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Determination of Panel Generation Factor for Ugbokolo, Benue State in Nigeria Using Experimental Method

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***Abstract*: The study is to determine the panel generation factor for Ugbokolo, Benue state, in Nigeria using experimental method. This has become necessary due to lack of such within the radius of three hundred kilometers. As a varying factor for solar energy installation, it is expected to be determined at the specific site of installation or within a short distance for design accuracy. The analytical values usually used during solar system designs may not be actual values hence reducing the sizing accuracies. The study measures the average daily energy generated in Ugbokolo by 600w solar panels from March to June 2024. The energy generated was measured at the time interval of 20 minutes from 6.00am to 6.00pm daily. The average energy generated was used to determine the experimental value of panel generation factor for Ugbokolo to be 3.965. On the other hand, the analytical value was found to be 3.938 representing a deviation of 0.68%. The small deviation of the experimental value and analytical value validate the experiment.**

***Keywords*: derating factor, fill factor, peak watt rating, power rating, solar array.**

1. Introduction

Solar radiation in recent times has become a targeted source of energy owing to its vastness, renewable, sustainable, easily available and environmental friendliness. The solar radiation is converted to electricity with the aid of an appropriate solar photovoltaic (PV) system [11],

[16]. Every solar system depends on the climatic conditions of a geographical location where it is to be installed [17]. One of the factors to be considered when sizing a solar system is panel generation factor (PGF) [1], [3], [4]. PGF depends on solar irradiance of a location and varies with different locations. Every solar system also depends on the energy requirement of the user's loads and the solar energy potentials of the location [2], [14]. A lot of solar system design tools calculate solar potentials for a location using data from metrological stations. This data obtained from metrological stations are not specific consequently liable to errors as compared to experimental determined data at the site. The study is to determine the Panel generation factor for Ugbokolo, Benue state of Nigeria. This has become necessary due to lack of such within the radius of three hundred kilometers. As a varying factor for solar energy installation, it is expected to be determined at the specific site of installation or within a short distance for design accuracy. Previous studies by other scholars shows that, the panel generation factor for Nigeria is 3.596 [10], [12]. Panel generation factor which is a varying factor dependent on the weather conditions of the site is a crucial factor to size a solar system. Therefore, a single panel generation factor for the country as recorded by some scholars will be approximations and prone to errors considering the size and diverse weather conditions of the country. It is therefore necessary to determine the panel generation factor for specific locations to size an appropriate photovoltaic system that will produce the required energy demand from such a place.

2. Determination of Panel Generation Factor Using Analytical Method

The analytical value of panel generation factor (Pgf) can be calculated using equation (i) stated as:

$$P_{pv}\ (Anal.) = f_{pv}\frac{G_T(t)}{G_{T.STC}} \quad (1)\ [6]$$

$P_{pv}(Anal) = panel\ generation\ factor\ of\ the\ pv\ analytically$

$G_R = solar\ radiation\ incident\ on\ the\ solar\ pv\ array\ in\ the\ current\ time$

Ugbokolo is located at latitude 7.7833N and longitude 8.03^0E. The solar radiation incident on the panels as stated by Global solar atlas is 5,707.3KW/m^2 [5].

$G_{R.STC} = incident\ radiations\ at\ standard\ test\ conditions$ (1000w/m^2) [7]

$f_{pv} = solar\ pv\ generator\ derating\ factor$

The derating factor which is a value used to reduce the rated capacity of the solar panels to account for various losses in real time, can be calculated using the formula (2),

$f_{pv} = (1 - temperature\ derating)\ X\ (1 - soiling\ derating)\ X\ (1 - inverter\ efficiency)\ X$

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$(1 - wiring\ and\ connection\ losses)$
$X\ (-other\ losses)$ (2) [8]

$$f_{pv} = 0.85 \times 0.95 \times 0.95 \times 0.9$$
$$f_{pv} = 0.69$$

The value of pgf calculated analytically is found to be 3.938.

3. Determination of Panel Generation Factor Using Experimental Method

In order to determine the panel generation factor, two solar panels of 300w each were used. The average daily energy generated by the 600w solar panels was used to calculate the panel generation factor using (3),

$$pgf_{exp} = \frac{w_r E_T}{w_p} \quad (3)\ [12]$$

pgf_{exp}
$= experimental\ value\ of\ panel\ generation\ factor$

$w_r = pawer\ rating\ of\ 1\ solar\ panel$
$E_T = average\ total\ energy\ generated$
$at\ the\ site\ per\ day$
$w_p = peack\ watts\ rating\ of\ the\ panels$

The watt-peak (wp) rating of a solar panel is the maximum power output under standard test condition (STC). It can be calculated using (4),

$$wp = I_{sc} \times v_{oc} \times FF \quad (4)\ [15]$$

Where,
$I_{sc} = short\ circuit\ current\ of\ the\ solar\ panel$
$v_{oc} = open\ circuit\ voltage\ of\ the\ soalr\ panel$
$FF = fill\ factor$

The experimental value obtained after the experiment was compared with the analytical value, then the percentage deviation was calculated using (5)

$$\%pgf_{deviation} = \frac{pgf_{experimental} - pgf_{analytical}}{pgf_{experimental}} \times 100 \quad (5)\ [9]$$

4. Experimental Set Up

The components of the pv system were arranged as seen in fig.1. This was to measure the real average daily solar energy at the site of the experiment. Fig. 1 is the block diagram of the experimental set up.

The components of the solar system as seen in fig.1 comprised of a deep cycle solar battery, charge controller, two solar panels (modules) rated at 300w and inverter. The panels were connected in parallel to improve the amount of current in the solar system. Table 1 is the details of the components used and their ratings

Table 1
Experimental components quantity and rating

Components	Quantity	Rating
Monocrystalline solar modules	2	600w
Solar battery	1	12v/100Ah
Inverter	1	1.2kvA
MPPT charge controller	1	12/24V, 30A
Cable	-	Low resistance
Multimeter	2	-
Switch	1	-
Solar panel hanger	2	-

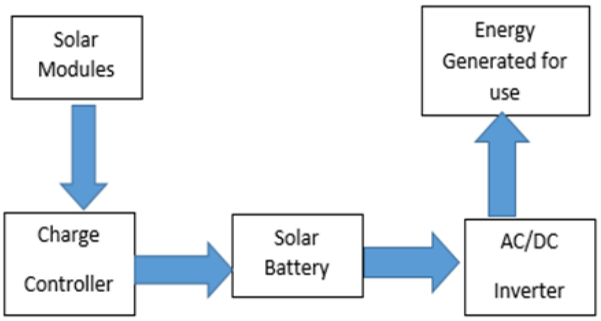

Fig. 1.

During the experiment, the current, voltage, wattage and energy from the solar system was measured using multimeters at the interval of 20 minutes from 6:00am to 6:00pm from March to June, 2024.

5. Results and Discussion

The panel generation factor was determined analytically to be 3.938 using (1), and (2). A sample of energy generated at the site per day is as shown in table 2.

Table 2
Sample of average energy generated per day at ugbokolo, benue state, nigeria

Time	Duration (h)	Current (A)	Voltage (v)	Power (w)	Energy (wh)
10:00	0.33	13.45	14.60	196.37	64.80
10:20	0.33	14.02	15.20	213.10	70.32
10:40	0.33	14.89	15.60	232.28	76.65
11:00	0.33	15.70	16.30	255.91	84.45
11:20	0.33	16.66	16.50	274.89	90.71
11:40	0.33	16.50	17.86	294.69	97.25
12:00	0.33	18.05	17.00	306.85	101.26
12:20	0.33	20.60	17.64	363.38	119.92
12:40	0.33	20.45	18.00	368.10	121.47
13:00	0.33	25.50	18.50	471.75	155.68
14:20	0.33	28.60	19.40	554.84	183.10
14:40	0.33	28.40	19.00	539.60	178.07
15:00	0.33	28.55	19.20	548.16	180.89
15:20	0.33	28.30	19.26	545.06	179.87
15:40	0.33	28.40	19.06	541.30	178.63
16:00	0.33	25.60	17.01	435.56	143.70

Table 3
Average energy generated per day

Day	Energy generated per day (wh)
1	2384. 10
2	2365. 09
3	2374 .14
4	2430.33
5	2353.67
6	2368. 53
Average energy generated	2379.31

The average energy generated per day from 600w solar panels at the site is 2,379.31Wh as is shown partially in table 3. The result of the average energy generated per day was used to determine the experimental value of panel generation factor as 3.965 using (3).

From the value of panel generation factor determined analytically and experimentally, the two values were compared and the percent deviation was found to be 0.68% using (5).

6. Conclusion

The study is to determine the panel generation factor for Ugbokolo, Benue state, Nigeria. From the experiment conducted at the site, it was founded that, the value of panel generation factor for Ugbokolo experimentally is 3.965 while the analytical value is slightly lower than the experimental value at 3.938. After comparing the two values, the percentage deviation was found to be 0.68. This deviation is so small thereby validating the experiment. There is a need for determination of panel generation factor for other places in Nigeria considering the size of the country for PV design accuracies.

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