Performance simulation of a grid connected photovoltaic power system using TRNSYS 17

To cite this article: Y Raja Sekhar *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **263** 062078

IOP Conf. Series: Materials Science and Engineering **263** (2017) 062078 doi:10.1088/1757-899X/263/6/062078

Performance simulation of a grid connected photovoltaic power system using TRNSYS 17

Y Raja Sekhar[1], D Ganesh[2], A Suresh Kumar[2], Raju Abraham[1] and P Padmanathan[1]
[1]School of Mechanical Engineering, VIT University, Vellore - 632014, Tamil Nadu, India.
[2]School of Civil and Chemical Engineering, VIT University, Vellore, Tamil Nadu, India – 632014.

E-mail: rajasekar.y@vit.ac.in

Abstract: Energy plays an important role in a country's economic growth in the current energy scenario, the major problem is depletion of energy sources (non-renewable) are more than being formed. One of the prominent solutions is minimizing the use of fossil fuels by utilization of renewable energy resources. A photovoltaic system is an efficient option in terms of utilizing the solar energy resource. The electricity output produced by the photovoltaic systems depends upon the incident solar radiation. This paper examines the performance simulation of 200KW photovoltaic power system at VIT University, Vellore. The main objective of this paper is to correlate the results between the predicted simulation data and the experimental data. The simulation tool used here is TRNSYS. Using TRNSYS modelling prediction of electricity produced throughout the year can be calculated with the help of TRNSYS weather station. The deviation of the simulated results with the experimented results varies due to the choice of weather station. Results from the field test and simulation results are to be correlated to attain the maximum performance of the system.

1. Introduction

The need for energy alternatives is increasing dramatically. The average rate of increase of oil production in the world is declining and a peak in production may be reached around 2018 [1,4]. Thereafter the production will decline gradually, most of the oil reserves of the world are likely to be consumed, and by the end of the present century as resources deplete, the need for using fossil fuels exclusively for such purposes may become greater. On the other hand, environmentalists has huge concern over demand of huge quantity of water for power generation for larger plants[7].Hence, alternate energy options need to be explored to meet increasing energy demand.

One of the clean, inexhaustible and free energy sources, which reaches the Earth in diffused form, is solar energy. This energy is approximately estimated as $1.8x10^6$ W where it can serve all the present and future power requirements of the world [8]. Solar photovoltaic power generation through use of semiconductor devices has been proven technology for the past two to three decades. However, one of the limitations of the application is conversion efficiency.

1.1 Photovoltaic Conversion

When solar radiation falls on solar cells, it is converted directly in to DC electricity. The advantages are that they have no moving parts and require little maintenance solar cells are now being used extensively in many consumer products and appliances and it is possible that in the future they will become one of the important sources of power for providing small amounts of electrical energy for localized use, particularly in remote locations [8].

1.2 Grid Connected PV System

Grid connected PV systems are the foremost well liked solar electrical system on the market nowadays. These systems are widely used because they are connected directly to the electric grid. The main components of their system are PV array and an inverter [2,3]. The DC electricity produced from the PV array is converted into AC electricity, which matches the electrical grid connected to the system. The advantages are less expensive and no need of batteries. If the electrical power produced by your grid connected PV systems is more, you can sell it to the government side end user and subsidies are available.

1.3 Performance Analysis

The performance analysis of photovoltaic system becomes prominent one due to the widely installation all over the world nowadays in order to increase the efficiency solar collector used in the photovoltaic power system, we have to analyses the field results with the simulation results [9]. This will give the required information and what is to be done to increase the efficiency. The main factors depends on the performance analysis are solar azimuth angle and array slope. Based on the results obtained from the simulation prediction we can improve the method of installation of grid connected photovoltaic system in our desired locations.

1.4 Simulation Tool

The simulation tool used in this paper for performance analysis is TRNSYS. It is a complete and extensible simulation of systems. TRNSYS is mainly used for building simulation as well as for the modelling of photovoltaic system [2,3]. The DLL based architecture in the TRNSYS allows users and third party developers can easily add custom component models using all common programming languages. TRNSYS can be easily interfaced to many other applications during the simulation and a user-friendly simulation software where you can find lot of library components, which can used in your simulation model [5]. The interface between the user and simulation software is good.

1.5 Description of The PV Power Plant

The PV power plant is located in Vellore (12.96°N, 79.15°E) India. The plant is installed figure1 on the roof of GDN block at VIT university of Vellore. There are no shadows on the field because the rooftop is high enough with the surrounding buildings. Totally 750 multi crystalline silicon panels which comes under the model TATA TS 250 serves 60 cell multi-crystalline solar photovoltaic modules. The technical details of PV panel are given in Table 1.

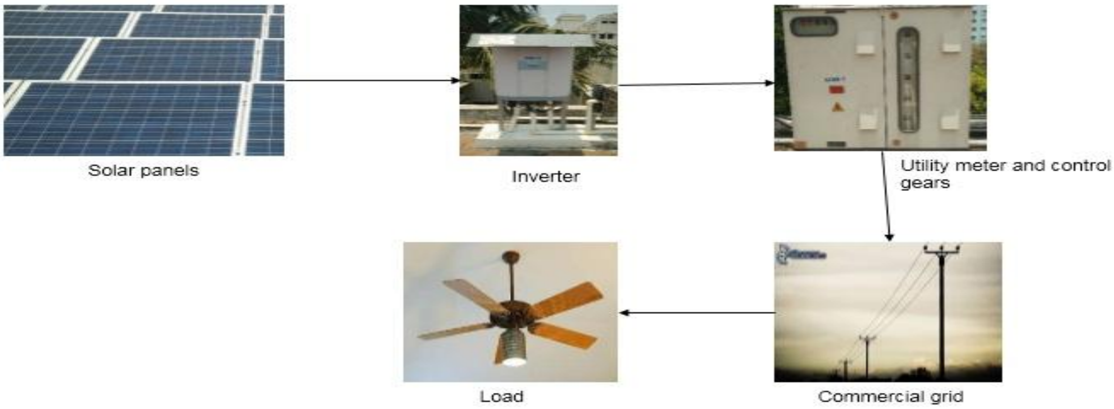


Figure 1. Block diagram of a grid -connected solar PV system

Table 1. Technical characteristics of PV panels (at NOCT)

Parameter	Value
Nominal power output	250W
Module efficiency(η)	15%
Power output (P_{max})	180W
Voltage at P_{Max} V_{mpp}	27.2V
Current at P_{max} I_{mpp}	6.64A
Open circuit voltage V_{OC}	33.5V
Short circuit current I_{SC}	7.15A
Module area	0.55m^2
NOCT	47°C

The photovoltaic power system is connected to the electrical grid via inverter for the conversion from DC to AC power supply. The inverter used here comes under the model of DELTA Three phase solar inverter (RPI M50A). The technical characteristics are given in Table 2.

Table 2. Technical characteristics of solar inverter.

Parameter	Variable	Value
INPUT (DC)	Max input power	58KW
	MPP operating voltage range	200-1000V
	Max current	100A
OUTPUT (AC)	Max apparent power	55KVA
	Voltage range	230/400V ±20%
	Nominal current	73A
	Efficiency	98%
	Frequency range	50/60 HZ

2. Methodology

In this paper we have to compare electricity output (Kwh) generated by the PV system in the field with the output generated from the simulation software [5,6]. Along with this, the prediction of electricity generated for a particular month is calculated for Tiruchirappalli and Coimbatore cities. The steps followed to carry out the analysis of PV systems is depicted as flow chart as shown in Figure 2.

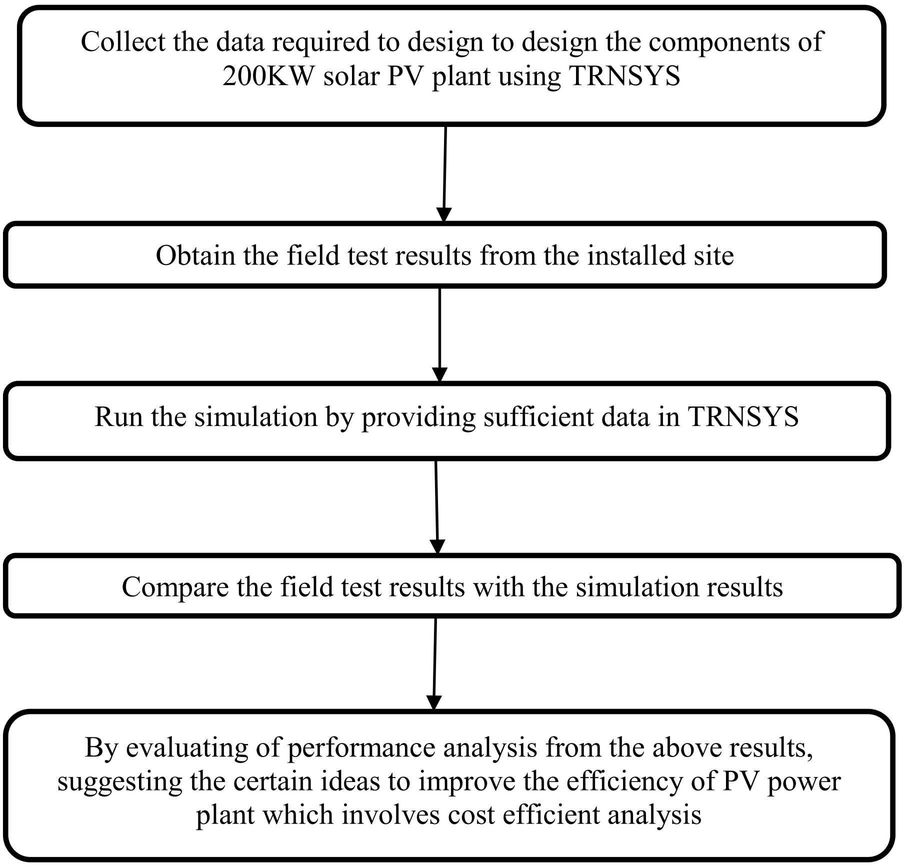


Figure 2. Flow chart for performance analysis of PV systems

2.1 TRNSYS Modelling

TRNSYS Model of photovoltaic system of 200KW capacity considered for the analysis is shown in Figure 3. For the performance analysis of photovoltaic panel the above modelling has been done in TRNSYS17. Based on the results obtained from the simulation software we can implement the procedure to improve its efficiency [2,3].

2.1.1 Weather Data Processor -This component serves the purpose of reading data at regular intervals from an external weather data file in the format of METEONORM the model also calculates the effective sky temperature, humidity ratio and other required radiation data.

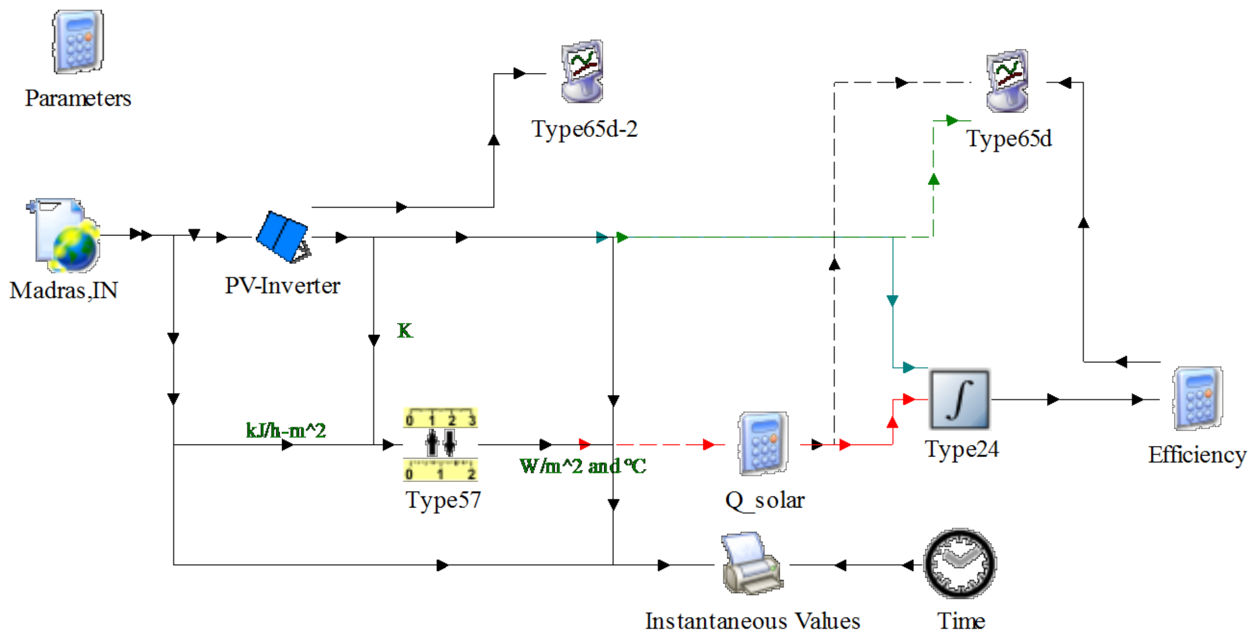
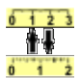


Figure 3. TRNSYS model of 200KW PV system

2.1.2 Photovoltaic Array with Inverter- This component determines the electrical performance of a photovoltaic array. It gives the current and power of the array at specified voltage. It is also coupled with inverter and therefore the inverter efficiency effects are thereby considered.

PV-Inverter

2.1.3 Unit Converter- This component converts the input from KJ/h-m^2 to W/m^2 and °C for our feasibility.



Type57

2.1.4 Q-Solar - This component is used for the calculation of solar radiation in the simulation.

Q-solar=IT*Area of installation*N-series*N-parallel

Q_solar

2.1.5 Quality Integrator - This component integrates a series of quantities over a period of time. It will be automatically reset at time 1.0, 2.0, 3.0, 4.0 etc.

Type24 .

2.1.6 Online Graphical Plotter - This component used to display selected system variables while the simulation is programming.

Type65d

3. Results and Discussions

The simulation of the designed PV power plant are carried out for the two months namely December (2016) and January (2017) for the comparison between the field and simulation results. The simulation time step method used here is successive method are value is 0.125hr.

Figure 4. TRNSYS Kwh vs. Actual Kwh during the month of May

The correlated result for the month of May is shown in Figure 4. The deviation obtained here is ±9% which is calculated with exclusive of three days 17, 18, and 19. The maintenance work was carried out on those three days due to the short circuit and inverter malfunction problems. Thus, the electricity output on these three days is very low.

Figure 5. Comparison of predicted power generation in kWh using TRNSYS model and actual generation during the month of December

The above figure shows the correlation between the experimental field results and simulation results for the month of December. The deviation obtained here is ±7.85% which shows the better experimented results. The prediction of electricity output (Kwh) for the month of May (2017) is shown in Figure 6. The 15000 Kwh can be produced in the month with deviation of ±5% output.

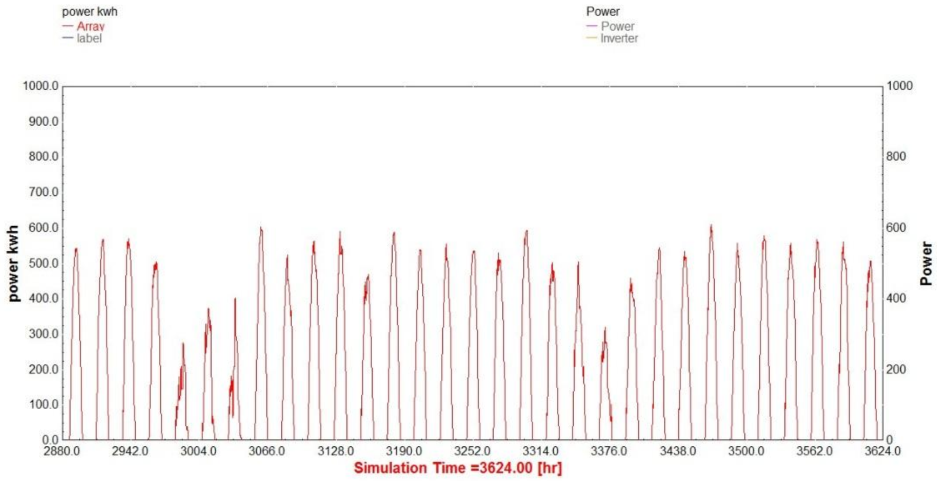


Figure 6. Result of power generation capacity in Kwh from TRNSYS model for May (2017)

The prediction of cumulative electricity output (Kwh) for the Tiruchirappalli and Coimbatore cities are shown in Figure 7 and Figure 8 respectively. The cumulative electricity output (Kwh) from the PV system for May month in the Tiruchirappalli city 18456 kWh and similarly for Coimbatore city is 17666 kWh.

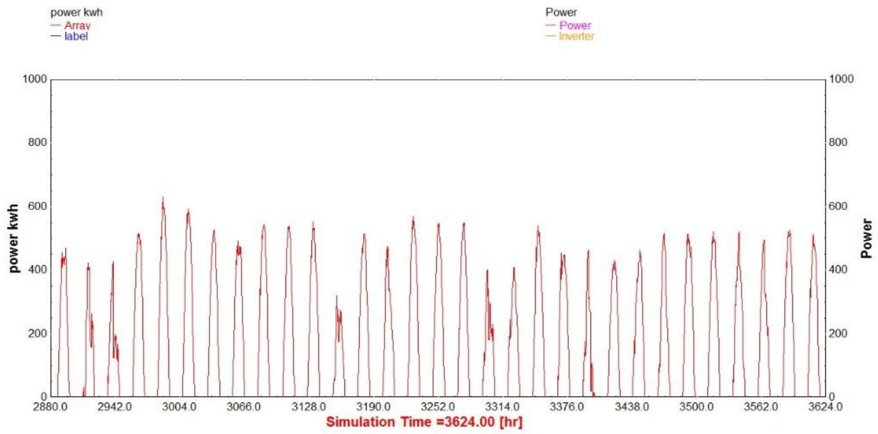


Figure 7. Predicted cumulative power generation for Tiruchirappalli during May

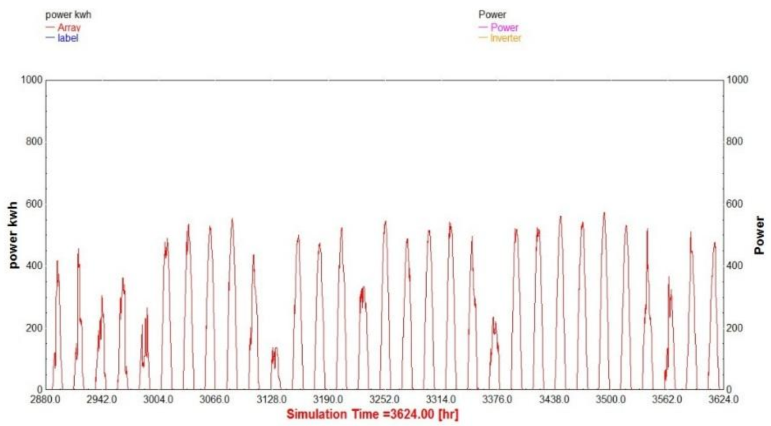


Figure 8. Predicted cumulative power generation for Coimbatore during May

The above predicted results may have a deviation up to ±5% with the experimental field results.

4. *Design of Solar PV Power Plant* [10].

The calculations involved in the design of 200kW Peak power requirement system for the month of May is shown below.

4.1 panel generator factor

The Power generation factor is calculated using the formula, $PGF = \frac{\text{Avg. solar irradiance} \times \text{sunshine hours}}{\text{STC}}$

For Vellore, $PGF = \frac{785 \times 5.2}{1000} = 4.08$

For Trichy, $PGF = \frac{860 \times 5.8}{1000} = 4.98$

For Coimbatore, $PGF = \frac{880 \times 6}{1000} = 5.28$

4.2 Monthly average electricity requirement for GDN block (Assumption)

Peak on season demand – 21,000 Kwh/month
Avg. off season demand – 15,000 Kwh/month

4.3 Energy requirement from PV module

Peak on season demand Kwh/day $= \frac{21000}{30}$ = 700 Kwh/day
Energy required = 1.3 × peak Kwh/day
= 1.3×700
= 910Kwh/day

4.4 Total Watt peak rating for PV modules

$$\text{Total Watt Peak} = \frac{\text{Energy required from PV module}}{\text{PGF}}$$

Vellore, $= \frac{910}{4.08} = 223.09$ kW

Trichy, $= \frac{910}{4.98} = 182.73$ kW

Coimbatore, $= \frac{910}{5.28} = 172.34$ kW

4.5 Specifications of PV module

The technical features of the PV module considered for the analysis is shown in Table 3.

IOP Conf. Series: Materials Science and Engineering **263** (2017) 062078 doi:10.1088/1757-899X/263/6/062078

Table 3. PV module specifications

Parameter	Value
Nominal power output	250W
Module efficiency(η)	15%
Power output (Pmax)	180W
Voltage at PMax Vmpp	27.2V
Current at Pmax Impp	6.64A
Open circuit voltage VOC	33.5V
Short circuit current ISC	7.15A
Module area	0.55m2
NOCT	47°C

4.6 Number of PV Module required

$$\text{No. of Panels required} = \frac{\text{Total watt peak rating}}{\text{PV module peak rated output}}$$

Vellore, $= \frac{223.09\times10^3}{250} = 892.36 = 892$ Modules

Trichy, $= \frac{182.73\times10^3}{250} = 730.92 = 731$ Modules

Coimbatore, $= \frac{173.34\times10^3}{250} = 693.36 = 693$ Modules

4.7 Inverter sizing

Total wattage required = 200Kw
= 200 Kw × 1.3
= 260 Kw

$$\text{Number of inverter required} = \frac{\text{Inverter size}}{\text{rating in watts}}$$

$= \frac{260\ Kw}{70\ Kw}$
= 3.71
= 4

Inverter wattage = 4 × 70
= 280 Kw

4.8 Battery sizing

$$\text{Battery capacity} = \frac{Total\ watt\ hrs/day \times Autonomy\ hrs}{0.85\times0.6\times nominal\ battery\ volt}$$

$= \frac{1\times700\times10^3}{0.85\times0.6\times96}$

= 15190.97
= 15191 Ah

4.9 PV module circuit

Maximum open circuit voltage = 780 volt.
Open circuit voltage of each PV modules = 33.5 volt.

Number of modules to be connected in series $= \frac{780}{33.5}$
= 23.28 = 23
Maximum power voltage of each PV module = 27.2V
Maximum power voltage of inverter i/p = 27.2 × 23
Total no. of PV arrays for producing = 625.6 Volt
Vellore,
$= \frac{893}{23}$ = 39 Arrays
Trichy,
$= \frac{731}{23}$ = 32 Arrays
Coimbatore,
$= \frac{693}{23}$ = 30 Arrays

4.10 Land required

For Vellore,

Number of modules = 893
Dimension of one PV module =1.66 m × 0.98m
Number of modules connected in series = 23
Total width of each PV array = 23 × 0.98 = 22.54m
Length of one PV module = 1.57m
Number of arrays in PV field = 39 Arrays
Number of arrays in rows = 23
Width of solar field = 23 × 22.54 = 518m
Number of rows in solar field = 2
Pitch distance between two arrays = 2 × 1.57 = 3m
Length of solar field = 2 × 4.57 = 9.14
Land required for PV field = 518 × 9.14= 1.16 acres

Similarly for Trichy and Coimbatore, Amount of land required is 0.98 acres and 0.83 acres respectively.

4.11 Project cost

4.11.1 Module and inverter cost

For Vellore,

Cost of each PV module = Rs 30000 (for Vellore)
Total cost for 893 modules = Rs 2.7 crore
Cost of each inverter of 70Kw capacity = Rs 1.5 lakhs
Cost of 4 inverter = 1.5 × 4 = Rs 6 lakhs

For Trichy,

Total cost for 731 modules = Rs 2.2 crores

For Coimbatore,

Total cost for 693 modules = Rs 2.07 crores

4.11.2 Design energy and management cost

Labour cost = Rs 200/man-hrs.
Time per Kw = 2h
For 200 Kw = Rs 80,000

4.11.3 Installation labour cost

Labour cost = Rs 50/man-hrs.
Installation man hour required per Kwp = 12 h

Total cost for 200 Kw = Rs 120000

4.11.4 Operation and maintenance cost

= INR 5.48 million / Mwh

For kWh = Rs 90000/Kwhr.

4.12 Project cost of PV power plant of 200Kw capacity

For Vellore,

1, Module cost = Rs 2.7 crore
2, Array structure = Rs 11 lakhs
3, Electrical items = Rs 16 lakhs
4, Inverter = Rs 6 lakhs
5, Design energy and module cost = Rs 80,000
6, Total labor cost = Rs 1, 20,000
7, Installation hardware cost = Rs 2, 50,000
8, Packaging = Rs 25,000

Total cost –off site plant = Rs 3.08 crore

9, Land cost = Rs 1.03 crore
10, Batteries = Rs 11 lakhs

Total cost – on site plant = Rs 4.22 crore.

Similarly for cities of Trichy and Coimbatore the calculated total cost estimated to be Rs 3.03 crore and Rs 3.1 crore respectively.

4.13 Capacity factor

$$CF = \frac{\text{Annual Kwh generator for each KWAC peak capacity}}{\text{8760 hrs. in a year}}$$

Energy requires to be generated from the plant = 700Kwh/day

Actual energy to be generated from the plant = 700×365

$= 0.255\times10^6$ Kwh

Peak capacity of plant = 200 Kw

$$CF = \frac{0.255 \times \frac{10^6}{200}}{8760}$$

$= 14.55\%$

5. Conclusions

A 200KW grid connected solar PV systems were modelled in TRNSYS17. Simulations were done for the two months for the comparison of experimental field results. The experimental field results were shown in the paper have mostly matched with the simulated results. The slight deviation occurs in the electricity output (Kwh) is becomes of the choice of weather station. Prediction of weather in a particular place is the most difficult process. And also the selected radiation model may provide variation up to ±4% in the simulated output with the small changes in the geometrical parameters for solar azimuth angle and array slope, we can improve the efficiency of photovoltaic power plant. Based on the results obtained in this paper, it is proved that the long term prediction and monitoring of photovoltaic power plant is becomes prominent. This leads to the importance of performance analysis of photovoltaic power plant using the simulation software.

References

[1] Mondol J D and Yigzaw Yohanis G and Brain Nortan 2007 *Energy conversion and management* **48** 1065-1080

[2] Quesada B, Sánchez C,Cañada J and Payá J 2011 *Applied Energy* **88** 1772-1783
[3] Kant kanyarusoke,Gryzagoridis Jasson and Oliver Graeme 2016 *Turkish Journal of Electrical Engineering & Computer Sciences* **24** 4763 – 4772
[4] Ponshanmugakumar A and Aldrich Vincent A 2014 *International Journal of Research In Engineering And Technology* **03(06)** 36-41
[5] Balasubramani N and Vijayakumar V 2016 *International Journal of Engineering Research & Technology* **5(4)** 657-660
[6] Tshewang Lhendup, Sonam Wangchuk,Lungten Norbu, Chimi Rinzin and Samten Lhundup 2016 *International Journal of Scientific and Engineering Research* **7(11)** 678-683
[7] Labed S and Lorenzo E 2004 *Renewable Energy* **29(7)** 1007–22.
[8] Luque A, Hegedus S. 2003 *Handbook of photovoltaic science and engineering. Chichester: John Wiley & Sons*; p. 915–927.
[9] Kim J-Y, Jeon G-Y, Hong W-H 2009 *Applied Energy* **86(2)** 265-272.
[10] How to design a solar PV system -*web link (http://www.leonics.com/support/article2_12j/article2_12j_en.php).*