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Original Article

Deployment and Sustainability of Solar Energy in the Niger Delta Area

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Abstract *- The Niger Delta area, located in the South-South region of Nigeria, faces constant epileptic power supply from the conventional power system that had drastically hindered her economic growth and development. Based on the geographical location of the area, electrical energy can be harnessed from the abundant solar power energy to argue the epileptic's power supply. The performance of installed solar street lights in Oleh, a University community in the area, was observed over a period of six months and also subjected to forecast analysis using the SPSS 7.5 application over another six months. An experimental setup was also carried out to propose a model for solar power generation for the area. The observed street lights showed good performance over a period of six months without maintenance, while the forecast analysis was of adequate sustainability over another six months. Data collation from power produced by the ten panels over one year was employed in a model formulation for solar power production for the area. The measured output power was compared with the predicted output power. The average energy generated by the PV panels for the duration was 1.550kWh, while the model-predicted power over the same period was 1.571kWh. The results show that the empirical model predicted power is higher compared to the measured power. Therefore, the developed model can be deployed for electrical energy production computation to serve as a tool for better PV system performance in the area.*

Keywords *- Solar energy, Photovoltaic (PV) panels, Forecasting, Model formulation, Power prediction.*

1. Introduction

Subsistence and constant power supply are key to the development and economic growth of any Nation [1]. Energy sources are classified into conventional and non-conventional. Conventional energy sources are non-renewable energy sources such as fossil fuels, petroleum, coal, etc. they are called non-renewable because they deplete with time. The challenges of conventional energy sources to the world environment, including Nigeria, have led to the seeking of alternative energy sources, such as solar and wind power [2].

Nigeria is blessed with both conventional and renewable energy resources [3]. Non-conventional energy sources, which are renewables, include solar energy that can be harnessed with either Photovoltaic (PV) cells or Solar Thermal Energy (STE) [4]. Most PV panels function in off-grid systems that also store excess electricity for some hours when there is no sunlight [5].

A PV panel is more efficient at an average temperature, and its performance is greatly influenced by its orientation and geographical position described by tilt and azimuth angles [6]. Over decades, the energy sector in Nigeria has suffered severe neglect by the subsequent Government and has been under poor performance even with the most recent deregulations of the power sector [7]. Nigeria falls within the Tropic of Cancer and Capricorn, where there is abundant solar radiation arising from the available sunshine if properly harnessed [8].

With an average solar radiation intensity of about 5kWh/m^2/day and adequate Photovoltaic (PV) module operations, it was projected that an average of 192000MW of solar energy could be harnessed daily of effective solar installation that covers only 1% of land area in the country [9]. The average annual solar radiation fluctuates in Nigeria around 3.5kWh/m^2/day in the coastal region, with an average sunshine of about nine hours per day in the dry season and five hours per day in the rainy season [5].

The Niger Delta area is located in the coastal region of the country. Based on the geographical location of the area, electrical energy can be harnessed from the abundant solar power energy to argue the epileptic power supply in the area [10]. To encourage the use of solar power, the Niger Delta Development Commission (NDDC), the Energy Commission of Nigeria, the World Bank, the Educational trust fund and other organizations have funded the installations of many solar energy systems across the area [11].

However, the consistently poor performance of installed solar systems in the area is a serious concern. An assessment of solar energy performance in the Niger Delta area revealed that Port-Harcourt, one of the cities in the area, is likely prone to fail installed solar systems [12].

Due to relatively low solar energy to electrical energy conversion, research and developmental efforts are made to optimize the overall system performance of the solar system and create new ways to predict the exact production from the environmental and climatic conditions available. To address the power problem, various mathematical models have been proposed for electrical power prediction of photovoltaic systems in different conditions [13]. Therefore, the need to develop an empirical model to predict PV power output with a view to establishing solar tank farms in specific zones within the area becomes paramount.

2. Materials and Methods

The analytical method was adopted to analyze the functionality of the solar street lights in the Oleh community. The materials used are voltmeters, wires, batteries and SPSS software.

2.1. Solar Street Light Installed in Oleh Community

Figure 1 is a photo-view of installed solar lights in the street at Oleh Community, Niger Delta area, located in the South-South region of Nigeria. The functionality and non-functionality of the street lights were carefully studied by moving around the town six months after installation. The result obtained from field observation of the street lights is presented in Table 1. In Table 1, the total number of street lights installed in Oleh Town is S, the number of functioning street lights is P, and the number of non-functioning street lights is Q.

Fig. 1 A photo-view of an installed solar street light in Oleh Town

Table 1. Condition of solar street lights in Oleh Town ten months after installation

Sr. No.	Street in Oleh Community	Number Installed (S)	Functioning (P)	Non-Functioning (Q)
1	Law Faculty, Oleh Campus	54	42	12
2	Engineering Faculty, Oleh Campus	47	39	8
3	Emore Street	40	28	12
4	Ibiegbe Street	21	14	7
5	Ottah Street	17	11	6
6	Iyenrhoma Street	15	12	3
7	Joe Street	11	7	4
8	Iyengide Street	15	12	3
9	Usevwhe Street	14	10	4
10	Iyanmede Street	16	12	4
11	Okporo Street	12	9	3
12	Ottio Street	11	10	1

13	Ikrigbenu Street	16	13	3
14	Uverhe Street	14	12	2
15	Edubi Street	11	10	1
16	Iyendor	12	9	3
17	Urenobevwho Street	13	9	4
18	Ogbodu Street	8	8	0
19	Amawa Street	9	7	2
20	Okalibo Street	10	6	4
21	Esaledor Street	`10	4	6
22	Othokwe Street	16	9	7
23	Erhuovo Street	9	8	1
24	Ovieba Street	9	7	2
25	Atavwhe Street	11	7	4
26	Omu Street	8	6	2
27	Ilolo Street	9	2	7
28	Ishofu Street	11	9	2
29	Oshiobi Street	13	12	1
30	Akpotu Street	8	6	2
31	Mallam Obi Street	8	7	1
32	Iyanmeta Street	12	10	2
33	Agberhe Street	7	7	0
34	Ivie Street	10	8	2
35	Otuye Street	14	12	2
36	Agberhe Street	7	7	0
37	Iviede Street	13	10	3
38	Esasan Street	7	5	2
39	Iviede Street	13	11	2
40	Emoniero Street	8	7	1
Total		**569**	**434**	**135**

The analysis of Table 1 shows the total street lights installed in Oleh Town, S = 569

Total functioning street lights after ten months, P = 434

Total non-functioning street lights after ten months, Q=135

Percentage of Functioning Street lights = (P/S)*100 (1)

= (434/569) X 100 = 76.27%

Percentage of Functioning Street lights =(Q/S)*100 (2)

= 135/569 = 23.73%

This study revealed a very low percentage of failure, as approximately 80% of the street lights were functioning ten months after installation. The Faculty of Engineering, Delta State University, Oleh Campus, has a total installed street lights 47, with only 8 that failed. Furthermore, the state of the street lights in the next twelve months was forecasted at intervals of six-month transformations with the aid of the SPSS75 program. Figure 2 is the outputs of the first performed forecast specified as transformed difference (1), while Figure 3 is the outputs of the second forecast specified as transformed difference (2).

The transformed difference (1) forecast of Figure 2 revealed an average percentage of failure in the functionality state of solar street lights in the next six months. This could be attributed to the area's usual six months of rainy season. The transformed difference (2) forecast of Figure 3 revealed a very low percentage of failure in the functionality state of solar street lights in the next six months. This could be attributed to the area's usual six months of dry season.

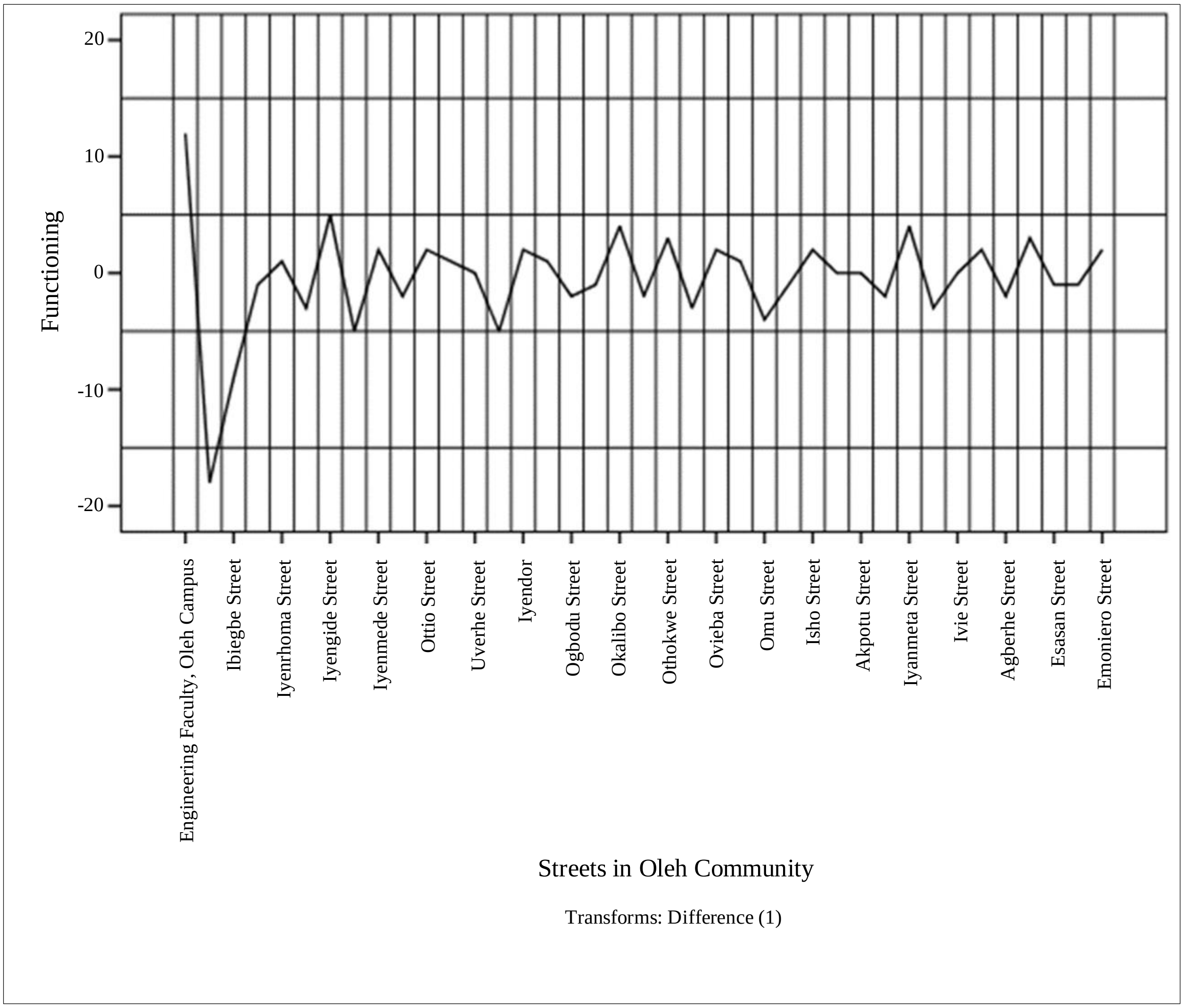

Fig. 2 Forecast on the functionality of solar street lights in the next six months

2.2. PV Power Production

The general overview of Figures 2 and 3 shows that about 65% of the installed street lights will likely function well after one year of installation. The street lights' success rate led to further investigation of PV panels' power production over the specified period. The Faculty of Engineering, Delta State University, Oleh Campus, was used as the pilot base for further investigation. Ten (10) polycrystalline PV panels were used with a power rating of 100 Watts, each having a power temperature coefficient of (-3W / ^{O}C) under STC temperature of (25^{0}C) with a voltage rating of 12volts and a thermometer for temperature measurement. Equation (3) is a developed model for PV panel output power [13].

$$P_O = P_{STC} D_F [1 + \propto_P (T_i - T_{STC})] \left(\frac{G_T}{G_{T(STC)}} \right) \quad (3)$$

Where,

P_{STC} is PV module power-rated capacity (i.e. power output under standard test condition, STC)

D_F is the derailing factor due to shading, losses, snow cover, wind, etc.

$\propto_P$ is the temperature coefficient for power (Watt/^{0}C)

Ti is the PV module's instantaneous temperature

T_{STC} is the PV module temperature (^{0}C) at STC

$G_{T(STC)}$ is incident radiation at STC

G_T is the incident radiation, which can be computed from the proposed Hay and Davies, Klucher and Reindl (HDKR model).

Equation (4) is obtained by Ignoring D_F and G_T.

$$P_O = P_{STC} [1 + \propto_P (T_i - T_{STC})] \quad (4)$$

3. Results and Discussions

3.1. Experimentally Generated Power

Table 2 presents the average monthly measured atmospheric temperature, Ti, and the corresponding average PV panel's power production, Po.

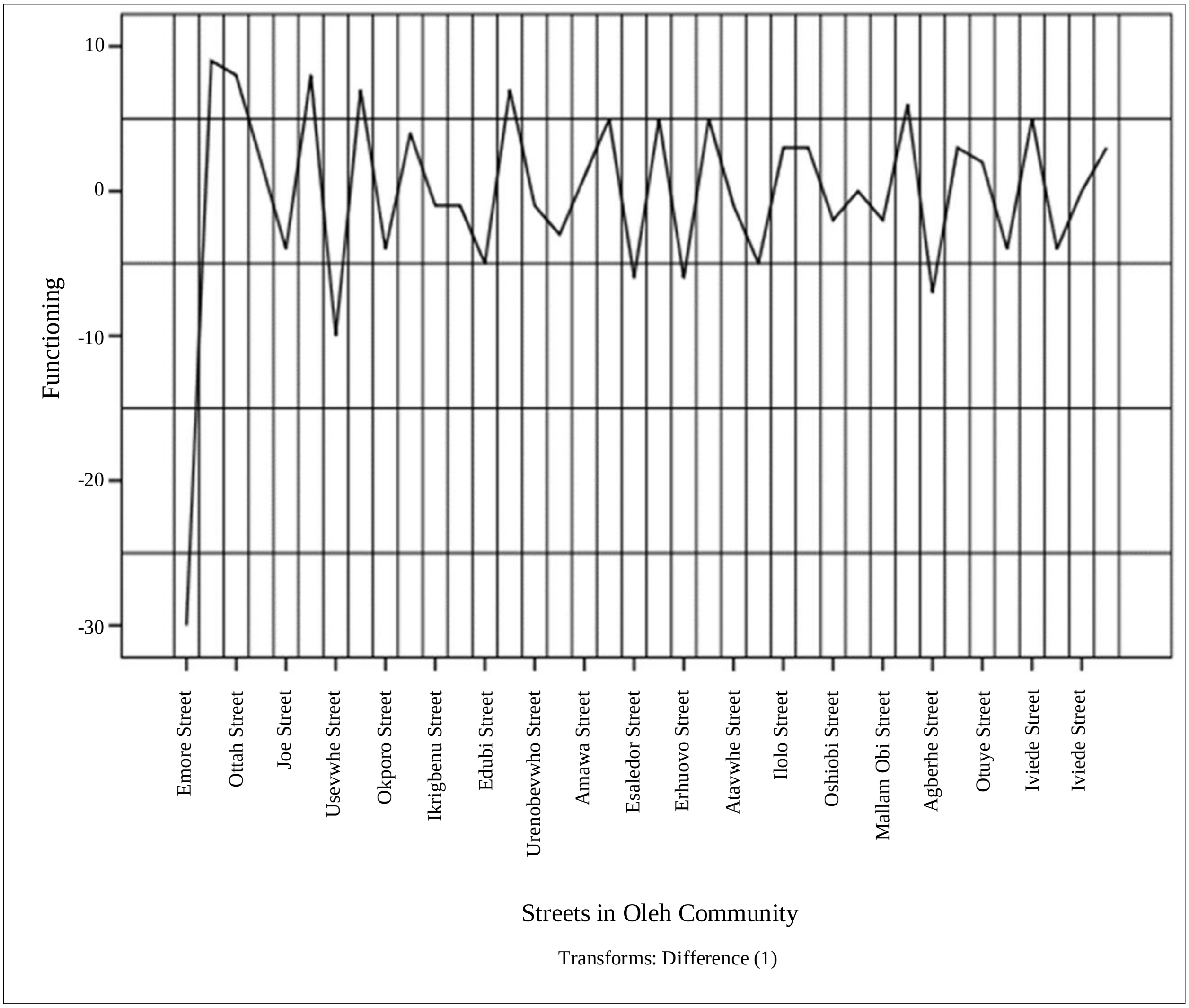

Fig. 3 Forecast on the functionality of solar street lights in the next twelve months

Table 2. Faculty of engineering PV panel power generated from January-December 2020

Month	Ti (◦C)	Po (Watt)
January	0	0
February	0	0
March	31	2452
April	30	1574
May	29	1689
June	29	1462
July	27	878
August	27	922
September	28	726
October	29	1566
November	31	2210
December	30	2023
Average	**29.1**	**1550.2**

Table 3. PV panel power predicted

Observations	Predicted Power Generated	Residuals
1	-102.37424	102.37424
2	-102.37424	102.37424
3	1679.9117	772.08827
4	1622.4186	-48.418633
5	1564.9255	124.07446
6	1564.9255	-102.92554
7	1449.9393	-571.93935
8	1449.9393	-527.93935
9	1507.4324	-781.43244
10	1564.9255	1.0744625
11	1679.9117	530.08827
12	1622.4186	400.58137

Figures 4 and 5 are graphs of average temperature and PV power generated on a monthly basis over a period of ten months, as obtained from the data. Figure 4 shows that an average temperature of 26^0C was recorded from July to September. These are usually the months of heavy annual rainfall in the region.

Figure 5 shows that low average energy production was recorded in the months of July to September, which coincided with the rainy season in the region, while other months recorded good power generation.

3.2. Predicted Power Generation

Table 3 shows the result from the model of Equation (2), which was employed for the computation of average predicted PV power generation from January to December 2022. From Table 3, the computed average predicted power generation is 1.571kWh.

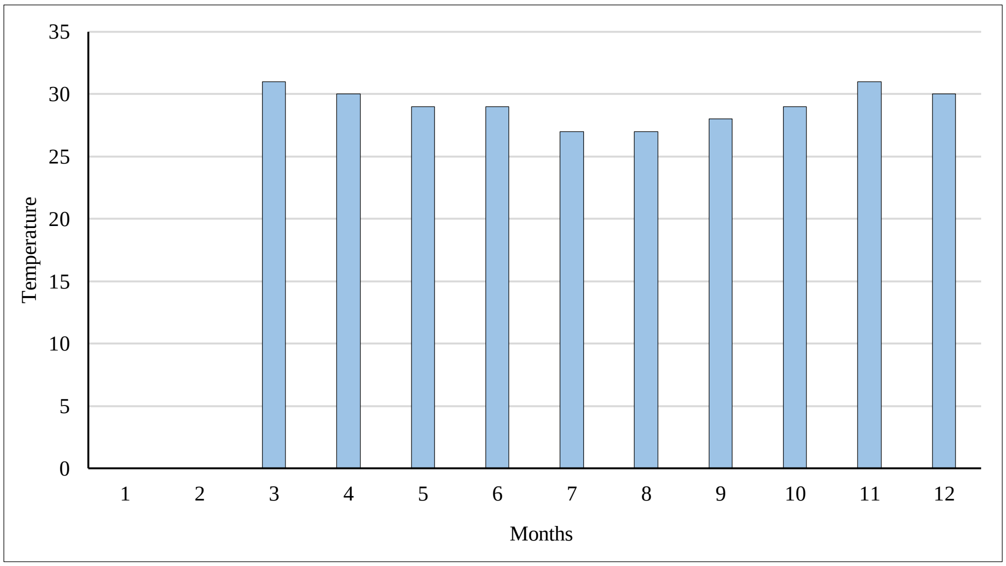

Fig. 4 Monthly average measured atmospheric temperature

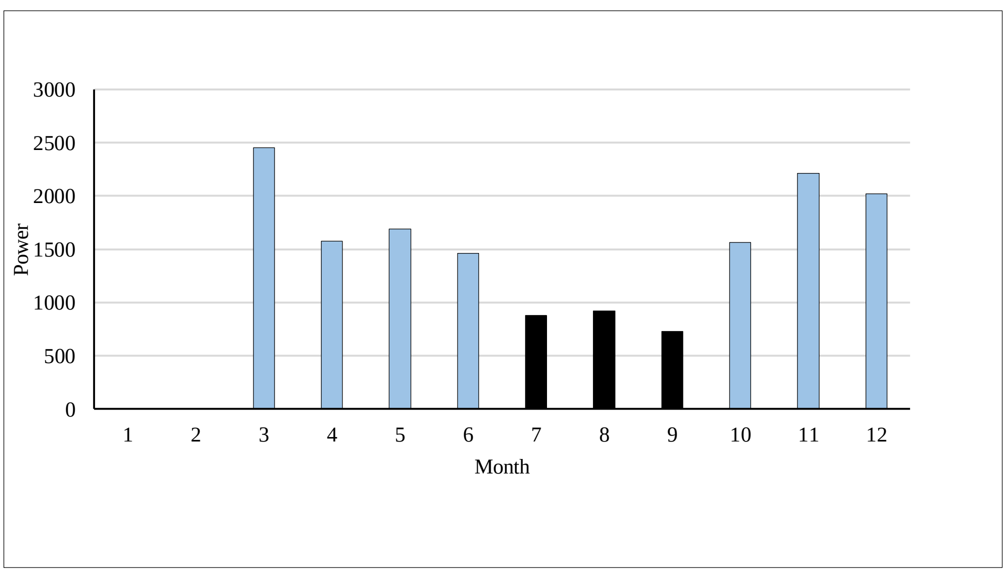

Fig. 5 Monthly average computed PV power

3.3. Power Model Formulation

Figure 6 presents a line fit plot of the computed predicted power generation in Table 3 and the average monthly temperature of PV panels in Table 2. Equation (6) is the power prediction model equation obtained from the line fit plot of Figure 6.

$$Y=57.595X - 102.373 \quad (5)$$

Where,
Y is PV predicted generated power, and X is temperature.

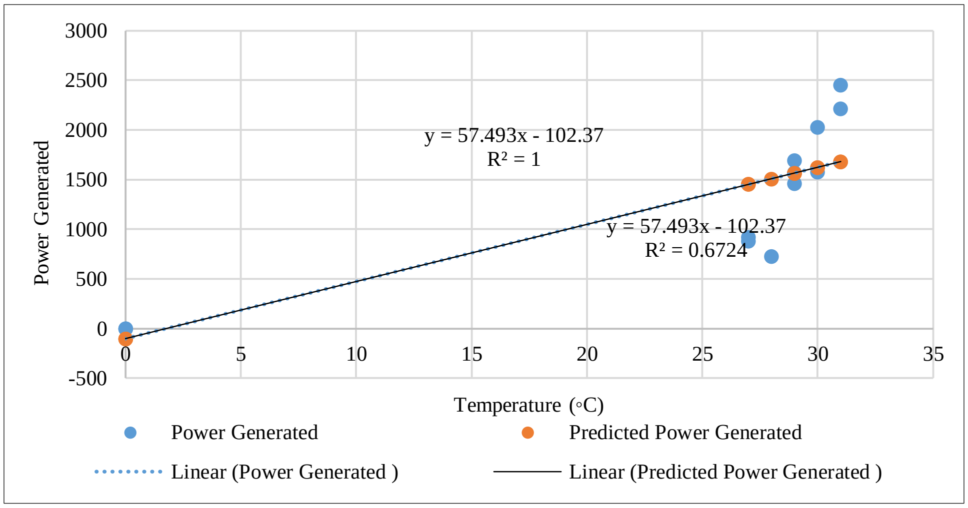

Fig. 6 Average PV power generated line fit plot

4. Conclusion

This paper addresses the great role solar energy system would have effectively contributed to the development of the Niger Delta area in Nigeria's power system and, in the long run, boost her economic activities such as industries, factories, schools, hospitals, businesses, service companies, hotels, hospitals and many others that require a constant and sustainable energy supply to function effectively and efficiently**.** From the developed model, the predicted average power of the PV panels is 1.571kWh, while the average measured power from the ten PV panels is 1.550kWh. Findings show that the predicted power using the empirical model is higher compared to the computed measured power. Therefore, the developed model, if deployed for electrical energy production calculation, can serve as a tool for a better understanding of the PV system performance within the area.

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