Performance Ratio and Losses Analysis of 1MW Grid-Connected Photovoltaic System

Dinesh Kumar Sharma[1], Varsha Verma[2], Shailendra Sharma[2]

[1]M.Tech Scholar, Energy Technology, Department of Electrical & Electronics Engineering
Mandsaur Institute of Technology, Mandsaur (M.P)
[2]Department of Electrical &Electronics Engineering,
Mandsaur Institute of Technology, Mandsaur (M.P)

Abstract: In recent time installation of Solar Photovoltaic power plant increasing day by day due to its renewable nature and conventional sources depleting rapidly. Installation of solar plant started few years back so it is important to evaluate the performance of installed Solar Photovoltaic system to access the technical analysis and performance of the plant. The performance of any photovoltaic plant is monitored by performance ratio. Performance ratio is defined as the ratio of actual yield to reference yield and sometimes it is used to compare grid-connected photovoltaic plants at different locations. This paper investigates the simulation performance ratio and practical performance ratio and result will be compared with simulation result for the same Solar Photovoltaic plant. In this paper author have selected a project located at Jaisalmer, Rajasthan (India).For this analysis we have collected one year actual onsite power generation data and on basis of these data, we will calculate the performance ratio manually this performance ratio will be compared with simulation performance ratio.

Key word: Losses, Photovoltaic system, Performance ratio and Simulation

1. INTRODUCTION

As we know that conventional sources of energy (fossil fuel) are depleting rapidly and their serious impact on environment, so focus is on the non-conventional sources of energy, photovoltaic system for power generation is one of the non-conventional sources and it does not produce harmful gases like conventional sources. The performance ratio is one of the most important parameter for evaluating the performance of a photovoltaic system. It is defined by EN 61724 international standards or Indian standards 61724. The EN 61724 defines the performance parameter that may be used to define the overall photovoltaic system performance ratio with respects to the energy production, irradiation and the impact of energy losses on the whole system due to the various factor. The main parameters of interest for this analysis, the reference yield, photovoltaic system yield and performance ratio.

2. SYSTEM PERFORMANCE PARAMETER

Photovoltaic systems of different configuration at different location can be compared by evaluating their normalized system performance indices such as yields, losses, and efficiencies. Energy yields are quantities normalized to rated array power, system efficiencies are normalized to array area and losses are the differences between reference daily yield and daily yield.

a) Daily mean yield

Daily mean yield are the quotient of energy quantities over the installed array rated output power P_0, yields indicate actual array operation relative to its rated capacity. The array yield Y_A is the daily array energy output /kW of the installed photovoltaic array

$$Y_A = \frac{E_{A,d}}{P_0} \quad (1)$$

Where Y_A =array yield, $E_{A,d}$= daily net energy from array, P_0=rated power output

The final photovoltaic system yield Y_f is the part of the daily net energy output from the entire plant that is injected to gird which supplied by the array per kW of installed photovoltaic array.

$$Y_f = Y_A \eta_{load} \quad (2)$$

Y_f=final yield, η_{load}=load efficiency

The reference yield Y_r can be calculated by dividing the total daily in-plane irradiation by the photovoltaic reference in-plane irradiance.

$$Y_r = \tau_r X(\Sigma_{day} G_I)/G_I, \mathrm{ref} \quad (3)$$

Y_r=reference yield, τ_r=reporting interval, E_{day}=summation for the day, G_I=total irradiance in the plane of the array, $G_{I,ref}$= reference total irradiance in the plane of the array

b) Normalized losses

Normalized losses in photovoltaic normalized losses can be calculated by reference yield minus array yield, losses can divided in two parts array capture losses and balance of system losses (BOS)

Array capture losses $L_c=Y_r-Y_A$ (4)

And Balance of system losses $L_{BOS}=Y_A X(1-\eta_{BOS})$ (5)

Loss is defined as the part of solar energy that is not converted into productive output. Photovoltaic losses can be classified in three parts namely pre-photovoltaic losses, module losses, thermal losses and system losses. Pre-photovoltaic losses are mainly due to the shading, dirt, snow and reflection before it hits the photovoltaic panel as we can see from figure 1. All these losses the shading, dirt, snow and reflection is 8% of total intensity of incoming light.

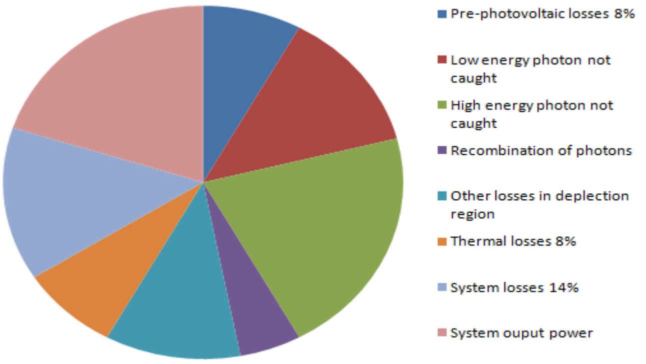


Figure1. Various losses in photovoltaic system

Another component losses is module and thermal losses which represent the efficiency of the photovoltaic module and temperature dependence of the solar module. These are mainly due to low energy and high energy photons are not absorbed by the module, recombination of photons, thermal losses. All included losses are about 58% of total intensity of the light.

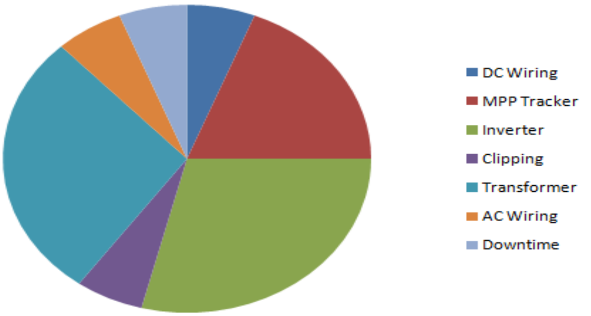


Figure.2 System losses in photovoltaic system

In figure 2 as shown system losses which contains direct current losses, maximum power tracker losses, inverter losses i.e. efficiency of the inverter transformer losses, AC wiring losses due to the resistant of the cable and plant down time due the maintenance or unavailability of the grid. System losses are about 14% of the total incident light.

c) Performance ratio

Performance ratio is the most important parameter of the photovoltaic system for evaluation of the efficiency of the solar photovoltaic system. As per the EN/IS standards 61724 performance ratio is defined as overall system performance with respect to the energy production, solar irradiance and the impact of the energy losses on the whole system.

$$PR = \frac{\text{Actual Yield}_{AC}}{\text{Target Yield}_{DC}} = \frac{Y_f}{Y_r} = \frac{\text{Meter Export Generation(kWh)}}{(\text{Total Monthly Radiation (wh/m2)} * 10853 * 0.092)/1000} \quad (6)$$

This equation is used to calculate actual performance ratio for the selected project site, .092 is the efficiency of the thin film photovoltaic module and 10853 is total photovoltaic module area.

Performance ratio indicates the overall effect of losses on the array rated output due to the array temperature, incomplete utilization of the irradiation and system component failure or inefficiencies.

3. PHOTOVOLTAIC SYSTEM SIMULATION USING PVSYST

Simulation of PV system is done to estimate the power generation during the period, system losses and performance ratio of the photovoltaic system. For this simulation authors have taken project location which Latitude-26.5°N, Longitude-71°E and Altitude 255m. PVsyst provide three options for photovoltaic design preliminary design, project design and tools in preliminary design a rough estimate provide for power generation with financial analysis. In tools we define meteo data, component database and in project design we define the project location, orientation, horizon, shading data photovoltaic panel and system inverter data. In this analysis and at the actual site use the NT-145AX NexPower module.

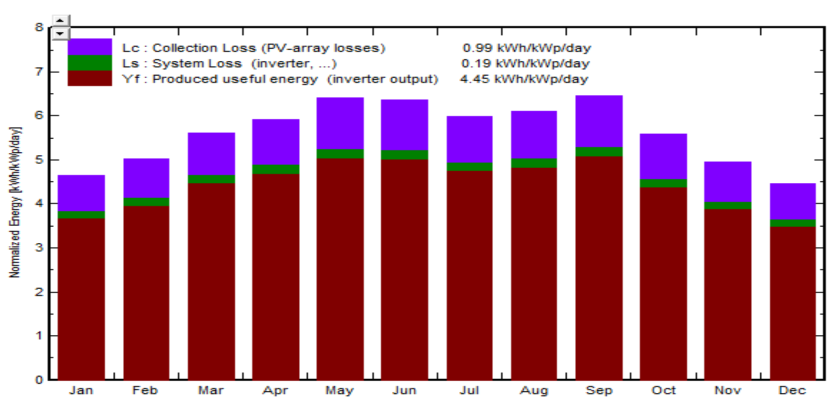
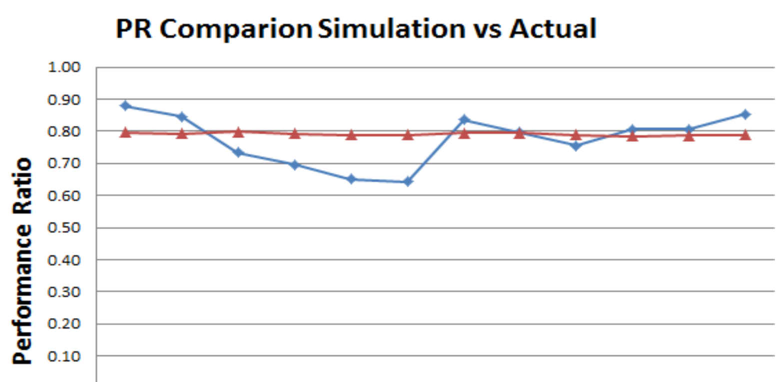


Figure3. Normalized production for the 1MW photovoltaic system for PVsyst simulation

In this project about 6903 solar modules has been installed 9 string in series and 767 string in parallel that makes module area 10839m^2 and cell area 10055m^2, two inverters PowerGate AE-500-50-PV-X-HV make by Satcon the minimum operating voltage 420V and maximum operating voltage 850V.In figure 3 we can see that normalized production of power from the photovoltaic system given from January to December month, the collection loss which are conversion and thermal losses about .99 kWh/kWp/day and system losses i.e. wiring losses, maximum power tracking, inverter and mismatch losses which are .19 kWh/kWp/day. The production of the useful energy (inverter output) was 4.45 kWh/kWp/day.

4. RESULT AND DISCUSSION

Performance ratio indicates the overall effects of losses on the array rated output power due to array temperature, ineffective utilization of the irradiation and system component inefficiencies or system failure or system downtime. When we simulate the photovoltaic system in PVsyst environment then grid injected energy was 1626294kWh and the actual site generation for the same period (one year generation data from January 2013 to December 2013) is 1659010kWh. The performance ratio for the same period was .79 in the simulation environment means 21% of insolation not converted into useful energy or we can say that 21% losses in the system including system losses and module losses.



	Jan '2013	Feb' 2013	Mar' 2013	April' 2013	May' 2013	June' 2013	July' 2013	Aug' 2013	Sept' 2013	Oct '2013	Nov' 2013	Dec' 2013
PRactual	0.88	0.85	0.73	0.70	0.65	0.64	0.84	0.80	0.75	0.81	0.81	0.85
PRsimulation	0.80	0.79	0.80	0.79	0.79	0.79	0.80	0.80	0.79	0.78	0.79	0.79

Figure4. Performance ratio actual result vs. simulation result

When we collect the data from January 2013 to December 2013 for the same project and calculated the performance ratio it is .78, which is slightly lower than performance ratio in simulation environment in this case we do not consider grid availability and plant availability. In another case when we consider grid availability and plant availability the actual performance ratio is .72, which has been calculated from the equation (6). As we have plotted a curve showing the monthly PR from January 2013 to December 2013 in figure 4.

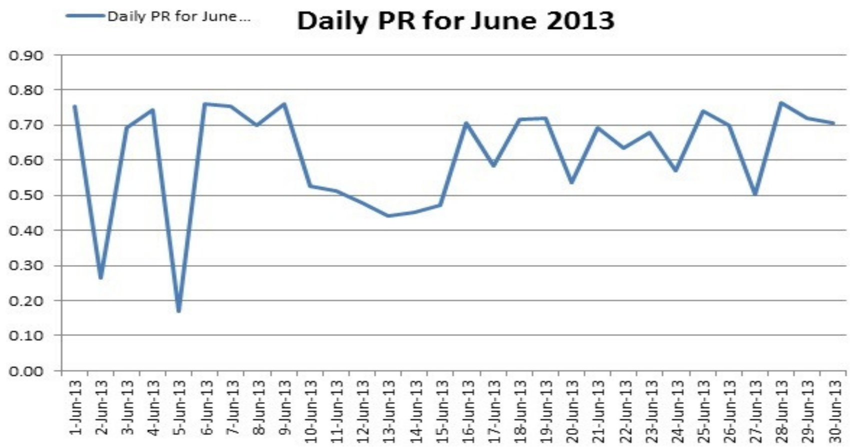


Figure5. Daily performance ratio for the month June 13

From figure 4 we can see that the performance ratio in simulation environment was all most similar for every month, but in actual data there is huge variation in performance ratio of the photovoltaic plant.

The highest .88 PR recorded in the month of January 2013 due to the low module temperature and in month of June 2013 lowest PR recorded .64 due to the high temperature of photovoltaic modules. In figure 5 as we have shown daily variation in performance ratio on 5th June 2013 lowest PR recorded due to the low grid availability this was only 44% and 27% on 2nd June 2013.

5. CONCLUSION

The performance of 1MW grid connected photovoltaic system has been analyzed and compared for the period of one year. As a result we found that the average performance ratio was .79 for the simulation, while the performance ratio for the actual project data is .78 when we do not consider plant and grid availability in performance ratio calculation. When we consider the plant and grid availability in performance ratio calculation, we found the performance ratio is .72 for actual site data. We can say the performance of the photovoltaic plant is quite good it only 1% less than we simulated in PVsyst when we do not consider grid and plant availability. When we consider plant and grid availability then the performance is lower than by 7% with comparison simulation result. The plant availability 98.76% is and grid availability is 92.76% for this project during the whole year, so if we want to increase performance of the plant near to the simulation result then we have to ensure the 100%plant and grid availability. The remaining 1% losses due the module temperature, air velocity, losses due to soiling variation, wire resistant losses to increase the performance of the plant we should ensure 100% plant and grid availability.

6. ACKNOWLEDGEMENT

We would like to thank Mr. Harish Sharma, Assistant Manager and Narendra Gohil, Head technical at Rays Power Infra for extending help and proving the site access and desired data for this analysis.

REFERENCE

[1] Jung Hun so, Young Seok Jung, Gwon Jong Yu, Ju Yeop Choi, Jae Ho Choi," Performance results and analysis of 3kW grid-connected PV system" Renewable energy 32 (2007) 1858-1872.

[2] Julie A Rodiek, Steve R Best, "Comparison of photovoltaic modeling analysis and actual performance data of Lee County Justice Center solar power installation project", 8th annual International energy conversion engineering conference, 25-28 July 2010 .

[3] Indian standard "Photovoltaic system performance monitoring-guideline for measurement, data exchange and analysis" IS/EN 61724:1998.

[4] Performance of solar power plants in India report submitted by Dr. B.D Sharma to Central Electricity Regulatory Commission, New Delhi in February 2011.

[5] Emilio Ghiani, Silvestro Cossu" On the performance ratio of photovoltaic installations",PowerTech (POWERTECH), 2013 IEEE Grenoble, page 1-6, 16-20 June 2013.

[6] Perlman, Jeff, Andy McNamara, and Dante Strobino. "Analysis of PV system performance versus modeled expectations across a set of identical PV systems." Proceedings of ISES Solar World Congress ‘‘Bringing Water to the World", August. 2005

[7] www.greenrhinoenergy.com/technologies/pv_energy_yield.php site accessed on 14March,2014