has been taken from Meteonorm file. The file generated from Meteonorm can easily be extracted in PVSyst. For importing file there is a utility given in PVSyst in Geographical sites section. In software PV array tilt angle was optimized to reduce the shading losses. The tilt angle was kept 25 tilt degrees[5].

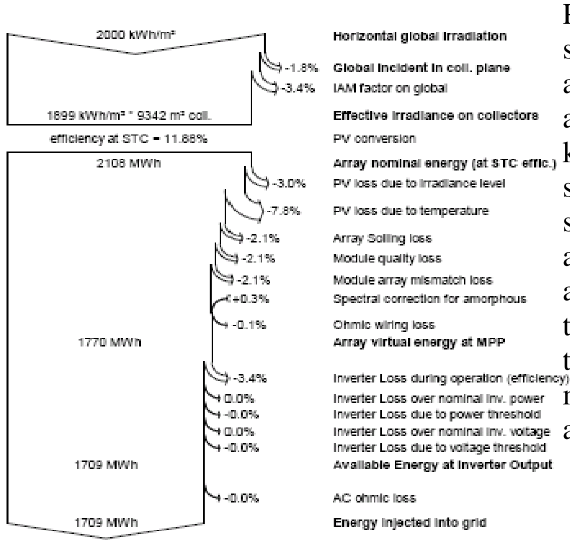


Fig. 9Various losses predicted using the PVSYST.

## IV. Results and discussion

The results of analysis of the actual measured performance and comparison with the predicted performance using PVSYST are presented in this section. The variation of measured monthly average solar radiation on the tilted PV modules indicates that solar radiation is minimum during November (132.4 kWh/m$^2$) and maximum in March(199.3 kWh/m$^2$). The mean monthly back of module temperature averaged during the day hours is 25.85 $^0$C. The performance ratio ranges between 79% and 99% with an annual average value of 84%. In order to compare the measured and the predicted output of solar plant, the normalized energy yield (kWh/kWp) is calculated. The measured total normalized energy outputis 1.66 million kWh whereas the predicted yearly output is 1.766 million kWh .The measured annual average PR of the solar plant is found to be 83% which is very close to the PVSYST predicted PR of 84%. PVSYST also calculates the various system losses based upon the inputs of site parameters (Long., Lat. and Altitude), global solar radiation, ambient temperature and electrical and mechanical specifications of the modules. The various losses predicted using PVSYST are shown in Fig.9. The performance of a solar power plant mostly depends upon the available incident solar radiation on the plane of array of the PV modules. Thus, the modules are kept inclined with Tilt angle 25 $^0$C to the horizontal surface facing south so as to maximize the incident solar radiation. This indicates that the optimum tilt angle is required to be determined for this plant so as to get maximum power generation throughout the year. There is already a provision for changing the tilt angle of the array which can be utilized once monthly, seasonal and yearly optimum tilt angles are determined for maximum power generation.

## V. Conclusions

The performance of the 1.1MW RLCP solar photovoltaic power plant has been analyzed for the month of Jan, Feb, March, April. The total expected electrical energy generated by the RLCP power plant was 1.766 million kWh(As per PV syst.) and 1.709 million units were sold to the grid. But Actual generation of the plant is 1.66 million kWh based on the performance Ratio of the plant. This is lower than the expected generation, but Actual monthly generation is higher than the expected monthly generation. The impact of temperature variation (of modules) on the performance of photovoltaic mono-crystalline silicon modules was studied. It is observed that the efficiency of modules is more sensitive to temperature than the solar Insolation. The normal daily trend is that the efficiency of Plant is high during morning hours but low during the middle of the day and again starts increasing from late afternoon. The daily efficiency of modules varied from 14.5% to 11.5% with the variation in the daily averaged modules temperature from 25 $^{0}$C to 50 $^{0}$C. Hence cooling of the solar modules may be desirable to increase the efficiency. There is a need to evaluate if the additional energy required for cooling the solar modules will be less than the additional energy generated due to higher efficiency.

1. The daily plots showing the variation of Performance ratio of the plant, generation varies due to tilt angle, inverter wise generation of the plant, inverter loading percentage, Inverter efficiency, generation loss, breakdown condition and Revenue loss.
2. The monthly average daily PV module efficiency, system efficiency and inverter efficiency were 12%, 15.6% and 93.5.2% respectively.
3. The average daily performance ratio and capacity factor were 83.7% and 10.1% respectively.
4. Monthly Performance ratio value is Jan-91%, Feb -87%, Mar-78%, Apr-79%.
5. Monthly Inverter loading is Jan-43.9%, Feb - 35%, Mar-40%, Apr-39%.
6. Ohmic loss is 1.27 % it is lower than expected.
7. Maximum no. of grid loss occurs in month of April. Percentage of grid availability in month of Feb is 97%, Mar-96%, Apr-98%.

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