Performance and Simulation Analysis of Proposed 100KWp Roof-Top Solar PV Plant

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Abstract - In a solar roof top system, the solar panels are installed on the roof of any residential, commercial, institution and industrial building. The solar roof top system may be off-grid or grid connected. In grid connected rooftop solar PV system, available rooftop area on buildings is used for setting up solar power plant and DC power generated from solar photovoltaic (SPV) cells is converted to AC power by solar grid inverter and is fed to the grid during day time. In night when solar power is not sufficient, loads are served by drawing power from grid. A Proposed 100KWp photovoltaic grid connected power plant with the site receiving a good average solar radiation of 5.43 kW h/m^2/day and annual average temperature of about 25.18 degrees centigrade. In this study the solar PV plant design aspects along with its annual performance is elaborated. The various types of power losses and performance ratio are also calculated using PV syst software. The final yield (Y_F) of plant ranged from 3.72 to 4.59KWh/KWp/d, and annual performance ratio (PR) of 74.9% with an annual energy generation of 154550 KW h/Annum. Simulation analysis of 100KWp solar rooftop power plant is carried out using PV Syst and simulation results of energy output of PV module, energy supplied to the load and energy injected into the grid are also presented.

***Key Words*: Electricity, grid connected solar photovoltaic panel, solar energy, rooftop.**

1. INTRODUCTION

Telangana state being located between 15° 54′ and 19° 37′ North latitude and the geographical location favors the harvesting and development of solar energy. Telangana state is having good solar radiation of 4.9 KWh/square-meter /day. Hyderabad city comes under Telangana state in India.

The yearly average solar radiation on horizontal surface is 4.9 KWh/m^2/day at latitude of 17.4 ^{0}N and longitude of 78.5 ^{0}E [6].

Electric utilities are finding it difficult to meet rise in peak demand and as a result, most of cities and towns are facing severe electricity shortages [5]. In order to meet the demand, the existing roof space of buildings is utilized to promote rooftop solar PV systems.

2. TYPES OF SOLAR POWER PLANTS

Solar plants are divided in two types based on storage systems.

a) OFF Grid Solar Plant - In OFF Grid Solar Plant whole system does not connect to the local grid. In this we have to use local batteries to store solar power for consumption during clouding days or in night time. OFF Grid solar plant is costly because the storage system like batteries must replace with in a particular time for better efficiency [1].

b) Grid-Connected Solar Plant - A Grid Tie System or Integrated System is called ON Grid Solar Plant. In this plant whole system is connected to the local grid for consumption of electricity during cloudy days or in night time. Grid connected Solar system is most efficient and cheap as no batteries are required [2].

A schematic sketch of a typical grid connected solar rooftop photovoltaic power plant is shown in Fig1.

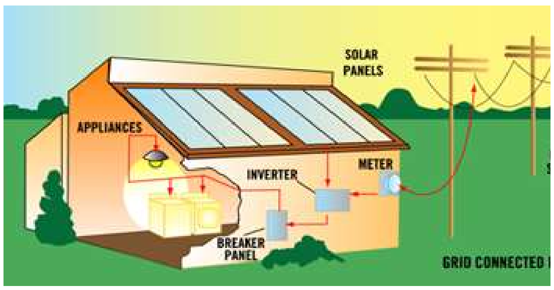

Fig1. Residential Grid connected Solar Roof Top Photo Voltaic Power Plant

3. SOLAR PANEL CHARACTERSTICS

The typical I-V curve and P-V curve for a solar panel are shown in fig.2 [3]

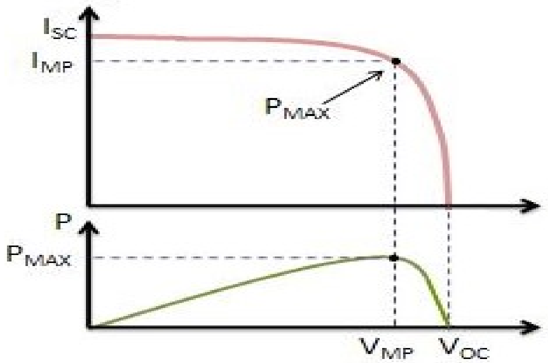

Fig.2. P-V and I-V curve of a solar cell at a particular temperature & irradiation

In the above figure, there is a power point on the knee of I-V curve. This point is called "maximum power point" (MPP) [4]. In the curve, I_{SC} is the solar panel circuit current in short circuit condition & V_{OC} is the solar panel circuit voltage under open circuit condition.

I_{MP} and V_{MP} are the tracking point for maximum current and maximum voltage respectively and can be track by MPPT system. Thus, the multiplication of both I_{MP} and V_{MP} gives the condition of maximum power for solar module as

$$P_{MAX} = V_{MP} * I_{MP} \text{ watt}$$

4. DESCRIPTION OF SOLAR PV GRID CONNECTED SYSTEM

A grid-connected PV system consists of solar panels, inverters, a power conditioning unit and grid connection equipment. It has effective utilization of power that is generated from solar energy as there are no energy storage losses. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load to the utility grid [7].

A Grid-connected solar PV system consists of following main components [8]:

A. Solar photovoltaic (PV) modules

Solar PV modules are mounted on the roof of buildings and convert sunlight into direct current. To achieve a required voltage and current, a group of PV modules are wired into large array called PV array.

B. Solar PV array support structure

These are galvanized steel structures secure the solar PV modules on the roof of building. The mounting structures require roof to be penetrated and mounting solar panels correctly is part of maximizing power generation

C. Solar grid inverter

Solar grid inverter converts generated direct current into alternating current and is fed to the grid.

D. Balance of system

All other components considered for solar rooftop power plant are cables, junction boxes, fuses etc.

The size of solar plant require depends on requirement of electrical load, number of KWh consumption

5. PERFORMANCE ANALYSIS OF PV SYSTEM

The performance parameters are developed by International Energy Agency [10] for analyzing the performance of solar PV grid interconnected system. Many performance parameters are used to define the overall system performance with respect to the energy production, solar resource and overall effect of system losses. The various parameters are the performance ratio, final PV system yield and reference yield.

5.1 System parameters [9]

Array yield

It is equal to the time which the PV plant has to operate with nominal solar generator power P_o to generate array DC energy E_A. Its units are kW h/d_* kWp. $Y_A = E_A/P_O$

Where, Array energy output per day E_A = $I_{dc*}V_{dc*}t$ (kW h),

I_{dc} = DC current (A)

V_{dc} = DC voltage (V)

P_0 = Nominal Power at STC.

Reference yield

The reference yield is the total in-plane irradiance H divided by the PV's reference irradiance G. It represents the under ideal conditions obtainable energy. If G equals 1 kW/m^2, then Yr is the number of peak sun hours or the solar radiation in units of kW h/m^2. The Yr defines the solar radiation resource for the PV system. It is a function of the location, orientation of the PV array, and month-to month and year-to-year whether variability.
Its units are h/d.

Y_R = [kW h/m^2]/1 kW/m^2.

$Y_R = H_t/G_o$

Where,

H_t = Total Horizontal irradiance on array plane (Wh/m^2), G_o = Global irradiance at STC (W/m^2).

Final yield

The final yield is defined as the annual, monthly or daily net AC energy output of the system divided by the peak power of the installed PV array at standard test conditions (STC) of 1000 W/m^2 solar irradiance and 25 °C cell temperature. Its units are kW h/d_*kW p.

$Y_F = E_{PV, AC} / P_{maxG,STC}$

Performance ratio

The performance ratio is the final yield divided by the reference yield. Performance ratio can be defined as comparison of plant output compared to the output of the plant could have achieved by taking into account irradiation, panel temperature, availability of grid, size of the aperture area, nominal power output, temperature correction values.

PR = Y_F/Y_R.

Capacity utilization factor

It is defined as real output of the plant compared to theoretical maximum output of the plant.

CUF = Energy measured (kW h) / (365 ∗ 24 ∗ installed capacity of the plant).

Inverter efficiency

The inverter efficiency appropriately called as conversion efficiency is given by the ratio of AC power generated by the inverter to the DC power generated by the PV array system. The instantaneous inverter efficiency is given by,

$\eta_{inv} = P_{AC} / P_{DC}$

System efficiency

The instantaneous daily system efficiency is given as PV module efficiency multiplied by inverter efficiency.

$\eta_{sys,T} = \eta_{PV,T} * \eta_{inv,T}$.

Energy output or energy fed to utility grid

The energy generated by the PV system is the measure of energy across the inverter output terminals for every minute. It is defined as the total daily monitored value of AC power output and the monthly AC energy generated.

5.2. Specific plant losses

Energy losses occur in various components in a grid connected SPV Power plant under real operating conditions. These losses are evaluated using the monitored data.

Array capture losses (L_C):

These are of two types.

- Thermal capture loss (L_{CT}): Losses caused by cell temperature higher than 25 °C are called thermal losses. Thermal capture loss (L_{CT}) is the difference between reference field and corrected reference field.

- Miscellaneous capture loss (L_{CM}): Losses that are caused by wiring, string diodes, low irradiance, partial shadowing, mismatching, maximum power tracking errors, limitation through dust, losses generated by energy conduction in the photovoltaic modules

$LCT = YR - YCR$
$LCM = YCR - YA$
$LC = YR - YA$

System losses (LS)

These losses are caused by inverter, conduction and losses of passive circuit elements.

$LS = YA - YF$

6. Simulation using PV SYST

PV syst software [11] is one of the simulation software developed to estimate the performance of the solar power plant. It is able to import meteo data from many different sources as well as personnel data. This software is capable of evaluating the

performance of grid-connected, stand-alone and pumping systems based on the specified module selection. The program accurately predicts the system yields computed using detailed hourly simulation data

6.1. Balances and main results

The maximum energy is generated in the month of March (14633KWh) and minimum energy is in the month of July (9989KWh). The total amount of energy that is injected in to the grid for the entire year is 146575KWh is shown in Table.1.

Table.1 The simulation input and the main results of grid connected 100KWP solar plant

New simulation variant

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E Load	E User	E_Grid
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh
January	118.0	14.70	147.5	144.1	12414	321.3	142.3	11778
February	137.0	17.29	159.6	155.6	13064	290.2	139.5	12409
March	188.0	22.70	195.2	189.7	15390	321.3	160.5	14633
April	207.0	28.80	189.9	183.6	14331	310.9	154.1	13618
May	222.0	32.51	183.7	176.8	13552	321.3	163.7	12838
June	197.0	32.90	157.5	151.0	11673	310.9	161.0	11027
July	167.0	30.30	139.6	134.0	10589	321.3	160.1	9989
August	160.0	29.91	142.9	137.8	10878	321.3	159.1	10264
September	171.0	29.51	168.1	162.9	12745	310.9	148.1	12094
October	165.0	26.21	184.5	179.9	14313	321.3	147.2	13616
November	129.0	20.90	160.7	156.9	13032	310.9	142.3	12385
December	115.0	16.00	151.2	147.6	12568	321.3	144.2	11925
Year	1976.0	25.18	1980.2	1919.8	154550	3782.9	1821.9	146575

Annual global horizontal irradiation is 1976 kWh/m^2. Global incident energy that is incident on the collector plane annually is 1980.2 kWh/m^2. Total energy obtained from the output of the PV array is 154550 kWh.

6.2 Performance ratio

The annual average performance ratio is 74.9% The PV syst results performance ratio is not much difference with the actual performance ratio of the solar plant observed using SCADA system in real time.

The normalized performance coefficients are shown in Table.2

Table.2 Normalized performance coefficients

New simulation variant

Normalized Performance Coefficients

	Yr kWh/m².day	Lc	Ya kWh/kWp/d	Ls	Yf kWh/kWp/d	Lcr	Lsr	PR
January	4.76	0.754	4.00	0.159	3.85	0.158	0.033	0.808
February	5.70	1.033	4.67	0.184	4.48	0.181	0.032	0.786
March	6.30	1.332	4.96	0.193	4.77	0.212	0.031	0.758
April	6.33	1.552	4.78	0.186	4.59	0.245	0.029	0.725
May	5.92	1.553	4.37	0.177	4.19	0.262	0.030	0.708
June	5.25	1.358	3.89	0.162	3.73	0.259	0.031	0.710
July	4.50	1.087	3.42	0.142	3.27	0.241	0.032	0.727
August	4.61	1.101	3.51	0.147	3.36	0.239	0.032	0.729
September	5.60	1.354	4.25	0.168	4.08	0.242	0.030	0.728
October	5.95	1.334	4.62	0.177	4.44	0.224	0.030	0.746
November	5.36	1.012	4.34	0.168	4.18	0.189	0.031	0.780
December	4.88	0.822	4.05	0.161	3.89	0.168	0.033	0.798
Year	5.43	1.191	4.23	0.169	4.07	0.220	0.031	0.749

6.3 Normalized productions

The Collection or PV array loss L_C value is recorded as 1.191 kW h/kWp/day and the system or inverter loss L_S value is recorded as 0.169 kWh/kWp/day and

produced useful energy or inverter output Y_F is given as 4.07 kWh/kWp/day as in Fig.3.

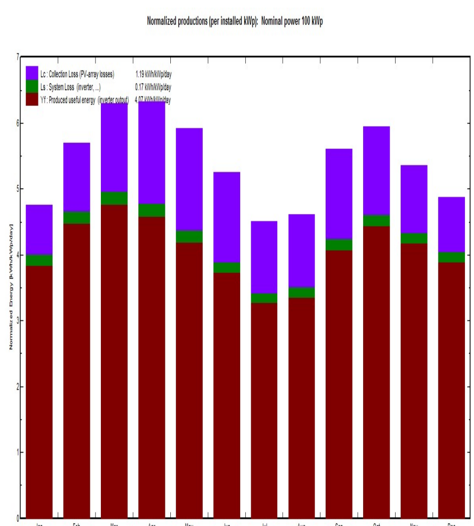

Fig.3 Normalized energy per month

6.4 Loss diagram

The global horizontal irradiance is 1976 kWh/m². The effective irradiation on the collector plane is 1920 kWh/m². Therefore, the loss in energy is 3.3%. The solar energy incident on the solar panels will convert into electrical energy. After the PV conversion, the nominal array energy is 192.8 MW h. The efficiency of the PV array is 15.68% at standard test condition (STC). Array virtual energy obtained is 154.6 MWh. After the inverter losses the available energy obtained at the inverter output is 146.6 MWh as shown in Fig.4.

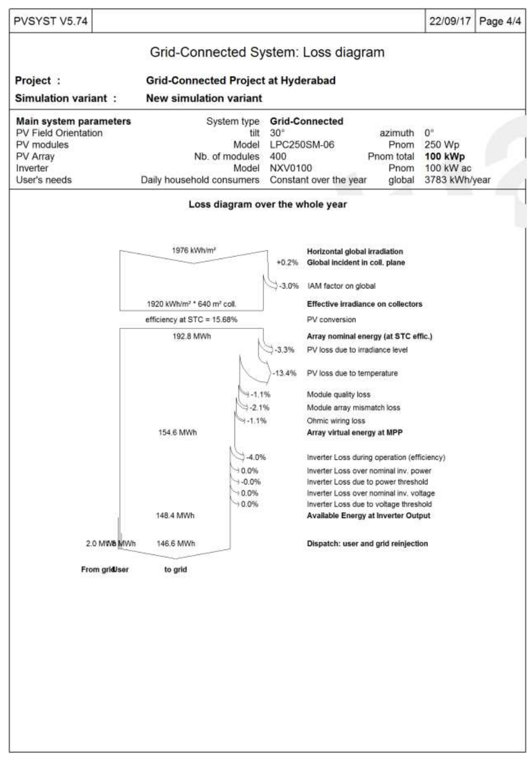

Fig.4 Loss diagram over the entire year

6.5 Global Horizontal irradiation

The plant has more global irradiation in the month of May is 222 kW h/m² The plant has more global in-plane irradiation in the month of march is195.2 kW h/m² as seen from Table.1. The reference incident energy on collector plane is shown in Fig.5

The average reference incident energy on collector plane is 5.425 KWh/m^2.day

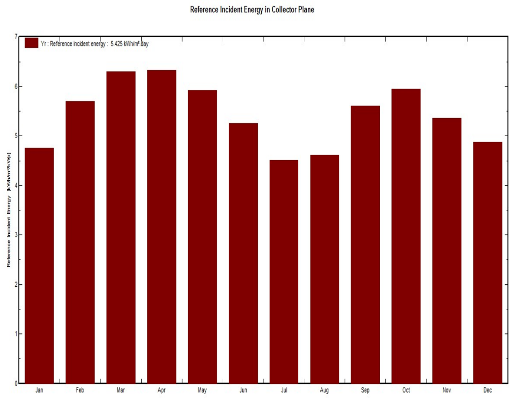

Fig.5 Reference incident energy on collector plane

6.6 simulation of energy output/day

Energy output/day is shown in Fig.6

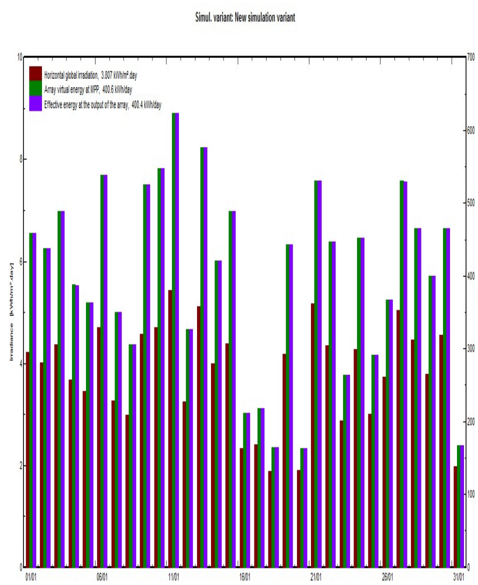

Fig.6 Energy output / day

Horizontal global irradiation is 3.807 KWh/m^2.day, Array virtual energy output at MPP is 400.6 KWh/day and the effective energy output of the array is 400.4 KWh/day as seen from Fig.6

Global inverter losses/day is shown in Fig.7

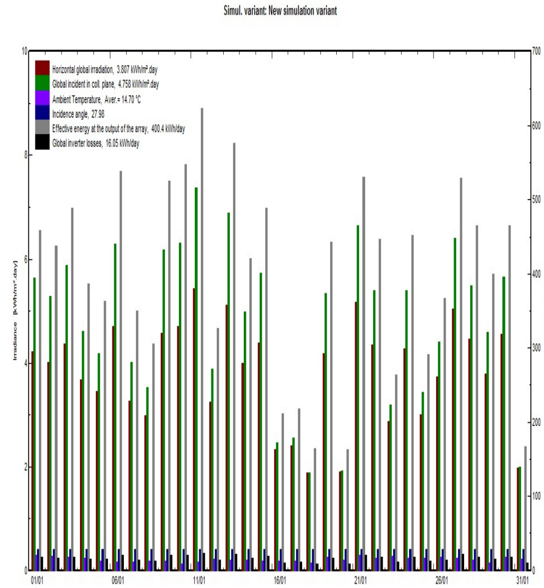

Fig.7 Global inverter losses/day

The horizontal global irradiation is 3.807KWh/m^2.day. The global inverter losses are 16.05 KWh/day.

7. CONCLUSIONS

A performance and Simulation analysis of 100 KW peak grid connected solar photovoltaic power plant installed at Hyderabad was evaluated on annual basis using PV syst. The following conclusions are drawn from the study.

- Maximum total energy generation of 14633 KWh was observed in the month of March and lowest total energy generation of 9989 KWh was observed in the month of July.
- Annual global horizontal irradiation is 1976 kWh/m^2. Global incident energy that is incident on the collector plane annually is 1980.2 kWh/m^2. Total energy obtained from the output of the PV array is 154550 kWh.
- The annual average array final yield is 4.07KWh/KWp/day at reference yield of 5.43KWh/m^2.day

- 100 KWp solar power plant is operating with good amount of PR of 74.9% and CUF of 16.73%.

- Horizontal global irradiation is 3.807 KWh/m^2.day, Array virtual energy output at MPP is 400.6 KWh/day and the effective energy output of the array is 400.4 KWh/day.

- The global inverter losses are 16.05 KWh/day.

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