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Photovoltaic Maximum Power Point Dependency on Geographical Location

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ABSTRACT:*The energy generated by solar PV technology system varies across different districts because irradiance and other meteorological factors are regionally dependent. As a function of these factors, the Maximum Power Point (MMP) also varies with districts. The maximum power point has been studied using the single diode two resistors modelin four Nigerian districts encompassing the sunny arid north and the mangrove rainy south. The study is comparative in nature and aimed at using the level of MPP prediction to justify photovoltaic deployment or otherwise in each of these districts. The model has been set up, run, prediction data obtained and plotted. Although the MMP predicted for each of the sunny arid northern districts is higher than those of the rainy mangrove southern districts, analysis has shown that the difference is insignificant to the extent that good performance and reasonable financial returns are to be expected of these installations in the rainy south.*

KEYWORDS*: Irradiance, Insolation, Photovoltaic, Meteorological data, Diode*

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I.INTRODUCTION

The relationship between photovoltaic (PV) technology operation, its geographical location and environment is complex. It is a known fact that location defined by the latitude and longitude together with the environmental characteristics such as the temperature all combine to influence the performance of the photovoltaic installation. Intermittency in operation is one other factor that exacerbates the complexity. This intricate relationship has been a major concern to researchers, system designers and manufacturers. However, there has been concerted efforts in monitoring and evaluating the situation with a view to improving performance across all regions and environs. Modelling is one of the techniques in use for the evaluation of the performance of PV systems under different environmental conditions and regional locations. Unpredictability in performance impacts adversely on global acceptability of the PV system credibility asa serious contender for an alternative to conventional energy resources

Even in regions with high photovoltaic generation potential, prospective investors still doubt the wisdom of committing funds to PV systems. This distrust is usually brought about by the lack of parity between kilowatt generated by conventional means and that sourced via the PV route. Regional PV generation variability and the high initial cost of PV equipment may account for the parity gap. It suggested therefore that these factors are responsible for the sluggish development and deployment of PV technologies. The financial justification for investment in PV technology cannot be achieved without price parity with conventional energy resources. However, as more and more people buy into the use of photovoltaic technology, the economy of scale as a market force will surely help to reduce the unit production cost of the solar cell. The net effect is a further fall in the upfront capital investment requirement and further reduction of the price parity gap.

Performance improvement is limited by various factors including the existing (current) low level efficiency of solar cell, poor system design and operations below the maximum power point level. It is expected that as more knowledge is gained in solar cell development, the production of solar cell of net efficiency better than the current value of about 20% will be possible. Until such a cell is developed and produced however, one has to contend with what is available. Most PV systems design and installation adhere strictly to industry standard in all its forms and so there is no meaningful performance gain to be expected from this sector. A typical photovoltaic installation has the tendency to operate off and below the maximum power point (MPP). It follows that maximising the performance of these technologies in different operating environments is still an issue confronting PV producers and engineers [1]. It therefore means that performance gain can be achieved if operation can be coerced to move towards the maximum power point. This goes to explain why such importance is attached to the maximum power point in PV studies and operations. Some of the factors that may affect the level of the maximum power point achieved by a typical PV system module installation include geographical location and environmental factors such as temperature and insolation. One is therefore constrained to examine the case of location within districts of varying geographical features to compare the levels of MPP attained. In this study, Nigeria is chosen not only because of its contrasting geographical features but also its epileptic power supply coupled with the lacklustre energy reform measures so far undertaken in the country. Nigeria as a case study can serve as a means of educating and gingering the authorities to take more active interest in renewable energy resources. In the country, mangrove and rainy districts dominate in the south and arid, sunny districts are found in the north.

Even with numerous reform policies and plans, Nigerian is yet to embrace the exploitation of its huge potential in the renewable energy sector. The country is blessed with plentiful supply of renewable energy resources especially the solar and the wind but for some inexplicable reason full advantage has not been taken to exploit these potentials. A decade or so ago, the high cost of solar energy equipment may have accounted for the reluctance of various governments to invest in renewable energy projects but this is not the case today. It is unfortunate because Nigeria is one of the countries around the equatorial region with an estimated average sunlight period of 6.5 hour daily and solar radiation of 3.5kWh/m^2/day in the coastal region rising to about 7.0kWh/m^2/day in the north with approximately a projected value of 17.439 TJ/day of solar energy over its land mass of 923,768km^2 [2]. In spite of these huge solar energy potential, Nigeria has over the years, concentrated all efforts to the development of non-renewable energy for electricity generation. Although different reforms and policies have been initiated in the power sector, none has been meticulously implemented. There was the Renewable Energy Master Plan (REMP) that was planned and developed with a view to diversifying the energy resource options and fully maximize their utilization for sustainable development. However, the REMP has not been realized. The Nigerian electricity generation capacity profile from 2017 through to 2019, reveals that solar, wind and biomass combined still account for less than one percent (<1%) of the total [3, 4]. Within the period under consideration, the non-renewable energy generation capacity was increasing, while that of the renewable was decreasing. This can only lead to the logical conclusion that government has its priorities in fossil fuel energy development over solar, wind and biomass. This can be attributed to numerous socio-economic factors as indicated earlier.

There is no evidence that the constant power outages will be reduced soon and the fact that only about 60% of Nigerian population has access to grid electricity does not help the situation [5]. These are the cumulative effects ranging from poor maintenance of facilities to shortage, inadequate transmission and distribution network [6]. However, the recent increases in the electricity tariff is gradually forcing both individuals and corporate bodies to consider investing in renewable energy especially the PV system. The result is evident in several areas including lighting, water pumping, vaccine storage and solar based rural electrification [7,8]. Investment in this area should be encouraged as it has been estimated [9] that PV panels covering about 1% of Nigerian land mass is more than enough for steady electricity supply to the entire country.

II.SINGLE DIODE PV MODELLING

The simplified single diode model employed in this study has continued to provide a balance platform between the ideal and practical PV models and as such has been wildly used in many PV modelling analysis [2].

The equivalent circuit for the single diode PV model shown in figure 1 consists of a photocurrent source (I_p), single diode (d), shunt resistance (R_{sh}) and series resistance (R_s).

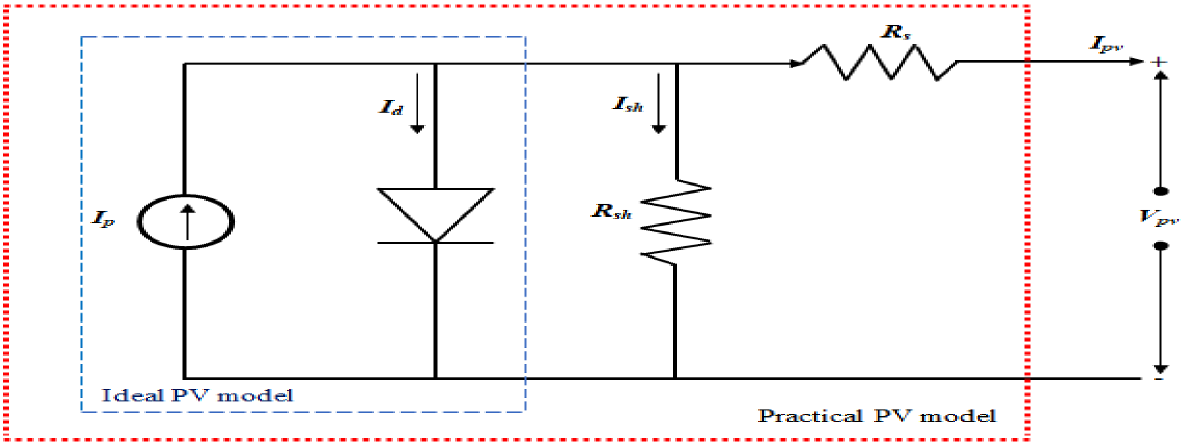

Figure 1: Single diode two resistors (SDTR) PV equivalent circuit model

where;T_{STC} is the temperature at standard test condition (STC) of 1000W/m^2 irradiance and temperature of 25^{o}C, G and G_{STC} are the irradiance on the device surface measured in W/m^2 at normal and at STC respectively. $I_{o,STC}$ equals the reverse saturation current at STC and E_g is the bandgap energy of the cell (typically 1.12eV for silicon cells).

The single diode PV model presented in this study has been modeled in MATLAB using reference PV module data given by [3]. Other details in the modelling work are to be found in [5,9]

The simulation model and the analysis of the single diode PV module system have been carried out in MATLAB/Simulink. The data for the evaluation is obtained from the 30 years Meteorological and Solar Monthly & Annual Climatologies (January 1984 – December 2013) database sourced from NASA Power Project on Solar and Meteorology database [6] for four different geographical locations in Nigeria. These locations are selected for evaluation of their PV power generation potentials using real meteorological data. The chosen locations are Lagos (latitude: 6.52441, longitude: 3.37921), Asaba (latitude: 6.20591, longitude: 6.69591), Abuja (latitude: 9.07651, longitude: 7.39591), and Kaduna (latitude: 10.51051, longitude: 7.41651). Asaba and Lagos are located in the southern region while Abuja and Kaduna are in the Northern part of the country. The solar energy data for these locations are used as input parameters in the PV model simulation. It is worth noting that over the years, NASA Surface Meteorological and Solar Energy data have been used by several authors [2,7,10,11] in various renewable energy studies and as such the data is considered reliable. Typical Simulink model blocks for this study are also detailed in [9]

III.RESULT AND DISCUSSION

The simulated results are presented in figures 2 to 7 as graphs and histograms. Also table 1 is a comparison of predicted result and reference data at STC . The predicted data in the table show good agreement with reference data. The maximum relative error between the two is 0.645% which is better than the acceptable margin of error [12,13] found in the literature.

Table 1: PV model parameter value at STC

Parameter	Reference model (Kyocera KK280P–3CD3CG) parameters	Simulated model parameters	Relative error (%)
P_{max} (W)	270 W	270 W	0.000
V_{mpp} (V)	31.0 V	31.200 V	0.645
I_{mpp} (A)	8.71 A	8.655 A	0.632
V_{oc}(V)	38.3 V	38.295	0.026
I_{oc}(A)	9.42 A	9.420	0.000

The average monthly irradiance and temperature for each of the selected locations form the input to the model. The model output consists of the I – V and P – V data which are plotted as the characteristics curves and histogram. Based on the output data, it is observed that an increase in irradiance leads to a corresponding increase in the generated current whereas an increase in ambient temperature leads to a reduction of the generated voltage. Also, the result shows that even though Lagos and Asaba lie in the rainy south of the country, the predicted MPP for these two locations though lower than those of Abuja and Kaduna, are sufficiently high enough to warrant recommending investment in PV systems with the prospect of good performance and acceptable financial investment return. The histograms exhibit similar characteristics, lower than Abuja and Kaduna but still high enough to justify PV installation in these locations.

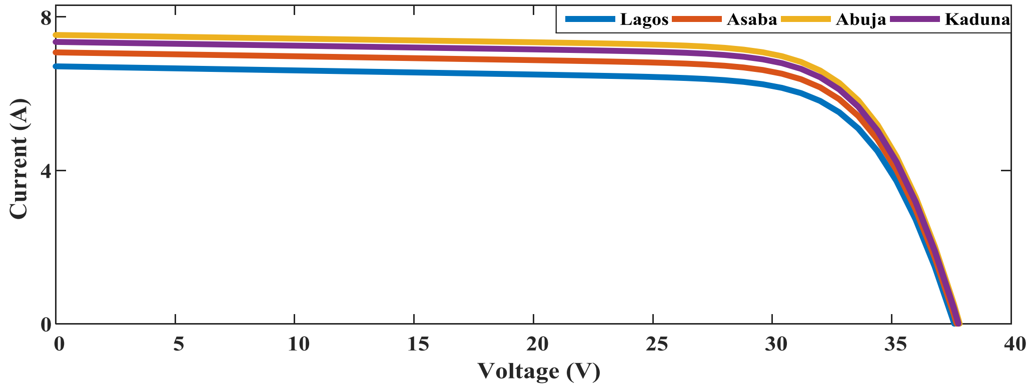

Figure 2 I– V CharacteristicCurves for the Month of January

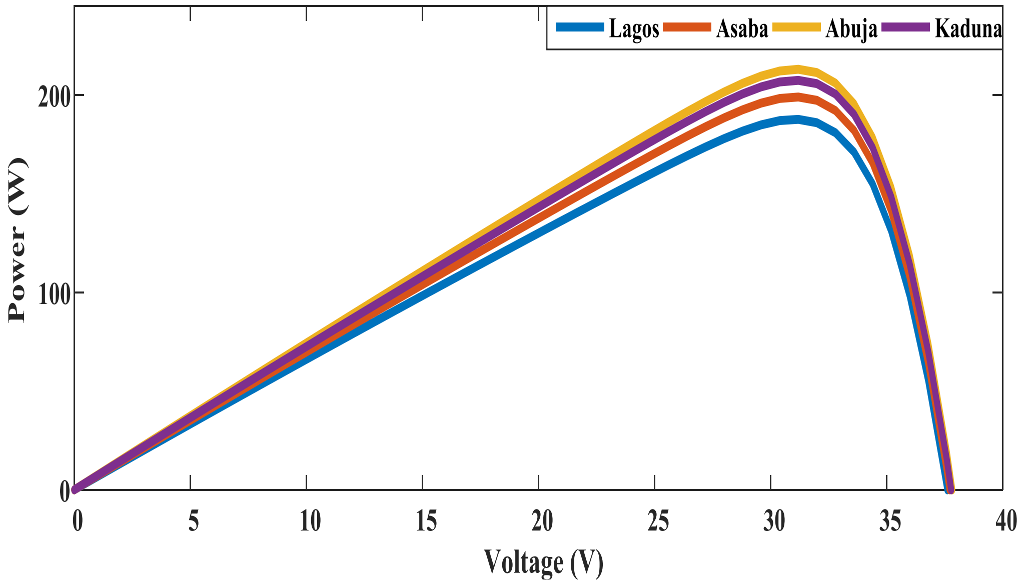

Figure 3: P – V Characteristic Curves for the month of January

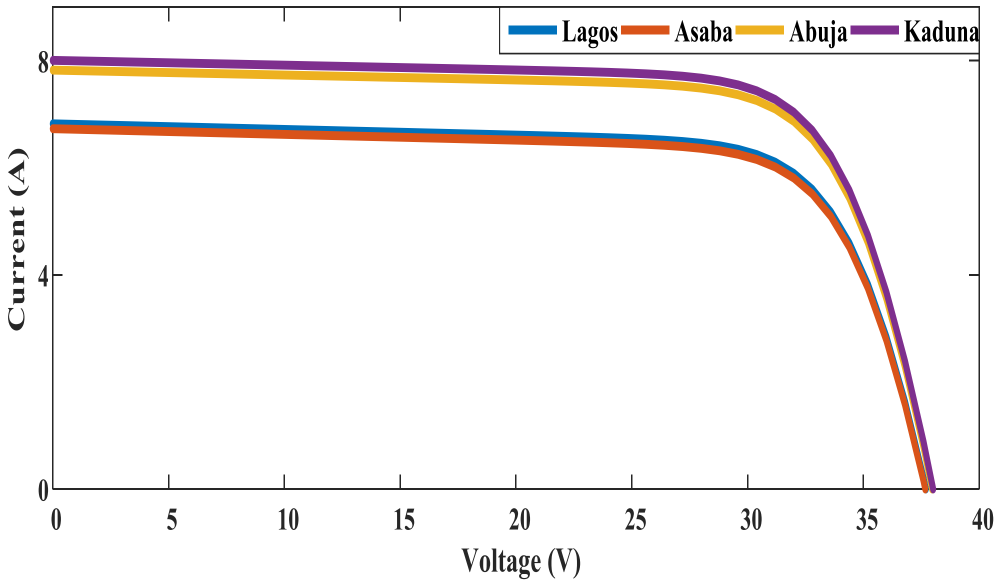

Figure 4: I – V characteristic Curves for the Month of March

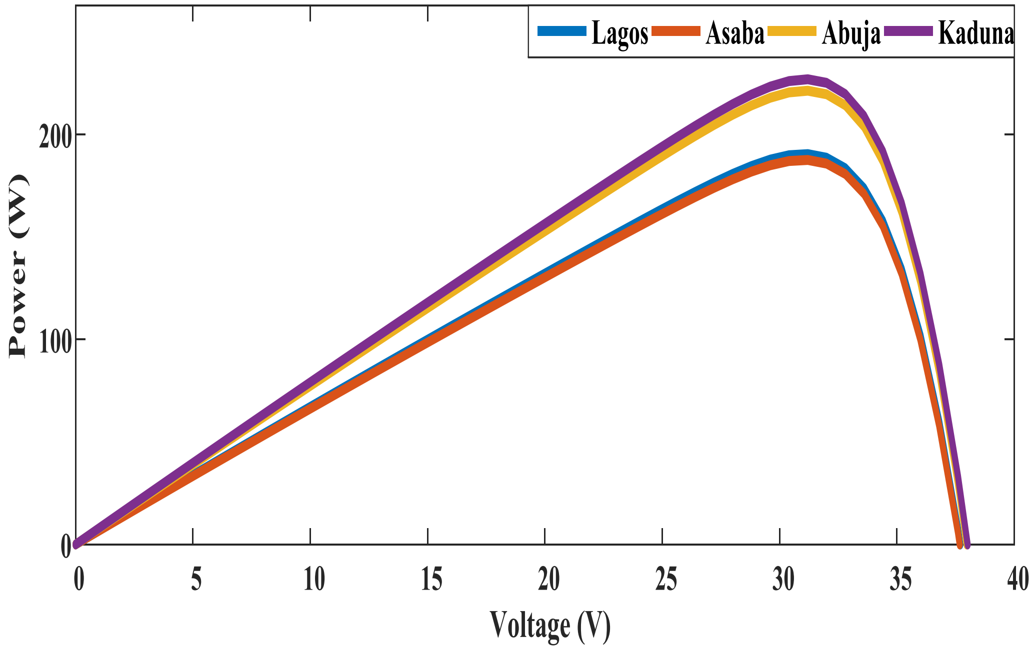

Figure 5: P – V characteristic Curves for the month of March

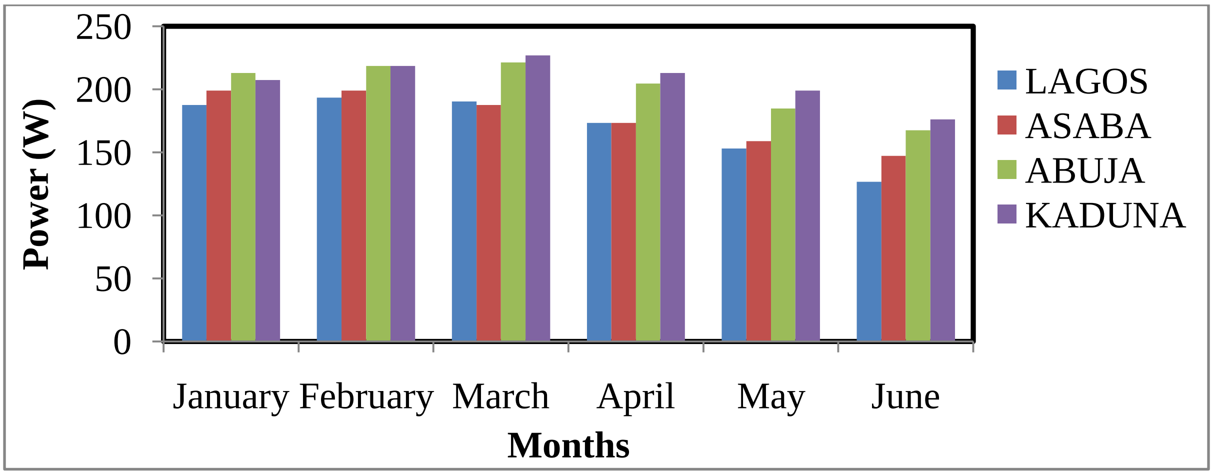

Figure 6: Average monthly (January – June) power generation of PV module

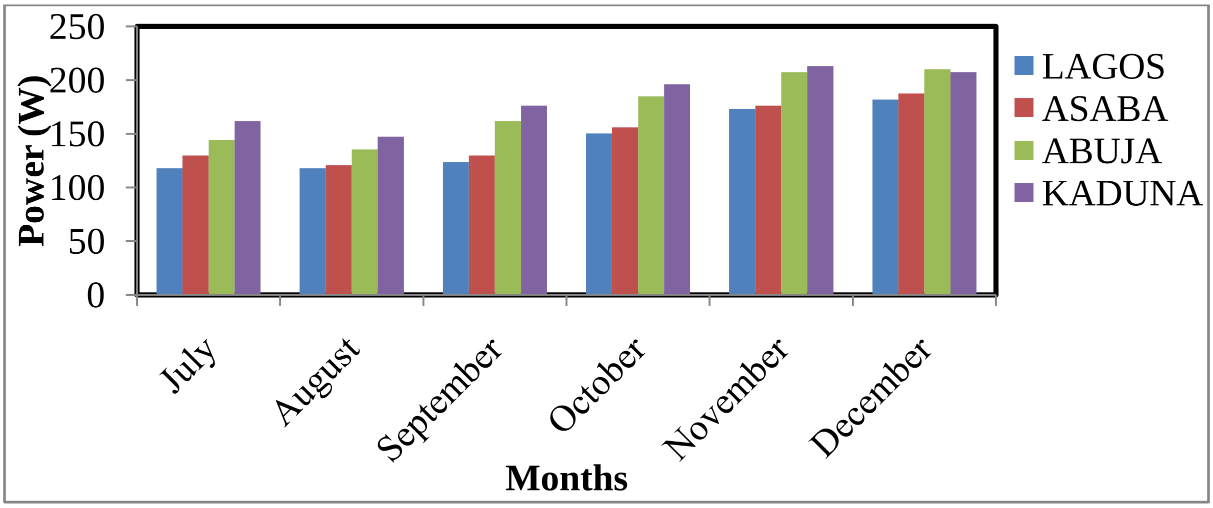

Figure 7: Average monthly (July – December) power generation of PV module

IV.CONCLUSION

The modeling and evaluation work have been carried out and result presented to show that MPP model prediction levels in the north are marginally higher than those in the south. The MPP predictions in the south however are still high enough to justify investment in photovoltaic installation with the prospect of good performance and acceptable financial returnsin this part of the country.

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