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ZONAL EVALUATION FOR SITING A SOLAR POWER PLANT IN CROSS RIVER STATE, NIGERIA.

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ABSTRACT

An experimental survey was embarked upon to establish the effect of solar radiation intensity, the panel power output, current density and the efficiency of solar panels in three major geographical zones in Cross River State, Nigeria. The zones are Mangrove, University of Calabar, Tropical Rainforest, Nko - Yakurr and Guinea Savanna, Abakpa - Ogoja. The result from the investigation shows that the Guinea Savanna produced the highest current density of 8.20 A/cm^2, power output of 152.3W, 36.5% efficiency and a solar radiation magnitude of 991.9 W/m^2 from a monocrystalline panel. However, polycrystalline panel generated better output for all the measured parameters thus: current density of 8.80 A/cm^2, power output of 170.72 W, 39.9% efficiency range for the same solar radiation magnitude of 991.9W/m^2. From the analysis of the survey performed across the three geographical zones. The Mangrove zone has shown greater potential to accommodate solar farms, hence generate good energy to bridge the vacuum created in the power generating sector.

KEYWORDS: Epileptic supply, mangrove zone, solar farm, output power, panels efficiency.

INTRODUCTION

Due to the poor and unreliable supply of electric power in major towns and villages in Cross River State, South-South, Nigeria, it is desirable to find a lasting solution to the sources of electrical power generation. Weighing the various sources of electrical energy generation in Nigeria, the researcher proposed the use of renewable (solar) energy in particular, as a lasting solution to the intermittent electrical power supply witness everywhere in Nigeria. Solar power is the transformation of energy from sunlight into electricity, by the use of photovoltaics (PV), or by the use of lenses and tracking systems that concentrated a large surface area of sunlight into a small beam. Photovoltaic (PV) solar cells convert sunlight into electricity, by absorbing solar radiation within the p-n semiconductor and transforming photons into electrical energy by producing electron-hole pairs that generate a voltage and a current flow. As acknowledged in the works of (Sharan, 2008) solar energy has free infinite source of energy with the competence to provide an alternative energy devoid of environmental pollution, with the capacity to decrease the rate of depletion of energy reserves without damaging the ozone layer. Photovoltaic are solid state devices that simply make electricity out of sunlight silently with little to no maintenance and depletion of material resources (Deo and Mark, 2005).

The design of the PV system relies on the input of measured data close to the site of the installation which is daily and yearly variation due to the apparent motion of the sun, and irregular variations due to the weather condition or cloud cover (Markvart, 1994), (DE Bassey et al, 2016). PV technologies have different seasonal patterns of behavior due to the variations in spectral response (Carr and Pryor, 2004), (Mfon and Fina, 2016). This confirmed that modules of differing technologies could be more suited to specific climates. The a-Si array in a tropical climate can produce up to 20% more energy with high ambient temperatures and high humidity during the wet season, than the p-Si array (Mieke, 1998). The a-Si modules is observed to be more suited to tropical climates (Akhmad et al, 1997). In better performance ratio (Nowshad et al, 2009) placed amorphous silicon and copper Indium Diselenide (CIS) solar cell to mono-and multi-crystalline silicon solar cells in Malaysia due to the climatic conditions.

It is against this background that we decided to use two different commercial PV modules commonly found within the state and taking into consideration the three vegetation of the Cross River State, so as to determine the best location for the solar farm taking into consideration some parameters like the effect of solar radiation intensity, the output power, the current density and the efficiency of the solar panels.

Related works

(Joseph and Faithpraise, 2016) "Experimentally demonstrated that the power generated by a photovoltaic panel depends on both the intensity of the sunlight and on the angle of its inclination towards the

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sun. The power performance can be enhanced when a photovoltaic panel is inclined at an angle of between 40^o to 50^o where the photovoltaic panel assumes a position directly in phase with the sun than any other". Relative humidity affects efficiency of solar panel as it affects the current of solar panels and shows little effect on the output voltage Ettah et al, 2012). Light intensity has a dominant effect on current parameters (El-shaer et al, 2014).

(Chow, 2007) states "short circuit current and maximum current are increased linearly with increasing light intensity. So, the maximum output power density increased by 80% with increasing light intensity from 0.2 sun to 1.0 sun. It was also observed that module temperature has a dramatic effect on voltage parameters.

Open circuit voltage and maximum voltage are decreased with increasing module temperature. Therefore the maximum output power density decreased by 25% and 14% for the monocrystalline and polycrystalline silicon with increasing the module temperature from 10^0C to 50^0C". Energy will forever remain the basic foundation which determines the stability of the economic development of any nation (Chow, 2007). For academic and economic activities to thrive and grow, the daily power supply must be continuous and permanent (Faithpraise et al, 2017a). The researcher further decry the change of attitude and fraud elimination as a major player to improve energy efficiency (Faithpraise et al, 2017b); (Faithpraise et al, 2018) in energy utilization. In order to accent the importance of solar energy (Jager-Waldau, 2002) expressed fear on fossil fuel reserves constraint and shrinking and therefore developed more efficient methods of producing energy from alternative sources. (Rabah, 2005) states that the increased use and promotion of renewable energy technologies seem to provide viable solutions to environmental problems caused by other energy sources. (Bala et al. 2000), (Joseph, et al. 2016)[a], (Joseph, et al. 2016)[b] experimented that module performance varies with location of use and actual environmental conditions, which they are subjected to, as a result of variation in air mass, and other meteorological parameters of the local environment such as irradiation (solar flex), temperature, relative humidity and wind speed.

PV modules are durable, long lasting, environmentally friendly and cost efficient compared to the amount spend on fossil fuel. For instance solar panels are very useful in the manufacturing of battery chargers and cash reserves as illustrated in (Faithpraise et al, (2016) and (Faithpraise et al, 2018)[a]. Due to the modular nature of PV systems, it can be designed to meet any electrical requirement no matter the size of the device or its appearance. It also can be connected to an electricity distribution system (grid-connected) or standalone (off-grid). Most PV's are durable with a warranty period of 25 years and with proper maintenance can attain a life span of 50 years. They are designed to withstand severe weather such as extreme heat, hail stone, snow and cold.

Site Survey and Data Collection

Data collection was done in specific locations across the three vegetation zones within cross River State. University of Calabar, for the mangrove vegetation, data gathering was done in **University of Calabar Campus**; **Nko** was used for the Tropical Rainforest and **Abakpa** for the Guinea Savanna.

Initial readings were collected on the two types of PV module using different measuring instruments, while monitoring the module output performance, the current and voltages were measured as well. Solar radiation which is one of the meteorological parameters were recorded. Data collections were made at hourly time intervals between the hours of 6:00am to 6:00pm all day long in each of the different locations across the three vegetation to ensure effective and accurate data records. The modules (monocrystalline and polycrystalline) and the meteorological sensors were placed on the same horizontal test plane. All the measuring instruments (photometer, multi-meter, charge controller) were connected in parallel with the PV modules. Finally, the coordinate readings were also taken in each of the locations to give it spatial information. The solar panel was theoretically enhanced by positioning it perpendicular to the sun's rays. The coordinate location of the test site for the three zones were: latitude: 4.9517N, Longitude 8.322E, height above sea level: 140 km for mangrove vegetation; latitude: 5.87577N, Longitude 8.18982E, height above sea level: 7.93 km, Tropical Rainforest and **Latitude:** 6° 39' 10.19"N, **Longitude:** 8° 47' 30.59" E, for Guinea Savanna.

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Result and Analysis

After careful measurement of some basic parameters (solar radiation, output power, current density and efficiency) of the two types of Solar panels used in this zones, the following results shown in Table 1 to Table 6 were obtained.

Table 1: Comparison of Solar Radiation in the three Zone

Time Hours	Solar Radiation Mangrove (Solar Rad_m)	Solar Radiation Tropical Rainforest (Solar Rad_T)	Solar Radiation Guinea Savanna (Solar Rad_g)
6.00am	0	0	0
7.00am	50	0.4	95.7
8.00am	251	10.8	170
9.00am	514	68.6	761.4
10.00am	530	118.4	901
11.00am	317	276.6	294
12.00pm	501	300.9	**991.9**
1.00pm	**782**	**576.5**	941.2
2.00pm	290	361.4	283.2
3.00pm	83.5	430.7	746.2
4.00pm	150	214.5	535.4
5.00pm	132	104.7	170
6.00pm	10.5	18.5	33.9

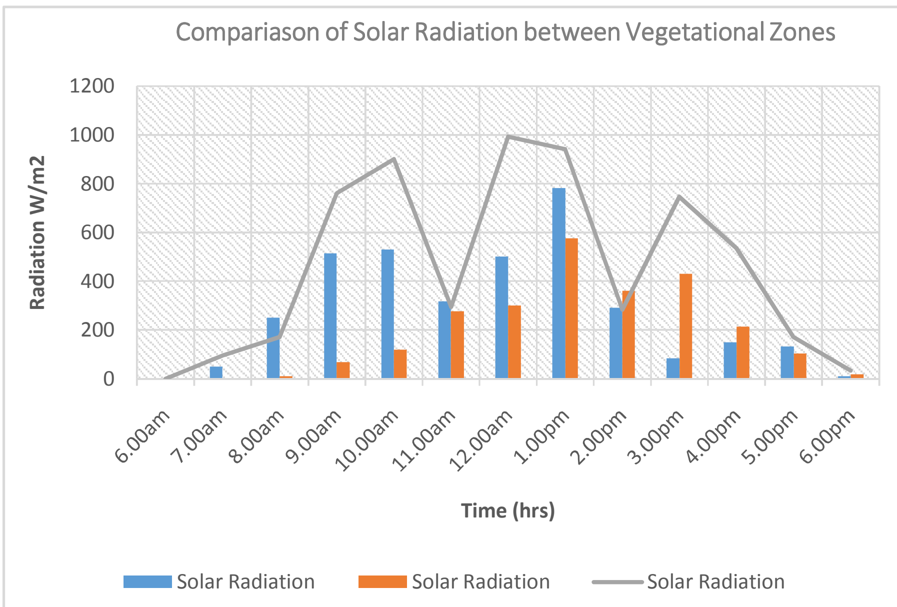

Fig. 1: Comparison of solar radiation across the cities in the three vegetation.

Table 1 and Figure 1, Shows the comparison of solar radiation across the cities in the three vegetation. Solar Rad_m to represent solar radiation value in the Mangrove zone. Solar Rad_T represent solar radiation value in the Tropical Rainforest zone and Solar Rad_g represent solar radiation value in the Guinea savanna zone

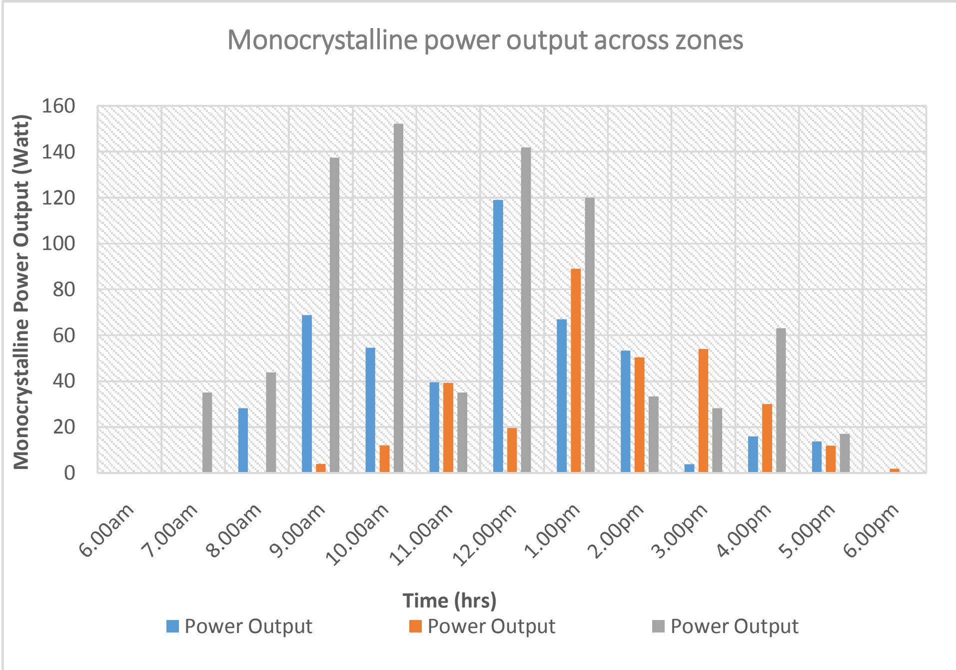

Fig. 2: Monocrystalline panel power output across the cities in the three vegetation.

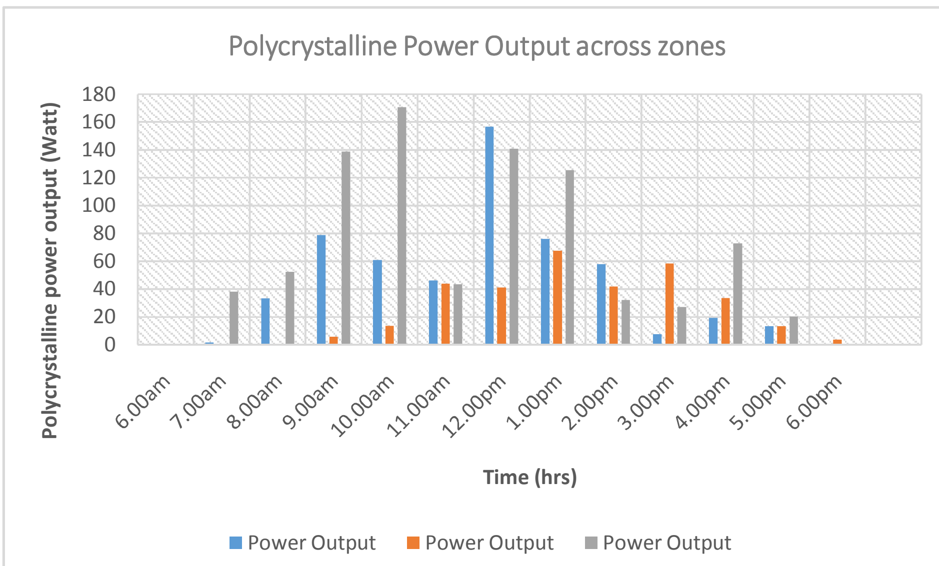

Fig. 3: Polycrystalline panel power output across the cities in the three vegetation.

Table 2: Current Density between the Zones

Time Hours	current Density A/cm^2) Mangrove	current Density (A/cm^2) Tropical Rainforest	current Density (A/cm^2) Guinea savanna
6.00am	0	0	0
7.00am	0	0	1.80072
8.00am	1.40056	0	2.20088
9.00am	3.40136	0.20008	6.80272
10.00am	2.70108	0.60024	**7.503**
11.00am	2.0008	1.90076	1.80072
12.00pm	**6.10244**	2.0008	**7.20288**
1.00pm	3.40136	**4.40176**	6.0024
2.00pm	2.60104	2.501	1.70068
3.00pm	0.20008	2.70108	1.40056
4.00pm	0.80032	1.5006	3.20128
5.00pm	0.70028	0.60024	0.90036
6.00pm	0	0.10004	0

Table 2: Shows the value of Monocrystalline panel Current density across the cities in the three vegetation.

Table 3: Polycrystalline panel Current density across the cities in the three vegetation.

Time Hours	current Density A/cm^2) Mangrove	current Density A/cm^2) Tropical Rainforest	current Density (A/cm^2) Guinea savanna
6.00am	0	0	0
7.00am	0.10004	0	2.0008
8.00am	1.70068	0	2.70108
9.00am	4.0016	0.30012	7.0028
10.00am	3.10124	0.70028	**8.80352**
11.00am	2.40096	2.20088	2.30092
12.00am	**8.20328**	2.10084	7.30292
1.00pm	3.90156	**3.5014**	6.5026
2.00pm	2.90116	2.10084	1.70068
3.00pm	0.40016	3.0012	1.40056
4.00pm	1.0004	1.70068	3.80152
5.00pm	0.70028	0.70028	1.10044
6.00pm	0	0.20008	0

Table 3: Shows the value of the Polycrystalline panel Current density across the cities in the three vegetation.

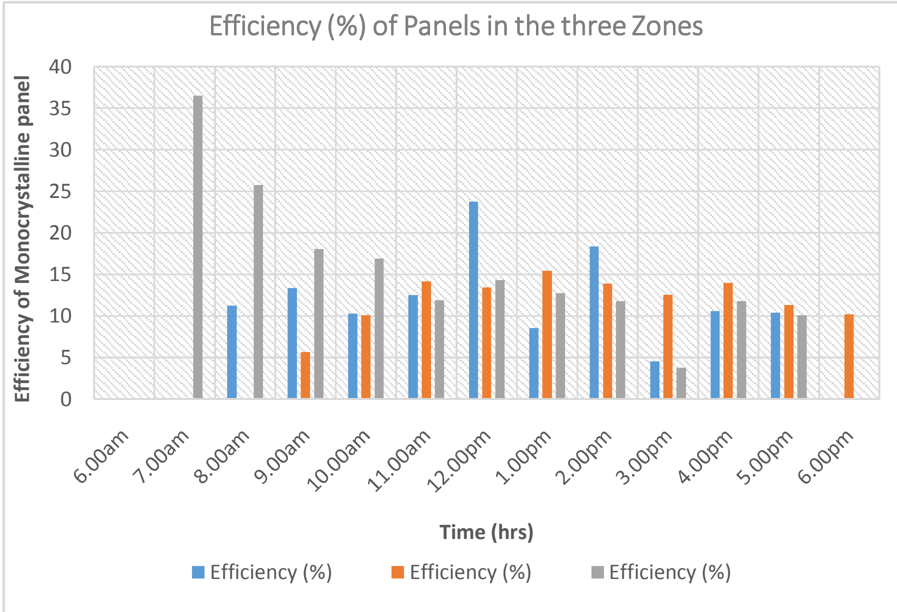

Fig. 4: Efficiency of Monocrystalline panel across the cities in the three vegetation.

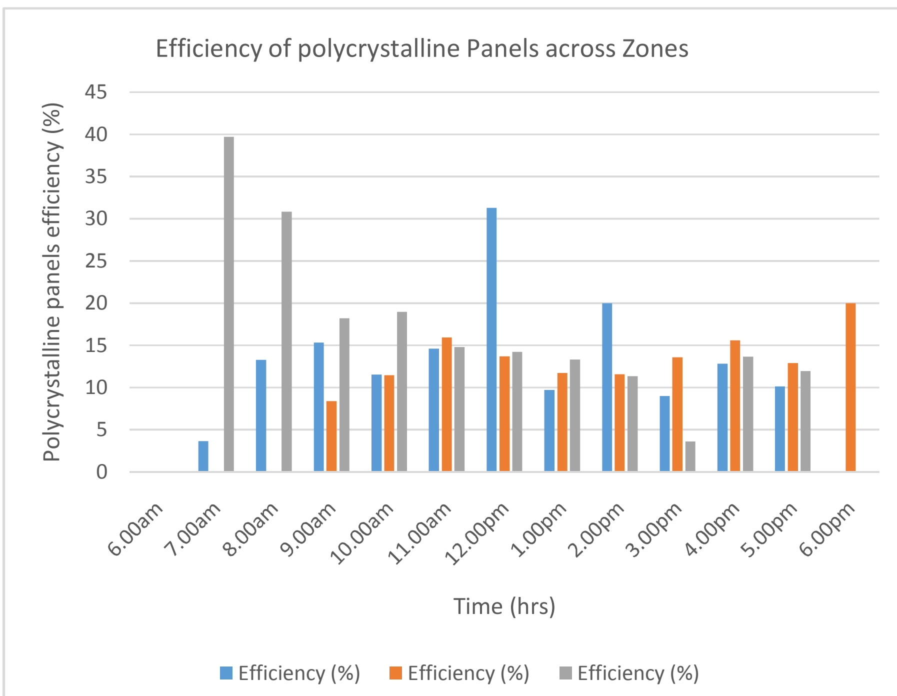

Fig. 5: Efficiency of Polycrystalline panel across the cities in the three vegetation.

Tables 4. Efficiency of Polycrystalline Panel across zones

Time Hours	Efficiency (%) Mangrove	Efficiency (%) Tropical Rainforest	Efficiency (%) Guinea savanna
6.00am	0	0	0
7.00am	3.64146	0	**39.7233**
8.00am	13.2802	0	30.8241
9.00am	15.3369	8.39986	18.2106
10.00am	11.5273	11.4742	18.9554
11.00am	14.6178	15.9138	14.7916
12.00pm	**31.274**	13.6844	14.2097
1.00pm	9.72896	11.7219	13.3341
2.00pm	20.008	11.568	11.3499
3.00pm	9.00959	13.588	3.62246
4.00pm	12.8051	15.6193	13.6326
5.00pm	10.1328	12.9087	11.9754
6.00pm	0	**20.008**	0

4.2.1 Analysis and Reliability of the Comparison

The graph of Fig. 1 to Fig. 5 represent the measurements of all the parameters from the two panels in the three different vegetation.

Fig. 1 compares the solar radiation values of the panels in all the three zones. The results show that highest radiation value of 991.9 W/m^2 was recorded from the panels in the Guinea Savanna (Abakpa) location at 12.00pm, followed by the Mangrove zone with 782 W/m^2 at 1.00pm and the Tropical Rainforest zone recorded the lowest of the peak radiation values of 576.5 W/m^2 at 1.00pm. Table 1 also elucidates that the signal trend varies by time of the day across the three zones. For instance in the Guinea savanna the radiation signal though high was observed to start rising from 7.00am to 4.00pm and fluctuates in between the hours before it constantly drop to '33.9' at 6.00pm. The same variation in signal trend were observed across the other vegetation zones.

Fig. 2, compares the power output of the monocrystalline panels of the three zones. The result shows that the highest power output of 152.3Watt at 10.00am was obtained from the monocrystalline panel in Guinea savanna, followed by the Mangrove zone with 118.9Watt at 12.00am and 88.9Watt at 1.00pm in the Tropical Rainforest zone respectively.

Fig. 3, shows the power output of the Polycrystalline panel across the three zones. 170.72Watt for Guinea savanna at 10.00am, 156.62Watt for Mangrove at 12.00pm and 67.6Watt for the Tropical Rainforest zone at 1.00pm respectively were the maximum values obtained from the panels.

Comparing the results of Fig. 2 and Fig. 3 shows the polycrystalline panel in the Guinea savanna has the highest power output value followed by the polycrystalline panel of the Mangrove zone and monocrystalline panel of the Tropical Rainforest zone respectively. It is also important to state that the signal trend was never constant as it varies between the times of the day from 6.00am to 6.00pm.

Table 2, shows the current density obtained from the Monocrystalline panel across the three zones. The highest current density of 7.503A/cm^2 was obtained from the Guinea savanna zone at 10.00am, followed by 6.10 A/cm^2 for the Mangrove zone at 12.00pm and 4.40A/cm^2 at 1.00pm for the Tropical Rainforest zone respectively.

Table 5, shows the current density obtained from Polycrystalline panel across the three zones. 8.80A/cm^2 was obtained at 10.00am from the Guinea savanna, 8.20A/cm^2 at 12.00pm from the Mangrove zone and 3.50A/cm^2 at 1.00pm from the Tropical Rainforest zone respectively.

Analysis of Table 4 and 5, shows the polycrystalline having the highest current densities across the zones as the panel's current densities varies constantly across the zones and the time of day.

Fig. 4, shows the efficiency of monocrystalline panels measured across the three zones. The result displayed 36.5% at 7.00am, 23.8% at 12.00pm and 15.4% at 1.00pm respectively as the maximum values obtained from the Guinea savanna, the Mangrove and finally the Tropical Rainforest zone.

Fig. 5, depicts the efficiency of the Polycrystalline panels to be 39.73% at 7.00am, 31.2% at 12.00pm and 20.0% at 6.00pm respectively being the maximum values recorded for the Guinea savanna, the Mangrove and the Tropical Rainforest zone.

The analysis of Fig. 4 and 5 indicates that the efficiency of the polycrystalline panel is better across the three zones. Although a downward drift was observed throughout the time of the day. It is important to state that at Guinea savanna the efficiency acquired from the different panels kept dropping continuously from 7.00am to 6.00pm. A trend that varies differently from the panels of other vegetation zones as observed in the figures. It was also observed that the efficiency of the polycrystalline panels in the Tropical rainforest increased geometrically abnormally at 6.00pm. A major inference on the signal trend observed here demonstrates that efficiency varies with the time of the day, and it's never constant no matter what type of panels used in all the three zones

From the above result, we can endorse that efficiency is independent on solar radiation and power output of the panel. Hence the efficiency of solar panels (monocrystalline and polycrystalline) varies with the time of the day.

Mathematically, we infer that the efficiency of solar panels (monocrystalline and polycrystalline) in particular is inversely proportional to the time of the day. We express this mathematically as follows:

let ε =efficiency

t_d= time of the day

So that

$$\varepsilon \propto \frac{1}{t_d}$$

CONCLUSION

From the observation in this research work, the polycrystalline panels are the most suitable panels to build or establish a solar farm in most parts of the Cross River State. The most suitable zone to establish a solar grid from this research is Guinea Savanna due to the maximum Solar Radiation value of 991.9W/m^2, the power output of 170.72Watt, the current density of 8.80A/cm^2 and the panel efficiency of 39.9% respectively measured from the panel in the Guinea savanna zone.

This result does not contradict the founding of Nowshad et al, (2009) whose world record for silicon based PolyVoltalic (PV) is 27.6%. His result was generalised world average value of efficiency for PV.

The 39.9% efficiency recorded in this research as shown in Table 4, is perculiar to a specific PV panel, zone, location and time duration. Therefore feature research should be performed in this area using triple junction technology (TJT) modules. Cross River is a virgin state in terms of renewable energy investment. Investors are therefore expected to exploit this area of renewable energy generation.

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