Performance Evaluation Of A 21 kW Solar Power Plant in Central India & Analysis by using BlueSol PV & Helioscope Software program.

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***Abstract* - Solar energy in the form of Photovoltaic is extensively used across the world. Solar PV can be installed in standalone, grid connected or solar powered satellites. Solar PV has huge potentials still it is not commonly used due to lack of awareness and information about installation technologies and economies of installment and operation. The performance evaluation of a Solar Photovoltaic plant is necessary before installation as it gives the necessary information about expected power generation and costs of installment. Many software simulation programs are available in technical market to predict the performance of a Solar Photovoltaic power plant. In this study after going through various literatures we have discovered the parameters which are needed to be determined to perform the Evaluation of a Solar Photovoltaic system. and we are going to compare the observed monthly power generation of a site in Central India with simulation results of expected power generation of two software programs BlueSol PV and Helioscope.**

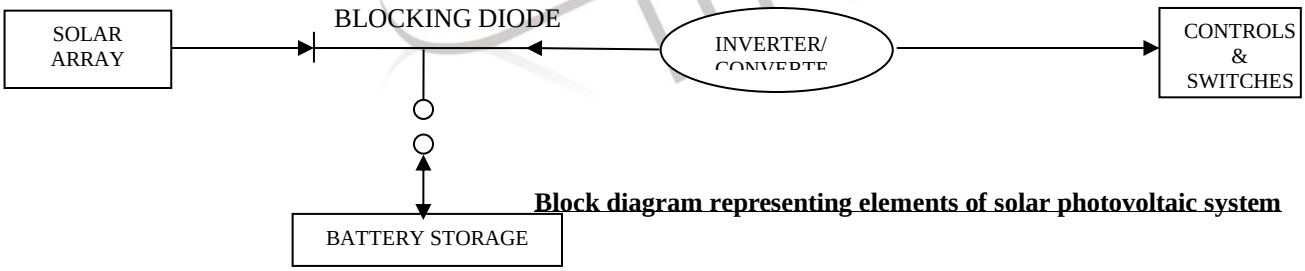
***keywords* - Solar energy, Solar photovoltaic, photovoltaic effect, semiconductors, solar array, renewable energy, sunlight**

1.0 INTRODUCTION

Solar energy which is a renewable source of energy , is radiant heat and light from sun. Solar Photovoltaic is a technology that converts sunlight into direct current by semiconductors using photovoltaic effect. The photovoltaic effect is defined as generation of electromotive force as a result of absorption of ionizing radiation. Energy conversion devices which are used to convert sunlight to electricity by use of photovoltaic effect are called solar cells .A single converter cell is called a solar cell or more generally a photovoltaic cell and combination of such cells designed to increase the electric power output is called solar module or solar array. There are three broad categories of Solar photovoltaic:

- Standalone PV system
- Grid Connected PV system
- Solar Power satellites

The elements of solar PV system includes Solar array, Blocking diode, Battery storage, Inverter/converters,



Block diagram representing elements of solar photovoltaic system

1.1 Elements of Solar Photovoltaic system

A basic photovoltaic system integrated with utility grid is shown in figure, its main elements are:
(a)SOLAR ARRAY – It is large or small array of solar collectors which convert solar radiation to useful DC electric power.
(b)BLOCKING DIODE- A blocking diode allows the array generated power flow only toward the battery or grid. without blocking diode the battery would discharge back through solar array during times of no insolation.
(c)BATTERY STORAGE –A battery stores the solar generated electric power for subsequent uses.
(d)INVERTER/CONVERTER – It is typically a DC–AC converter which converts the battery bus voltage to AC frequency and phase to match that needed to integrate with utility grid.
(e)APPROPRIATE SWITCHES & CIRCUIT BREAKERS-Switches and circuit breakers are used to permit isolating parts of system from battery.

Solar photovoltaic has wide applications in Industrial, commercial and social sectors. Global growth of solar PV has achieved an exponential growth from 1992 to 2018. The top installers are India, USA and China. There are 24 countries around the world which have a cumulative capacity of more than 1 Gig watt. This technology is not used commonly for power generation in central India due to lack of awareness, its costs and certainty of amount of power generation. A study

for evaluating the power performance of a solar photovoltaic power plant before installations is necessary to create an awareness about technologies and economies of power plant installations.

2, LITERATURE SURVEY

H. Banda, Karidewa Nyeinga, Denis Okello(1) (2019): In this paper Performance evaluation of 830 kwp grid connected **Mavuto** photovoltaic power plant at kamuzu International airport in Malawi is done on monthly and annual basis. The PV array comprises 3540 solar modules of hetero junction with intrinsic thin layer (HIT) technology rating of each module 235 w and tilted at 30 degree .the four year average annual efficiencies are:

Array efficiency-15.3, Inverter efficiency- 95.2 and Overall efficiency-14.6 percent. Comparison of performance parameters which are obtained from monitored data are done with with simulated data considering same parameters are done using PV SYST software. The grid connected PV power plant operated nearer to predicted performance. The normalized mean bias errors, which in most cases are within $\pm$ 5 percent . this result clearly shows that simulation done are reliable and useful.

Manish kumar, Arun kumar(2) (2019): In this paper the performance of the world's first commercial multi crystalline silicon based utility scale 10 MW canal top solar PV system located in Indian state of Gujrat has been carried out for initial two years and 8 month operation and assessed to estimate the long term performance and reliability of canal top PV systems as the environmental conditions are different from land based system which may effect its performance and degradation rate. An experimental setup was fabricated to compare the canal top PV system with land based system and measurements were carried out in outdoor conditions, The monthly average performance ratio was found 77.85 percent, System efficiency- 11.90 percent and Capacity factor- 17.36 percent. The results of canal top system with land based conclude that water tank based PV module has a lower performance than the land based despite its low temperature due to evaporative cooling, Water tank based module has lower operating current and voltage in comparison to land based modules.

Thus it can be concluded on the basis of an experimental study that multi Si based canal top PV system have lower performance as compared to land based PV system. this is in opposite of general prediction that multi Si based land top PV system has higher power production.

Md. Bengir, Ahmed Shuvho et. Al.(3) (2019): In this paper Performance analysis of 80 KW grid connected solar power plant located in capital of Bangladesh Dhaka is conducted. A solar irradiation prediction model based on fuzzy logic and artificial neural networks which aims to achieve a good accuracy at different weather conditions. The performance obtained from this photovoltaic power plant is compared with other heuristic models and also with other grid connected PV systems in the world. The accuracy of fuzzy logic model was obtained at 97.47 percent and the accuracy of ANN model was obtained 98.78 percent with actual irradiation. The analysis work performed shows that ANN model is better than fuzzy logic model for solar irradiation prediction and This power plant is operating with good amount of performance ratio i.e. 66 PR.

S Martin-Martinez, M. Canas-Carreton et al.(4) (2019): The performance evaluation of six large PV power plants located in south central region of Spain with different layouts over a time interval of up to 5 years is done. Moreover the evaluation of different mounting technologies in almost the same geographic site i.e. under the same meteorological conditions, completes the analysis with data rarely available for this type of study. The PR results obtained in this analysis coincide with those expected, considering the geographic location and configuration of PV power plant. A seasonal trend is observed in all the power plants with lower PR values in summer than in winter but the behavior of this trend changes with mounting conditions. Sites having dual axis tracking the PR values exhibits greater variability than PR values presented by fixed axis and single axis tracking is found to be an intermediate case but closer to fixed axis behaviour. This variability is also presented in monthly and yearly values .Photovoltaic power plant size has been identified as an important parameter effecting PR values, lower PR values are observed in largest one due to higher probability of occurrence of failures in dual axis trackers.

Total system efficiency of power plant for all the years is between 10-12 percent except in PV power plant with dual axis trackers as it encounters many failures, partly due to wind causing efficiency to be decreased by 9 percent. Based on this wind speed can be identified as another important parameter that must be considered in a design process of photovoltaic power plant. PR values of dual axis power plants under conditions of wind are less than normal conditions, while fixed axis power plant do not represent this type of behavior. Therefore in areas of high winds the advantages of using dual axis system is diminished due to operation and maintenance difficulties and ultimately selection of fixed axis or single axis configuration emerges as a better solution.

Simak jamali, Arash Nemati et al.(5)(2019): In this study an integrated semitransparent PV system and solar chimney system is prepared for enhancing the cooling of STPV panels. A mathematical model is proposed for analyzing this system and results are validated using experimental data for solar chimney and PV panels. Furthermore a comprehensive economic evaluation for proposed system is carried out. In the first step influence of main decision variables and ambient conditions is investigated, then the simulation effect of decision variables on economic parameters are presented in 3D diagram. Finally the economic performance of proposed system is studied for different cities with variable climatic conditions. Considering constant values for decision variables increasing both chimney height and collector radius improves power production. Power generated shows a maximum value by power factor varying, payback period and unit cost of produced power are both minimized by packing factor, bigger collector radius and shorter chimneys are desirable from economic viewpoint. Considering all 3d diagrams which represents simultaneous effect of decision variables on economic performance. It can be concluded that desirable range for packing factor is 0.3-0.5 and for collector radius and chimney height the suitable range is collector radius should be more than 120 m and chimney height should me less than 250 m. in these ranges payback period and unit cost of produced power have their lowest amount which are payback period of 8 years and unit cost of 0.0602$/kWh.

.**Mert Gurturk(6) (2019):**In this study economic feasibility analysis of a solar power system which is located in Elazing turkey has been carried out by considering many parameters and methods. The parameters involved are investment costs, operation and maintenance cost, solar radiation, optimum angle of PV module and many more. The methods used in this study are levelized cost analysis ,and solar radiation forecasting. In the cost analysis carried out with parameters considered in this study,

payback period is calculated as 13 years and annual profit of 1 MW solar energy plant is $ 89,467.
Present worth of plant is 1156763 US dollars and annual capital cost of solar power plant is 181875 US dollars respectively. At the completion of lifetime of power plant the salvage value of 1 MW of solar power plant was calculated as 115676 US dollars.The income of the power plant for 5 months of a year is less than the average monthly capital cost flow because the power generation during this period is not enough. But the solar power plant makes profit in remaining 7 months.Results obtained from the analysis for considered location shows that this location is suitable for power plant. However , the economic conditions of country must be predictable to invest on suitable technical parameters such as sunshine time or radiation value is not enough. In addition it is seen that economic condition must meet appropriate condition for investing in power plant.

Satish kumar yadav , Usha Bajpai (7) **(2018):** In this paper a performance evaluation of 5 KW rooftop solar photovoltaic power plant has been presented based on available data of a year. The effect of temperature on performance of plant has been compared with other installed plants in India. The Annual average reference yield was 5.23 kWh/kW/day, Array yield (4.51 kWh/kW/day), Final yield (3.99 kWh/kW/day)System yield shows that working of system is quite satisfactory. Average PV array efficiency- 11.34 percent, Inverter efficiency- 88.38 percent, System efficiency- 10.032 percent. Annual average performance ratio of plant is 76.97 percent and CUF is 16.39 percent which is comparable to other plants installed in India.The yearly yield of plant- 7175.4 kWh/year with an average of 24.54 percent total losses. Capture losses-12.92 percent and system loss-11.62 percent. Capture loss due to rise of cell temperature is calculated as 6.34 percent. System losses can be reduced by using a more efficient inverter the plant prevented 7.032 ton of carbon dioxide from entering into the atmosphere, throughout the year. Results show that energy loss is maximum during month of May when temperature is highest.

Charaf Hajjjaj, Ahmed alami merruni et al. (8) **(2018):** In this paper the accuracy of twelve models to predict the performance of photovoltaic plants performance were analyzed by comparing between simulated data and those measured at ground level using 252 W polycrystalline photovoltaic PV module exposed under real working conditions for a time period of one year at different times. The results obtained from this analysis shows an annual electricity output of 504.855 kWh and a performance ratio more than 80 percent for complete year. The results show that Mid south of Morroco can be determined as a good location for PV plants. Results show that models developed by Twidell, Yamawaki and Nishoka named M1, M2, M3 are most adequate to simulate PV performance under semi arid and hot climatic conditions, with an hourly NRSME of 7.07 percent during spring, 4.23 percent during summer, 7.56 percent in autumn and 10.11 percent in winter. Considering the site measurements , mid south of Morocco can be considered as a very good location for PV plants with a higher PR higher than 80 percent and an average efficiency of 16 percent.

Hassan Z, Al Garni ,Anjali Awasthi (9) **(2018):**In this paper a critical and in depth assessment of various studies based on site suitability of utility scale photovoltaic plant with integration of GIS and MCDM tools.GIS based MCDA is continues to expand in research output to offer an efficient decision support. This proposed review can assist solar developers in identifying sites for solar projects that have a significant technical performance along with minimum cost and low environmental impact.
In the solar PV site suitability studies solar irradiation is the highest reported decision variable followed by proximity to power lines and land slopes whereas the protected land and watercourses considered the highest restriction factor. For the last fifteen years development of grid connected PV surpasses the off grid installations worldwide. The exploitation of grid connected solar PV is proven and has gained favour where huge areas are accessible and significant amount of irradiation is available. China's installed PV capacity doubled in 2016 turning it into world's largest producer of solar energy by capacity. At the end of 2016 installed PV capacity rose to 77.42 GW with adding of 34.54 GW over the course of year while Spain has added 55 MW in 2016, A 1.12 percent of year on year increase. As a result of such installations growth in both the countries China leads the site suitability followed by Spain and India.

S Bhakta, V Mukharjee (10) **(2017):**In this paper the study of a standalone power system located in Andaman and Nicobar island, which is one of the isolated island in India where there is no grid extension from main land is available clearly due to its geographical location. The supply of power in this island is done mainly from several sets of diesel generators.
A detailed assessment of solar potential, evaluation of normalized performance indices and techno-economic based feasible analysis of such PV power plant under the climatic condition of island is done. It is found that considered island is fulfilled with sufficient solar radiation of 5.29 kWh/m_2/day. While clearness index lies within the range of 0.42-0.68. Annual average PV cell temperature is 33.75 degree centigrade and air temperature is 27.2 degree centigrade. Calculated performance ratio ranges 68.55-80.22 percent. Techno economic analysis is performed by using HOMER simulation software to obtain optimal size by assuming typical seasonal load profile for single household from simulation result it is found that 2.5 KW PV array, 12 number battery and 2.0 mw converter size may be optimal plant mix for this site. The cost of energy is found to be $0.398, net present cost of $9637, operation cost of $224/year. A battery life of 9.3 years. Initial capital cost of $ 6773. Annual average electric production of 0.41 KW. Hence adoption of such PV plant act as a key option as an alternative for such island.

Renu Sharma, Sonali Goel(11) **(2017):** In this paper a 11.2 kilowatt grid connected PV system installed on rooftop of a constituent institute of Siksha 'O' Anusandhan University Bhubaneswar, India was monitored from September 2014 to august 2014 and its monthly and annual parameters were studied. This PV system is tilted at an angle of 21 degree on the top floor of a 25 height building. The performance of the PV system was compared with that of other grid connected PV system installed worldwide . The total energy generated during this period was found to be 14.96 MWh and the PV module efficiency, inverter efficiency and PR was 13.42%, 89.83% and 0.78 respectively. The yearly average final yield of the present system is 3.67 h/d (1339.55 kWh/kWp/year). The overall system efficiency was found to be 12.05% with annual supply of 14.96 MWh to the grid. The installed PV system in SOA University has caused a reduction of about 14.661 tonne of CO2 from atmosphere per year. Considering overall performance of the system it is feasible solution for power supply in Eastern India .

B. Ravindra(12) **(2017):** Solar resource maps created by a number of agencies worldwide indicate that areas of high intensity of solar radiation suitable for power generation are in deserts and semi arid zones . These regions are dusty and are subjected to both anthropogenic pollution and natural sandstorms. The impact of these events on solar PV plant yield is significant. Often

the solar panels are tilted at an optimal angle and global tilted radiation value falling on the panels changes significantly during and after the sandstorms. . It is noted that decrease in power output of a solar PV plant during such event is high enough to warrant further considerations while forecasting the output. Integrating dust storm monitoring with PV power plant yield prediction algorithms is necessary for a efficient operation of PV plants . Additional observations on amorphous silicon PV plants indicate that the drop in output due to dust storm is higher than that of crystalline silicon PV plant. Thus the increase in diffuse component of solar radiation impact solar cells and modules in different ways.

Mrs Sunitha, Mrs. Naina et. Al.. (13) (2017): In this research Solar PV generation during period from October 2016 to march 2017 is assessed in Shivasamudram, Mandya district, Karnataka state. It is found that in month of February highest PR value of 137.41 percent and the lowest PR value of 97 percent recorded in month of march 2017. The performance ratio of 10 MWp solar PV plant is 116.2 percent for 6 months average value, which gives overall performance of plant. The 6 months average value, which gives overall performance of the plant. The six months energy yield generation is 9032.05 MWh which is more than targeted generation value of 7344 MWh. Here CUF considered is 17 percent because of techno commercial aspects. It can also be verified bu considering cable losses, transmission losses by using simulation software PVSYST. Here PR is showing as 80.9 percent.the comparison between PR of actual and theoretical is not matching. Hence the CUF need to be evaluated based on six months actual performance of plant and PV syst simulation values.

Mr. Mukesh Gujar(14) (2017) Better performance is required in each solar PV plant to utilize the energy and quickly recover the invested money. In this paper the focus is on wrong measurements done by the sensing hardware. The monitoring of performance is effected by the quality of measurement hardware and professionalism of the installation. Hence therefore the measurement error must be least in evaluating the performance parameters of a plant which can be achieved by good hardware and sensors .

Kamal Attari, Ali Elyaakoubi et. Al.(15) (2016): This paper presents an evaluation of a grid connected photovoltaic system installed on the roof of government building in Tangier, Morocco. The experimental data was taken from 1st January 2015 to December 2015 based on real time observations. The system consists of 20 modules of 250 Wp and 1 inverter of 5 kilowatt. The assessed parameters of the PV installation includes energy outputs, final yield modules temperature, efficiency module, performance ratio and others. The PV park supplied the grid with 6411.3 kilowatt hour during the year 2015. The final yield lies from 1.96 to 6.42 kwh/kwe. The performance ratio ranged from 58% to 98% and the annual capacity factor was found to be 14.84% . The annual average final yield was compared with other plants installed worldwide and its value was 4.45 kwh/kwp and average annual performance ratio was 79%

A. Elkholy, F.H. Fahmy et. Al.(16) (2016): An experimental observation study of 8 Kw grid connected solar PV system installed in Electronics Research Institute (ERI) Giza, Egypt is presented. This paper includes the quality of electrical power generated and ejected into the network. The considered system consist of 28*295 Wp multicrystalline PV modules StecaGrid three phase 8 kw grid connected inverter and a solar log 300 PM+ for data acquisition and remote monitoring. The power quality parameters at the inverter output site are monitored. using CA8335 power quality analyzer. The system has been installed in august 2014 and generated 5.7 MWh till February 2015. The produced electricity by system is injected directly into grid without storage device. Results for two different scenarios have been considered namely cloudy and sunny and the effect of solar irradiance on power cquality measurements have been investigated. It has been found that a low solar irradiance has a significant impact on the power quality of output of PV system. As PV module and PV array outputs are degraded on the system performance over lifetime of PV system the designer or planner must be careful to keep the operating array DC voltage matched within the range of chosen inverter.

B. Shiva kumar, K Sudhakar (17) (2015): A performance study of 10 MW photovoltaic grid connected power plant commissioned at Ramagundam receiving a good average solar radiation of 4.97 kWh/m2/day and annual average temperature of about 27.3 deg, centigrade is evaluated on annual basis. The various types of power losses such as temperature, internal network, power electronics and performance ratio are also calculated. The performance results obtained from this plants are then compared with the simulated values obtained from PV SYST and PV GIS software.A 10.34 MW peak power output and40.83 KW minimum power output with maximum total energy generation of 15111.03 MW in month of January and lowest total energy generation of 950.228 MW in month of july. In comparison of monitored data with PV SYST and PV GIS simulation results, the results obtained are closed to predicted data output.

Sivasankari sundaram, Jakka sarat chandraprakash (18) (2015): A 5 MW grid connected PV power plant located at Sivagangai was monitored annually between may 2011 to April 2012. The performance evaluation of this site are performed on monthly average cdaily basis. The total annual generation was found to be 8495296.4 kWh with an average of around 70941.4 kWh per month. In addition, real time performance of plant is validated through a system software named RET screen plus which employs regression analysis for validation. The average annual energy generated by 5 MW system is 24116.61 kWh/day which is approximately close to predicted annual average which was found to be 24055.25 kWh/day obtained by RET screen

Annual average daily array yield was 5.46 h/day, Corrected reference yield 5.128 h/day .Module efficiency 6.08 percent, Inverter efficiency 88.2 percent, System efficiency 5.08 efficiency. Annual average in plane solar insolation was 5.414 Kw/h. Ambient temperature 30.76 degree centigrade. Module temperature 37.9 degree and Wind speed was 3.191m/s.

The module efficiency is found to be less at an annual average of 6.08 percent and the performance ratio of plant is found to be high at 0.8915. The significance of real time PV system is then validated by RET screen plus where a overall coefficient of best fit for selected key performance parameters changes from a minimum better combination with actual and predicted values.

Dragana D Milosavljevic et al. (19) (2015): Experimental determination of energy efficiency and other performance parameters of 2 KW solar PV plant installed on the building of Faculty of Science and Mathematics (FSM) building in Republic of Serbia is conducted depending on real climatic conditions from January 2013 to January 2014. The main objective is to apply these results for the integration of solar generation into a transmission network in order to increase the installations of solar PV plants

for commercial purposes in Serbia. The Power generated by the plant was found to be 2323.329 kWh with Annual mean value of performance ratio 93.6 percent and Annual capacity factor as 12.875 % in 2013. Annual energy efficiency was 11.35 %.
Increase in ambient temperature causes a decrease in energy efficiency. With an increase in 1 degree centigrade temperature experimental energy efficiency decreases by 0.3 %.
With increase of wind speed there is a slight increase in experimental energy efficiency of solar PV plant due to condition of solar modules caused by wind in summer.
As a conclusion integration of this renewable energy generation into transmission network was considered satisfactory. Research shows that PV system work efficiently. The radiation obtained from sun are good enough to provide electrical energy to supply a small load or to sell it to utility grid.

Kunwar Sangram singh Pundir, SK Singal et. Al.(20) (2015): This research presents the detailed investigation on performance evaluation of Solar Photovoltaic system installed in IIT Roorkee campus. The solar radiation data from NASA and NREL are collected and found that the minimum sunshine hour for the site is 3.16 for the month of January 2014.collected data of energy generation, solar radiation were analyzed and performance ratio, capacity factor and efficiency were found to be 59.94 percent, 15.39 percent, 8.26 percent respectively. Through this analysis it has been found that the system is viable, efficient and cost effective. The payback period of the PV system is 5.4 years. The CO_2 reduction 2464 ton p.a. shows the solar PV system is Eco friendly and good for environment.

Pratish Rawat, Yashika Rawat(21) (2015): In this study performance evaluation of 100 KW rooftop solar photovoltaic grid connected power plant commissioned at Poornima University, Jaipur is conducted and solar PV plant design aspects and its annual performance is elaborated. The various power losses such as losses due to temperature, losses due to internal network, power electronics losses, grid connected losses etc. and performance ratios are calculated. The performance results of 100 Kw rooftop solar photovoltaic plant are also compared with the simulation values obtained from PV syst V 6.39 S software. Average daily energy output in September 2017 is 423.342 KWh. The average final yield of solar PV plant ranged from 1.6 to 5.6 h/d and average performance ratio of 77.79 percent and capacity utilization factor (CUF) OF 18.1 Percent it is an important measure to assess the output energy of solar pv system it has impact on economics of system.

3.0 CONCLUSIONS

The performance evaluation of Solar system in any given location can be done by using different software programs and by numerical simulation methods considering various physical environmental and technical parameters which influence the output of the system. Many software programs are available in technical market to predict the performance of a Solar PV plant. In this study we are going to evaluate the performance of Solar PV plant in Central India by comparing its actual or theoretical monthly power generation data obtained after observations, with the predicted power generation data of two software program which are BlueSol PV and Helioscope. As we know that no any system in the universe is 100% efficient, the actual power generated will be less than the predicted simulated power, The variations obtained in both the cases will be stated and studied for creating an appropriate framework for the researches and technicians of Central India who are working in this field. .

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