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Photovoltaic Modules Performance Loss Evaluation for Nsukka, South East Nigeria and Mitigable Designs

Daniyan O.L.[1], Daniyan I.A.[2], Okere B.I.[3], Aliyu N.[4], Ezema E. E. [5]

[1,3,4]NASRDA Centre for Basic Space Science, University of Nigeria, Nsukka.
[2]Dept. of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado – Ekiti.
[5]Weiz Engineering Limited, Enugu, Nigeria.

ABSTRACT
The Photovoltaic (PV) systems and technology offer excellent reliability when designed with the right implementation tools and based on good technical judgements of components that make up each of the critical sections of solar power system. The PV array is an essential section of a solar power system and it is expected to function to deliver pre – estimated power based on design estimations. There are factors that derail the performance of PV modules; the contributions of these factors are peculiar to specific sites of installation, hence the need to empirically evaluate and characterize installation sites before deployment of PV systems. This paper presents the characterization of Nsukka (South East, Nigeria) environment using decent instrumentation; and consequently highlights the power loss indicators for PV modules in the target site while presenting equally mitigable design.
Keywords - Array, Irradiance, NECOP, Power, PV, STC, String

I. INTRODUCTION

PV modules are assigned ratings in watts based on the maximum power they can produce under ideal sun and temperature conditions. The function of the PV array is to produce energy to be stored in the battery bank via the charge controller or be fed onto the grid via appropriate inverter [1].

There are certain factors which derail the performance of PV modules; these are the temperature and the solar irradiance. The temperature coefficient of PV modules plays a major role in estimating the loss in power of PV modules especially in hot environment as PV performance declines as the temperature rises. Our target environment has a fair share of the hot periods in a year usually the months February and March.

The power loss equation is given by [2] below.

Loss in power = (Y-25) x temperature coefficient
Eqn (1)

Where, Y is the ambient temperature; $Y > 25^0C$.

Characterizing the target environment in hot periods can give the picture of the expected loss in power of the PVs in the hot months. The procedure we used is explained in section 3 below. The characterization was carried in the hottest months of February and March 2013; and in the mostly cloudy months of July and August 2013 so as to enable comparative analysis of the temperature and solar irradiance factors of the two periods.

II. INSTRUMENTATION

The characterization was carried out using Nigerian Environmental Climatic Observing Program (NECOP) instrumentation. NECOP is a project designed by National Space Research and Development Agency (NASRDA) Centre for Basic Space Science (CBSS) to establish a network of meteorological and climatological observing stations spatially located across Nigeria with the aim of setting up such a network of stations to carry out in - situ measurements of meteorological and climatological variables in real time with an update cycle of five minutes [3]. Data from the Nsukka station was used in the course of this work. Relevant parameters for this work are the ambient temperature and the solar radiation data out of the nine variables being generated by the station.

Figure 1: The NECOP Station

The solar radiation sensor is a Licor pyranometer while the temperature sensor is a HMP 50 sensor. All the sensors are interfaced with a CR1000 measurement and control unit. The whole station is based on Campbell Scientific facilities.

III. METHOD AND RESULTS

The procedure for measuring the coefficient(s) for modules and arrays are not yet standardized and systematic influences are common in the test methods used to measure them [4]; however standard test condition (STC) is usually at 25^0C, 1000W/m^2. The purpose of this work and hence the procedure used was not to yield the temperature coefficient but tailored to estimate power loss in PV modules for Nsukka environment. All the data were taken at 5mins resolution for months of February, March, July and August in 2013 and only data at sun hours set be 8am to 5pm was used in the plots. Standard test condition being at 25^0C was first co - plotted with the ambient temperature at sun hours for the four months of February, March, July and August to yield a comparative view of the ambient temperature deviations from the standards test conditions of PVs (Figure 2 below) which is vital in evaluating power loss (at site of PV installation); and secondly, as shown in figure 3 below, the solar irradiance for the four months were co – plotted at sun hours to yield a comparative view which in turn revealed the losses contributed by cloud cover effects for the months on July and August.
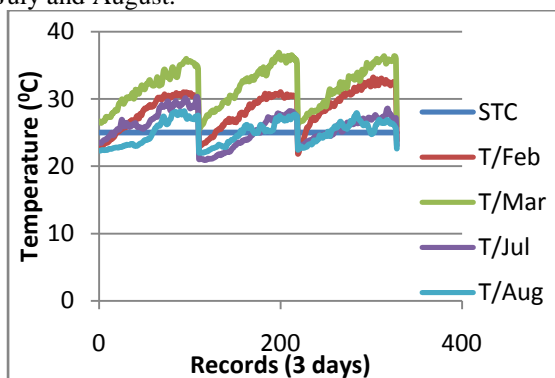

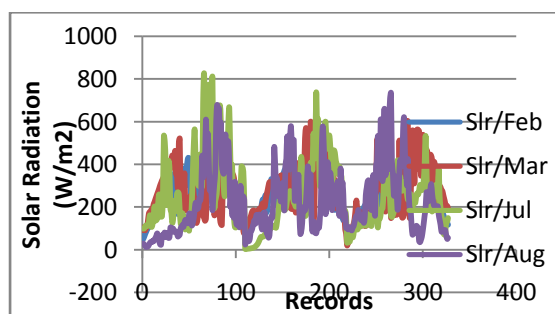Figure 2: Comparative temperature variations with STC (8am – 5pm)

Figure 3: Solar radiation variations at sun hours (8am – 5pm)

IV. RESULT ANALYSIS

The data sets used were for months of February, March, July, and August, all within the sun hours set to be 8am to 5pm. To afford clarity of view of the plots, only data sets for the first three days of the months were plotted but the general trend is similar throughout the months under investigation. From figure 2 above, STC is maintained at 25^0C, and the other four variations represents Y defined in (1) above. Y in March stayed above STC and showed major and highest deviation from the STC all through the sun hours each day. Y in February equally deviated quickly rising from below STC within the first to second sun hour of each day to far above 30^0C and staying high. Y in July and august showed similar variation pattern (except for few cases as seen in day 1 in figure 2) staying below STC for close to four hours and then showing a deviation above STC of not more than 3^0C for the rest of the sun hours.

While temperature coefficient plays a major role in estimating the power loss, Y remains a variable that dictates the extent of the power loss. Hence the region above the STC depicts a region that the PVs would experience power loss; the extent of which is proportional to the degree of Y variation from STC. In hot environment where this deviation above STC is critical, it is logical to use a compensative PV array (strings in parallel) and a pattern of installation that allow air flow under the PV sets to enable some level of cooling to be achieved.

Figure 3 shows a swinging irradiance pattern especially for July and August having the most cloud cover with solar radiation going down below 100 W/m^2, an indication much cloud cover which grossly dips PV performance. Equally, the two months experience the highest irradiance which is an indication of clear sky condition presumably after much cloud cover and much precipitation.

V. CONCLUSION

The calculation and optimization of the energy output and economic feasibility of solar energy systems such as buildings and power plants requires detailed solar irradiance data measured at the site of the solar installation [5]. The need to understand specific site environmental in-situ information of critical factors that affect the performance of PV modules is critical to decent PV installation. PV installation should be tailored not just towards specific energy needs but equally towards specific site requirements. The result of this work revealed that a PV string set up in Nsukka South East Nigeria could perform well at some time in the year and may not perform well during the months investigated. This underscored the need to ensure a compensative design of PV arrays at the investigated site. This compensative design is such that if for instance a string of say eight PV modules provides needed

power on a good day; creating an array of two eight – PV strings connected in parallel would compensate for performance losses that could be brought about by environmental or climatic situations in bad sky periods and equally provide about doubled performance in good sky periods.

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