Design and simulation of 20MW photovoltaic power plant using PVSyst

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Article Info

Article history:

Received Aug 8, 2019
Revised Dec 12, 2019
Accepted Jan 2, 2020

Keywords:

Grid
Irradiance
Photovoltaic
PV Array
PV syst

ABSTRACT

This paper deeply explains the analysis through simulation and sizing of grid connected photovoltaic plant of 20MW for the site Devdurga, Karnataka India with use of PV syst software tool. Primarily, the trajectories obtained from the software describes performance of PV configuration at a particular location. It gives results for the geographical position taken by maps for sizing of the components which projects the installation with very much realistic conditions. The projected area is of about 110 acres would generate 44854 MWh/year for a 20MW PV configuration, with a performance ratio of 76.28%.Loss fraction taken for simulation and sizing is 2%. The paper also includes the study and behavior of the system with tilt and orientation of the PV Panel which gives better simulation results at similar latitudes for any feasible sizing.

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1. INTRODUCTION

India is one of the few countries with an annual GDP growth of above 4.5%. The GDP of the country is positively correlated with electricity demand. Until now, the major contributors of electricity generation were fossil fuels in India. Now India is keen to consider fuel substitution from the point of view of energy security. The "National Action Plan on Climate Change" is one of the major initiatives by the Government of India with 8 National Missions one of which is the Jawaharlal Nehru National Solar Mission [1]. The mission has been set with a target of achieving grid-connected solar power capacity of 1000 MW by the year 2013, 10000 MW by 2017 and 20000 MW by 2022. The enforcement of Renewable Purchase Obligations and the growth of the Renewable Energy Certificate market are also likely to fuel a rapid expansion in the installation of solar power plants. The demand for energy, shortfall of its availability and the increased focus on renewable energy sources like the sun encourage the installation of solar photovoltaic power plants to generate green energy. It is not only a need of the hour but also a good investment for the future [2].

1.1. Solar power scenario in India

India is enriched with inexhaustible solar energy potential, which is equipped for delivering 5,000 trillion kilowatts of clean Power. Nation is honored with around 300 bright days in a year and Sun isolation of 4-7 kWh per sq. m every day [3]. This energy is saddled effectively, it may use to reduce energy deficiency as per present demand and that is without harmful gases. Numerous States in India have effectively perceived and recognized solar energy generation and other are arranged to meet their developing energy needs with long lasting solar power.

2. GRID-TIED PV SYSTEM SIZING

Grid connected PV systems are becoming popular because of their applications in distributed power generation and efficient of PV array power. To optimize the system sizing of the components is required and to achieve the same proper space, climatic conditions and power is the main objective. The Figure 1 of the grid connected system has two stages of conversion, one is to process PV Power and secondly to feed into the grid. In this stage the increase voltage will track the maximum power. And in the Second stage AC power of improved quality will be inverted from DC Power [4-5].

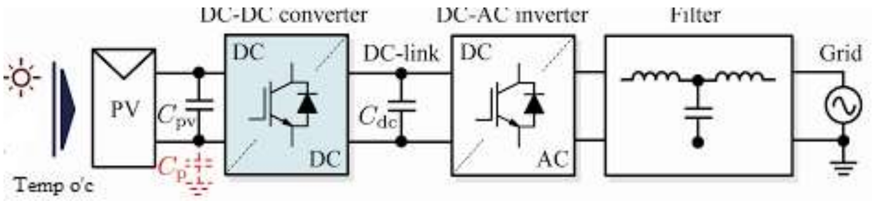


Figure 1. Block Diagram of PV Grid connected Power Plant

2.1. Components

The PV module is the group of PV cells combined together in series and parallel. Depending on the availability at the time of the project and the site suitability, any one of the following types of the modules could be deployed for the project. There are two major types of the solar cell technologies in Figure 2 available in the market on commercial basis. These are crystalline solar cells and Thin-film solar cells [6].

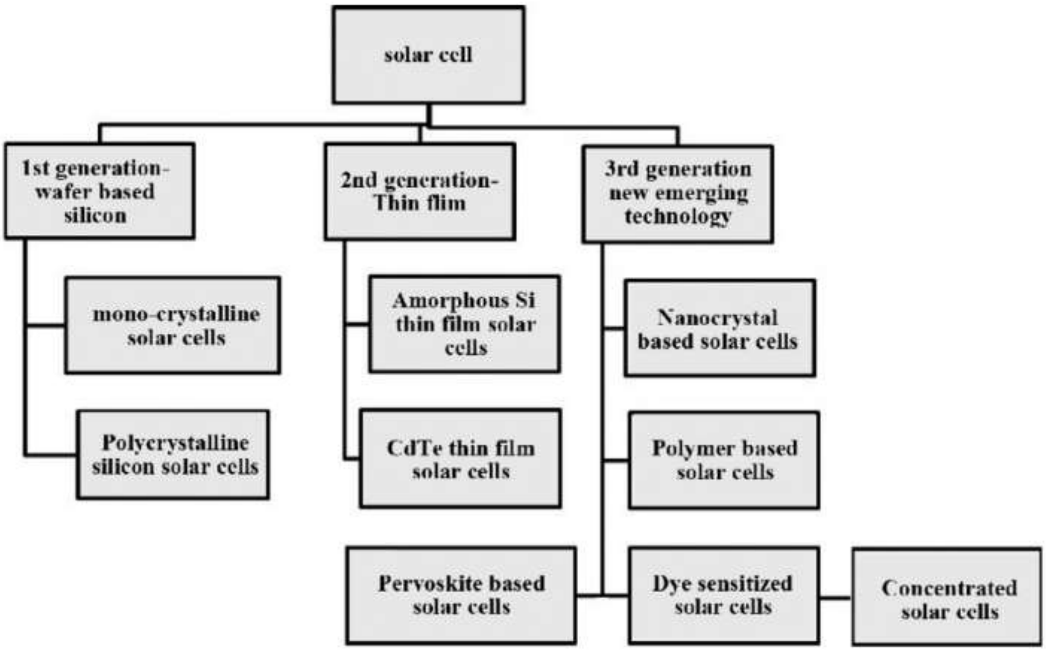


Figure 2. Solar Cell Technologies

The 20 MW Solar PV plant will use Crystalline with single axis (E-W) tracker [7]. The standard technical arrangement of 20 MW solar projects mentioned in Table 1. The PV modules will be electrically connected in series with UV Resistant copper cables with proper size to get minimum DC losses. The production obtained from PV modules will be provided by cables to string monitoring boxes, where current of each string will be monitored for operation and maintenance of the plant. The inverters are connected to string monitoring boxes, which will convert the DC Power of 380V into alternating power [8]. Each of this structure can support 21 modules. The structure is made of galvanized steel profiles and is inclined (-45 to +45) deg to horizontal. PV modules are directly mounted on the module support members. The aluminium frame of each solar module is galvanic ally isolated from the steel supporting beam to prevent localized corrosion and high quality stainless steel fixings are used throughout [9].

Table 1.Parameters of 20 MW PV Power Plant

Summary of 20 MW Solar PV Power Plant	
Nominal location	16°18'9.00"N; 76°50'40.00"E
PV module	Multi crystalline
Inverters	1000 kW
Inverter power(kW)	1000 KW
Inverters per plant	20
Power of plant(MW) AC	20 MW
Plant DC:AC ratio	1.12

2.2. Inverter selection

In solar system, power is conditioned through a control circuit which consists of inverter. The other control devices used in grid-connected solar structure are maximum power point tracker (MPPT), synchronization and remote controlling electronic devices. The main functions carried out by control circuit are:

a) The inverter converts DC supply generated from PV modules in AC supply. The generated power has less harmonic distortions for better efficiency [10].
b) The inverter also behave as protective device which will trip the circuit if the voltage, current or frequency are not within acceptable ranges.
c) On the basis of PV module selected, required inverter is of rating such that it will generate power of 1000kW at voltage level 110 Volts DC [11].

2.3. Installation location

The metropolitan area of Devdurga, Karnataka has been taken as site location of the grid-tied solar photovoltaic installation with geographical coordinates: 16°18'9.00"N; 76°50'40.00"E.

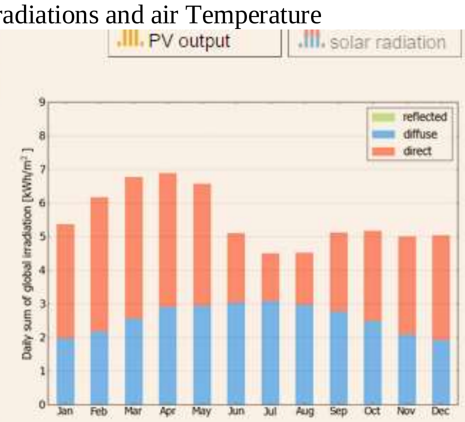
2.4. Irradiance in PV module

The irradiance data for the site which includes irradiance, temperature, wind speed etc has been downloaded from NASA. The Table 2 shown give details of the site [12-13].

Table 2. Yearly Range of Solar radiations and air Temperature

Solar radiation and air temperature — Manage/explain columns

Month	Gi_m	Sh_{loss}	Gi_d	Di_d	Ri_d	T_{24}
Jan	166.3	0.0	5.37	1.97	0.00	23.3
Feb	172.5	0.0	6.17	2.16	0.00	26.1
Mar	209.7	0.0	6.77	2.55	0.00	30.0
Apr	206.2	0.0	6.88	2.90	0.00	33.2
May	203.1	0.0	6.56	2.94	0.00	33.6
Jun	152.9	0.0	5.10	3.03	0.00	29.2
Jul	139.4	0.0	4.50	3.06	0.00	27.0
Aug	140.1	0.0	4.52	2.96	0.00	26.2
Sep	153.6	0.0	5.12	2.76	0.00	26.5
Oct	160.2	0.0	5.16	2.49	0.00	25.6
Nov	150.1	0.0	5.00	2.09	0.00	23.8
Dec	155.8	0.0	5.03	1.91	0.00	22.2
Year	**2009.9**	**0.0**	**5.51**	**2.57**	**0.00**	**27.2**



3. SIMULATION USING PVSYST SOFTWARE

The PV performance for the sizing of units is mainly done with help of PV syst. The experiment results may be calculated on hourly based generation which will be performed for the year. The performance of the system may be tracked for the yearly generation and then arrangement of the system will be obtained with desired environmental conditions, temperature and speed for the maximum power output. The software has inbuilt database of irradiance values for different regions of the world along with various components of PV system to design a plant. PVsyst designs the system in different stages. Firstly by the PV syst, approximate dimensions for the system will be obtained and also the size of the components to be applied. It will provide pre-sized production of the system [14].

The design stage of the project provides detailed simulation results of system by taking the photovoltaic components values on hourly basis. The next stage is database, the irradiance data may be entered from external source either manually or automatically for the location selected from NASA SEE RET screen [15-16] .The software imports the meteorological information only by entering geographical coordinates. Further, the software has vast library for database of climatic conditions, components, analysis and behavior of measured data for Photovoltaic systems. Below, represents the actual simulation results on Devdurga site for photovoltaic grid connected system [17].

3.1. Trajectories of PV modules

Figure 3 shows the movement of the sun based on deteriorated trajectories at different angles. The figure shows the incidence solar rays on PV modules which depends on the tilt and azimuth values [18]. Figure 3-6 shows the performance results of 20 MW Grid connected solar power plant.

3.2. Results and findings

After Simulation, PVsyst gives us the following results:

1) Energy Output: The energy produced is 41854 MWh/year in Figure 7 and a performance ratio (PR) of 76.28 % at 50 °C as operating temperature PV modules. The results shows that maximum energy is produced in the month of March 4291 MWh and minimum energy is produced in the month of July [19-20].
2) Balances and main outputs: Yearly horizontal radiations coming on solar panels is 2000 Kwh/m2.Annually global energy focusing on collector is 2450KWH/m2. Output energy received from the PV array is 44052 annually.
3) The annual efficiency [21] of rough area obtained for PV array i:e Eout/Array is 13.25% and for whole system Eout/System is 12.59%.
4) Normalized Energy Outputs values: The loss value inverter side, LC is recorded as 1.32 kW h/kW p/day and the loss value of system, LS is 0.27 kW h/kW p/day and inverter energy output is given as YF is 5.12 kW h/kW p/day [22].
5) Loss Diagram: The value of global horizontal irradiance is 2000 kW h/m2 [23]. The effective irradiation on the collector plane is 2286 kW h/m2. The values shows that total loss energy is 0.2%. The energy conversion of solar radiations into electrical energy, so total energy generated by PV array is 51203MWh shown in Figure 8 and the efficiency at standard test condition is 16.56%. The available array virtual energy is 44052 and the available energy to inverter output is 43272 MWh [24-25].

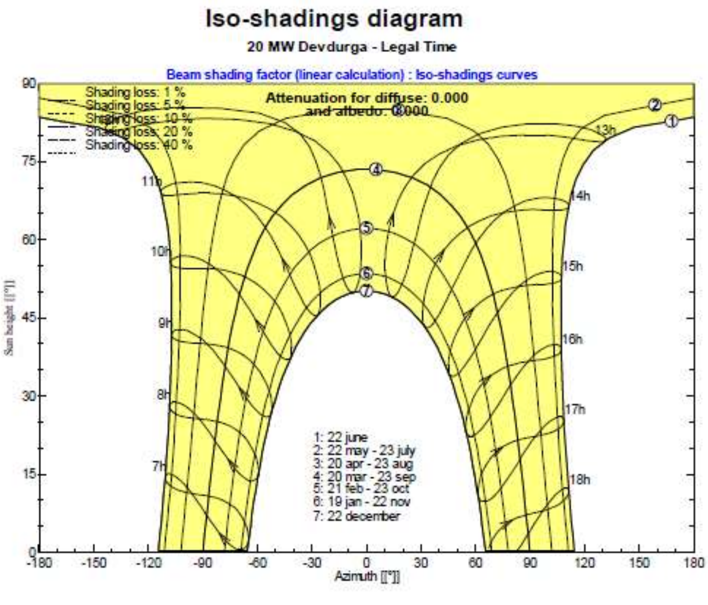


Figure 3. PV Shading Diagram using PVsyst

Grid-Connected System: Simulation parameters

Project :	**20 MW Devdurga**				
Geographical Site		**Devdurga**		Country	**India**
Situation		Latitude	16.40° N	Longitude	76.90° E
Time defined as		Legal Time	Time zone UT+5.5	Altitude	386 m
		Albedo	0.20		
Meteo data:		**Devdurga**	Synthetic		
Simulation variant :	**PARN**				
		Simulation date	01/03/17 11h24		
		Simulation for the	**first year of operation**		

Simulation parameters				
Tracking plane, tilted Axis	Axis Tilt	0°	Axis Azimuth	0°
Rotation Limitations	Minimum Phi	-45°	Maximum Phi	45°
Backtracking strategy	Tracker Spacing	4.50 m	Collector width	1.96 m
Inactive band	Left	0.20 m	Right	0.20 m
Models used	Transposition	Hay	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	Linear shadings			
PV Array Characteristics				
PV module Si-poly	Model	**JAP6-72-320/3BB**		
Original PVsyst database	Manufacturer	JA Solar		
Number of PV modules	In series	21 modules	In parallel	3332 strings
Total number of PV modules	Nb. modules	69972	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**22391 kWp**	At operating cond.	20089 kWp (50°C)
Array operating characteristics (50°C)	U mpp	706 V	I mpp	28474 A
Total area	Module area	**135633 m²**	Cell area	122604 m²
Inverter	Model	**Solar Ware 1000 - PVL-L1000E**		
Custom parameters definition	Manufacturer	TMEIC		
Characteristics	Operating Voltage	605-950 V	Unit Nom. Power	1000 kWac
Inverter pack	Nb. of inverters	20 units	Total Power	20000 kWac
PV Array loss factors				
Array Soiling Losses			Loss Fraction	2.0 %
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	0.56 mOhm	Loss Fraction	2.0 % at STC
LID - Light Induced Degradation			Loss Fraction	1.0 %
Module Quality Loss			Loss Fraction	0.0 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Module average degradation	Year no	1	Loss factor	0.4 %/year
Mismatch due to degradation	Imp dispersion RMS	0.4 %/year	Voc dispersion RMS	0.4 %/year
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

Figure 4. 20 MW Grid Connected Simulation results

Grid-Connected System: Simulation parameters (continued)

System loss factors				
AC wire loss inverter to transfo	Inverter voltage	418 Vac tri		
	Wires: 3x20000.0 mm²	157 m	Loss Fraction	1.9 % at STC
External transformer	Iron loss (24H connexion)	21922 W	Loss Fraction	0.1 % at STC
	Resistive/Inductive losses	0.2 mOhm	Loss Fraction	2.0 % at STC
Unavailability of the system	1.8 days, 3 periods		Time fraction	0.5 %

Figure 5. System loss factors

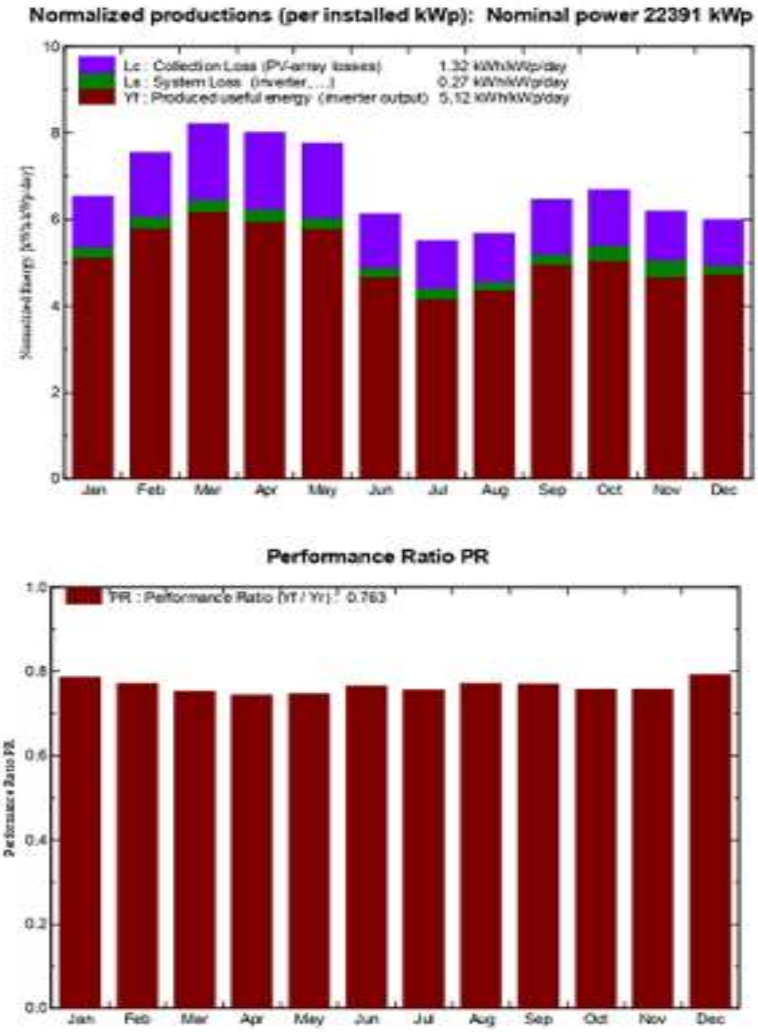


Figure 6. Yearly Irradiance

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	%	%
January	159.0	24.50	202.5	189.5	3729	3564	13.57	12.97
February	165.0	27.20	211.0	198.0	3813	3642	13.32	12.72
March	201.0	30.20	254.4	238.9	4496	4291	13.03	12.43
April	196.0	32.60	240.4	224.8	4193	4005	12.86	12.28
May	197.0	32.70	240.4	224.6	4203	4016	12.89	12.32
June	157.0	29.20	183.8	170.3	3289	3143	13.20	12.61
July	149.0	27.80	170.6	157.5	3069	2886	13.26	12.47
August	153.0	27.00	176.1	162.2	3178	3038	13.31	12.72
September	159.0	27.10	193.5	180.2	3494	3333	13.32	12.70
October	169.0	26.70	206.9	193.3	3748	3504	13.36	12.49
November	148.0	25.10	185.6	173.8	3403	3146	13.52	12.50
December	147.0	23.59	185.5	173.0	3436	3285	13.66	13.06
Year	2000.0	27.80	2450.6	2286.3	44052	41854	13.25	12.59

Legends:

GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

Figure 7. Yearly generation output using PVSyst

Main system parameters	System type	**Grid-Connected**		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis Azimuth	0°
PV modules	Model	JAP6-72-320/3BB	Pnom	320 Wp
PV Array	Nb. of modules	69972	Pnom total	**22391 kWp**
Inverter	Model	Solar Ware 1000 - PVL-L1000E		1000 kW ac
Inverter pack	Nb. of units	20.0	Pnom total	**20000 kW ac**
User's needs	Unlimited load (grid)			

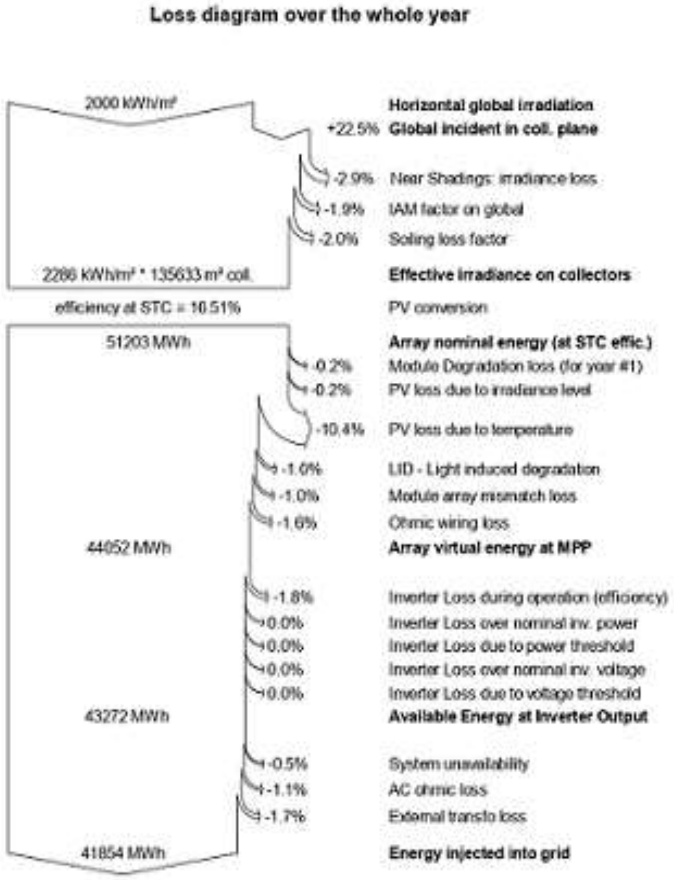


Figure 8. Annual Loss diagram of 20 MW plant using PVsyst

4. CONCLUSION

To validate the design of the PV Grid tied system, it is difficult to coordinate the theoretical calculations for real data obtained from geographical positions. The PV syst has given authentic results for the genuine data received from maps. This must be done so as to dissect and identify potential causes that assists in accomplishment of the photovoltaic system .This investigation has demonstrated the constancy of the PVsyst in the estimating the size of the components solar integrated grid. A detailed analysis of 20 MW grid tied solar power plant at Devdurga, Karnataka has been done using PVsyst software. The performance of the plant has been observed on annual basis. The analysis gives peak output power of 22.4MW and the minimum power of 80.1 MW. The maximum energy output of 4291 MWh is perceived in the month of March and the minimum energy output is in 2886 MWh in the month of July.

Therefore, the investigation has affirmed the reliability of the PVsyst programming in estimating and in planning of photovoltaic application. The issues which impact the execution of based solar powered modules are a result of the operational temperature of the photovoltaic cells. To lessen the misfortunes in existing innovation, low wind speed and high temperature of PV module may give vital outcomes. To accomplish the correct measuring of the network associated project, it is necessary to correlate the hypothetical calculations through logical estimations utilizing PVsyst and afterward making comparison analysis with real time generation.

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