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A Case Study: Performance Evaluation of 100kW SRPV at GNDEC, Bidar

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***Abstract*--In recent years, increased emphasis has been placed on Photovoltaic(PV) Technology as the application of this technology has shown a sustained growth.In the emerging PV markets worldwide, the use of appropriate estimation of the operating performance grid-connected PV system is becoming more and more crucial. This paper presents an assessment of the electricity generated by 100kW PV grid connected system installed on the rooftop of Electrical Science Block of Guru Nanak Dev Engineering College, Bidar.A central issue in the sustainable diffusion of PV technology is represented by the actual energy efficiency of the PV system. For this reason, a performance analysis needs to be carried out. The various performance indices that are used to analyze thesystemperformanceareperformanceratio,system loss, system efficiency and specific yield. The experimental data was recorded from July 2016 to July 2017 based on real timeobservation.**

Index terms: Photovoltaic technology, PTC, STC, PVUSA (Photovoltaics for Utility Scale Applications).

I. INTRODUCTION

India is densely populated and has high solar insulation, providing an ideal combination for solar power in India. Power is the lifeline of any development of the nation. In order to bring down the dependence of finite fossil fuel for power generation, it is necessary to look into the viability of generating power locally using renewable energy sources.

Fortunately, India lies in sunny regions of the world. Most parts of India receive 4.7kWh of solar radiation per square meter per day with 300-325 sunny days in a year. So, far 10,572 villages have been electrified using various renewable energy systems. About 2.55 lakh street lights, 9.93 lakh solar home lightening systems, 9.39 lakh solar lanterns and 138MW of decentralized solar power plants have been installed.

Considering the good potential of solar power plant, GNDEC Bidar has set up a 100kWh Rooftop Solar PV based Power plant with 400 PV Modules, 6 String inverters as the major components and other accessories for the power production. All the Necessary auxiliary facilities of the power plant like plant monitoring system, safety equipment's, instrumentation, control system etc has been provided.

This paper presents the performance analysis of 100kW Solar Power Plant installed on the roof top of Electrical Science block of Guru Nanak Dev Engineering College, Bidar. Solar roof top was installed in August 2015. The data collected for monitoringisfromJuly2016toJuly2017whichhas been used to analyse and estimate the operating performanceoftheplant.Thesignificantparameters which dominates the performance of the grid-connected PV system such as total yield, specific yield, performance ratio, and modified PVUSA rating based performance ratio have been obtained.

II. SYSTEM TECHNICALDESCRIPTION

A 100kW grid-connected rooftop solar system was installed on the rooftop of Electrical Science Block of Guru Nanak Dev Engineering College, Bidar in August 2015. The PV array consists of Polycrystalline Silicon Module designed by Alpex Solar fixed to the roof using metal mounting structure with 17º tilt angle. The plant specifications are given in Table 1. The module specifications are given in Table 2. The output of the 6 inverters are collected at the distribution box and is connected to form a three-phase system.

TABLE 1

Sl.no	Parameter	Value
1	Rated Power at STC	100Kw
2	Number of modules	400
3	Number of inverters	6
4	Number of module/string	22
5	Number of strings	18
	Number of strings/inverter	3
7	Plant output	3 phase 415V AC

PLANT SPECIFICATIONS

TABLE 2

MODULE SPECIFICATIONS

Sl. No.	Parameter	Value
1	Model	ALPX 250W (AlpexSolar)
2	Maximum Power P_{mpp}	250W
3	Voltage at maximum power V_m	29.95V
4	Current at maximum power I_m	8.35A
5	Open circuit voltage V_{oc}	37.20V
6	Short circuit I_{sc}	8.75A
7	NOCT	-46°C ± 2°C
8	Temperature coefficient of Power	-0.45%/°K
9	Temperature coefficient of Voltage	-0.31%/°K
10	Temperature coefficient of Current	0.05%/°K
11	Temperature Range	-40°C to 85°C

III. PERFORMANCE CHARACTERIZATION

Normally, the starting point in the system performance analysis of the PV systems is its rated dc power at Standard Test Conditions (STC) i.e. irradiance of 1000 W/m^2, AMI=1.5 and cell temperatureof25°C.Nextstepistodetermineactual ac power produced once system is put into the field conditions which is givenby

$P_{ac} = P_{dc,\,STC}$ **conversionefficiency*....................(1)

Where $P_{dc,\,STC}$ is the name plate Power rating of the system at STC and conversion efficiency includes the effect of the inverter efficiency, dirt accumulation at the module surface, module mismatch and effect of variation in ambient conditions from STC. In this paper, authors use frequently utilized indices to estimate the performance of the grid-connected PV systems whichdictatesoverallsystemperformancerelatedto energy production, solar resource and different conversion losses. In what follows, the performance parameters-Total Yield, specific yield, performance ratio (PR), and PVUSA rating are briefly described. In the last subsection, major operation and maintenance issues are alsoreported.

A. TotalYield

The total yield of the system is defined as net or total energy produced by the plant in a given time e.g. a day, a month or a year.

B. SpecificYield

The specific yield of the PV system is defined as the ratio of the net or total energy output to the name plate dc power rating of the system specified at Standard Test Conditions (STC).

Specific yield = Net/total energy output (kWh) / Name plate dc powerrating(kWp)…………..(2)

Specific yield normalizes the plant output to the systemsizeandcanbeusedtocompareperformance of the plants of different power rating. In other words, specific yield indicates the number of hour plant operated at its ratedcapacity.

C. Performance ratio (PR)

The plant performance ratio is one of the mostly used performance indicator and commonly known as plant quality factor which can be effectively used to compare plants installed at different locations. The PR is defined as the ratio of actual and theoretical or nominal plant output.

PR=Actualplatoutput(kWh)/Calculated,nominal plantoutput(kWh)………………………………(3)

Where nominal plant output can be calculated using followingrelation

*Nominal plant output=incident solar irradiation at the modules surface of the plant (kWh) * efficiency of the PVmodules*

PR can be determined on daily, monthly or yearly basis. It indicates the proportion of the energy available for export to the grid after deducting thermal losses and conduction losses. The performance ratio tells the plant owners that how energy efficient and reliable their plant is. The determination and monitoring of PR at regular intervals can lead towards the possible faults and other issues in case abnormal deviation is observed in the PR value. There are number of factors which influence the PR such as temperature, irradiance, soiling of module or sensors, module and inverter efficiency, solar technology, and recording period.

D. PVUSARating

In order to account for the change in the power produced due to higher cell temperature, PVUSA rating system is used to calculate the ac power produced under PVUSA test conditions (PTC). The PTCtestconditionsaredefinedasirradianceof1000 W/m2,ambienttemperatureof20ºCandwindspeed of 1 m/sec. The power produced at PTC, $P_{ac,\ PTC}$ is good indicator of the actual power delivered at full sun (1000 W/m2) irradiance as compared to name plate rating $P_{dc,\ STC}$. The difference between $P_{dc,\ STC}$ and $P_{ac,\ PTC}$ is a good indication of the system losses associated with dc to ac conversion. The reduction in the PVUSA rating with time reflects permanent loss in the system performance. In order to determine $P_{ac,\ PTC}$, first step is to calculate cell temperature T_{cell} using followingrelation.

$$T_{cell} = T_a + ((NOCT - T_a)/0.8)G \qquad (4)$$

Where G is full sun solar irradiance. Now to obtain Pac, PTC following relations are used.

$$P_{dc,\ PTC} = P_{dc,\ STC}\,[1 + k_{mpp}(T_{cell} - 25)] \qquad (5)$$

$$P_{ac,\ PTC} = P_{dc,\ PTC} * \eta_d * \eta_m * \eta_i \qquad (6)$$

Where, NOCT is the Normal Operating Cell Temperature, $k_{mpp}$is temperature coefficient of the maximum power, η_d is the efficiency factor due to dirt accumulation on the module surface, η_m is the efficiency factor due to module mismatch and ηi is the module efficiency.

In the presented work, authors use ratio of $P_{ac,PTC}$to $P_{dc,STC}$to estimate the system losses associated with dctoacconversion.ModifiedPTCconditionsbased on actual monthly mean module temperature rather than one obtained using fixed ambient temperature of 20ºC is considered in the study. Specified values of the $k_{mpp}$and $\eta_i$are used while the realistic values are assumed for η_d andη_m.

TABLE 3

TOTAL CONSUMPTION AND GENERATION WITH AND WITHOUT SOLAR

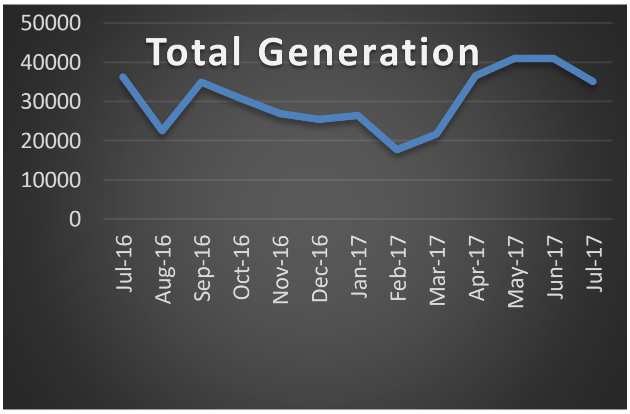
Total Unit Consumed before solar	501534.00
Total Unit Consumed after Solar	361500.00
Solar Generation per Year of 100 kWp	140034.00
Solar Generation per Month of 100 kWp	11669.50
Solar Generation Per Day	388.9833333
Solar Generation Per KW	3.889833333

The above table shows that 501534 units were consumed before installing solar and after its installation, the consumption has been slightly reduced to 361500 units. The generation of solar per year of a 100 kWp solar plant is 140034 and that per a month is 11669.50. solar generation per day is 388.9833, and hence the generation of solar per kW per day is 3.889833.

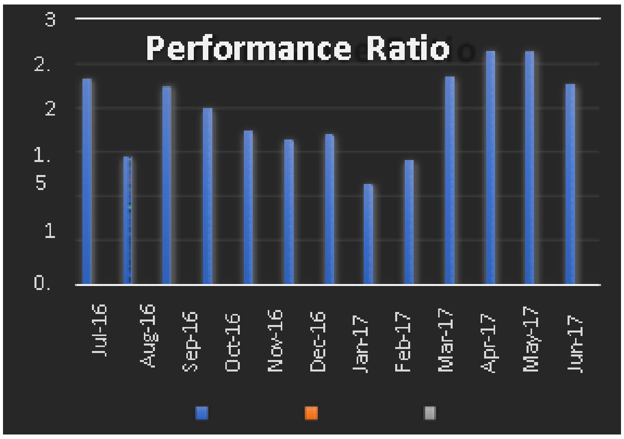
IV. RESULTS

This section gives a detailed information about the case study of 100kW rooftop PV system. Graph 1,2 and 3 shows the plotting of monthly based total generation, specific yield and performance ratio's respectively.Fromthecollecteddataofoneyeari.e. , from July 2016 to July 2017 the graphs have been plotted. For the calculation of PR, we need nominal plant output which can be calculated using the formula mentioned above in section III that uses module efficiency of15.54%.

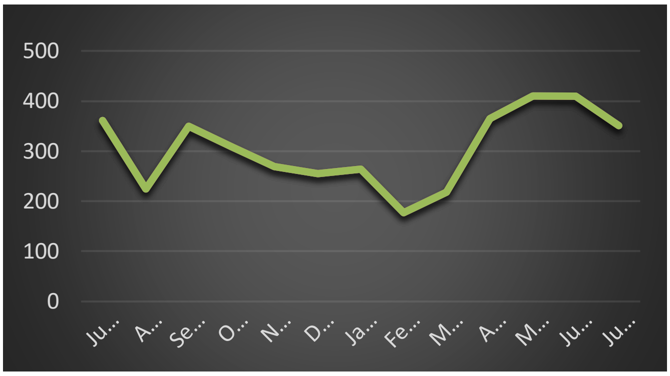
Graph 1: Total Generation from July 2016 to July 2017



Graph 2: Total Specific yield of 100 kW SRPV plant



Graph.3: Performance Ratio of 100kw solar plant



V. CONCLUSION

This paper presents the case study of 100kW grid connected roof top PV system using the factors of performance indices such as total yield, specific yield and performance ratio. Performance ratio of the plant considered ranges from 1.14 to 2.63. Specific yield and Performance Ratio are important factors which can be used for comparison of the plant performance with different plants of different locations.

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