
EXPERIMENTAL DETERMINATION OF PANEL GENERATION FACTOR FOR APO AREA OF FEDERAL CAPITAL TERRITORY IN NIGERIA

Abstract: The nature of renewable energy resources makes it necessary to perform site-specific resource assessment in order to achieve fairly accurate estimate of energy harvest so as to meet requirements of energy consumption and storage. Available design tools are based largely on remote modeling and estimation of site's resource potentials. These design tools provide analytical value of the panel generation factor which may not represent the true value. The Panel Generation Factor is used for design of solar photovoltaic systems. This paper reports on the panel generation factor obtained from experimental determination of its value for Apo Area of the Federal Capital Territory in Nigeria. The value of the panel generation factor obtained for Apo Area is 3.625. The panel generation factor reported in literature for tropical climate of Apo is 3.596. The value obtained for the experimentally determined panel generation factor represents a deviation of 0.88 % in comparison with the value reported in literature, validating the value obtained experimentally. The site-specific requirement of renewable energy deployment is indicative of the usefulness of this experimentally determined panel generation factor.

Keywords: Photovoltaic Systems, Panel Generation Factor, Irradiance, Deep Cycle Battery.

1. INTRODUCTION

Panel Generation Factor (PGF) is used in sizing solar photovoltaic (PV) systems and is dependent on the irradiance for a given location [1]–[4]. It is a factor used in sizing the generation and storage assets of a solar PV system, offgrid or grid-connected [5]–[7]. The appropriate size of the generation asset is dependent on the energy demand of the load as well as the potential renewable resource available at the site [8], [9]–[11]. Majority of design tools estimate site's resource potential using remotely developed models that are based on meteorological data [12]–[14]. This remotely modeled data or data obtained analytically are prone to errors which make them less reliable in comparison with data obtained from the site through experimental methods. This work presents experimental determination of PGF for Apo area of the Federal Capital in Nigeria. Nigeria is a tropical country and therefore is classed as *Typical Tropical Climate* with the panel generation factor reported in literature to be 3.596 [1]. This factor helps to determine the appropriate size of active components as well as the balance of system. For Apo area, it is determined to be, representing a deviation of 0.88 % from the value reported in literature.

2. ANALYTICAL DETERMINATION OF PGF

The value of PGF determined analytically can be obtained using (1).

$$PGF_{analytical} = \frac{f_{PV} \overline{G}_T}{\overline{G}_{T,STC}} \quad (1)$$

where, f_{PV} is the derating factor of the PV, \overline{G}_T is the solar radiation incident on the PV array in (kWh/m² per day) and $\overline{G}_{T,STC}$ is the incident radiation at standard test conditions (1 kW/m²).

Derating factor comprises of temperatures above 25°C (15 %), sunlight not striking the panel directly (5 %), not using maximum power point tracking (10 %), dirt (5 %), the solar panel being below specification and ageing (10 %) [15].

The daily energy generated (E_{PV}) can be obtained by (2).

$$E_{PV} = Y_{PV} \frac{f_{PV} \overline{G}_T}{\overline{G}_{T,STC}} \quad (2)$$

Y_{PV} is the rated capacity of the PV array (Wp). From the Global Solar Atlas as reported in [16], the horizontal irradiance for the location where the experiment was done is 5.208 kWh/m² per day (\overline{G}_T). The derating factor in this case, f_{PV} , is given in (3).

$$f_{PV} = 0.85 * 0.95 * 0.95 * 0.9 = 0.69 \quad (3)$$

Using (1), the value of PGF determined analytically is 3.596.

3. EXPERIMENTAL DETERMINATION OF PGF

Apo Area of the Federal Capital Territory of Nigeria has tropical costal climate and the average daily energy generated from a 640 W_p solar panel is used to determine the experimental value of PGF for the area.

The PGF can be determined experimentally using (4).

$$PGF_{experimental} = \frac{1W_p \times E_{Total}}{W_p} [1] \quad (4)$$

where,

$PGF_{experimental}$ is the experimental value of PGF.

$1W_p$ is the rating of a 1- W_p panel.

E_{Total} is the average daily total energy harvested from the site in Wh.

W_p is the Watt-peak rating of the panel(s).

The per cent deviation of $PGF_{experimental}$ from $PGF_{analytical}$ is obtained using (5) [17].

$$\%PGF_{deviation} = \frac{PGF_{experimental} - PGF_{analytical}}{PGF_{experimental}} \times 100 \quad (5)$$

4. EXPERIMENTAL SETUP

A PV system was designed and deployed in order to measure the actual average daily energy of the site. **Fig. 1** shows the block diagram of the system configuration.

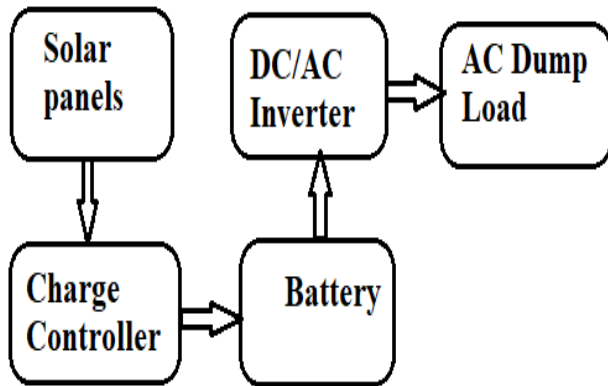


Fig. 1. Block diagram of the setup

The PV system consists of two monocrystalline panels of $320W_p$ rating each connected in parallel, giving a total of $640W_p$, an MPPT charge controller, an inverter and a battery as shown in **Table 1**. **Fig. 2** presents major components of the setup deployed in Apo Area of Federal Capital Territory in Nigeria for this work.

Table 1: Rating of major components in the setup

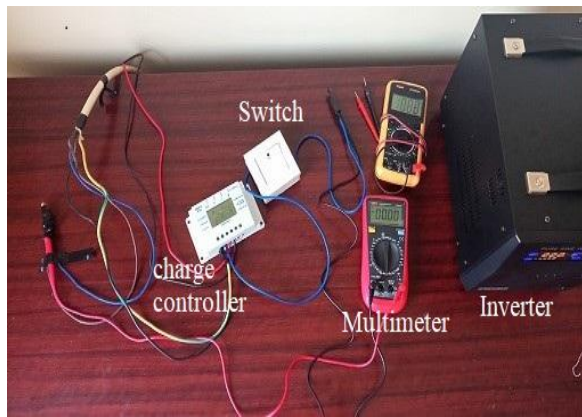
Components	Quantity	Rating
Monocrystalline Solar panel	2	320W
MPPT Solar charge controller	1	24 V, 30 A
Pure Sine wave Inverter	1	1.2kVA
Deep Cycle Battery	1	12V/ 200Ah/10hr



(a)



(b)



(c)

Fig. 2. Photo of the setup: (a) 640 W_p Monocrystalline solar panels; (b) Storage (c) Control and associated devices

Energy generated by the solar panels was measured at a time interval of fifteen minutes from 6:00 am to 6:00 pm daily, from February to May, 2019.

5. RESULTS AND DISCUSSION

From (1), (2) and (3), the PGF is analytically determined to be 3.596. Energy generated in watt-hour was determined experimentally and a sample is shown in **Table 2**.

Table 2: Sample of average daily energy generated in Apo Area

Time	Duration (h)	Voltage (V)	Current (I)	Power (W)	Energy (Wh)
11:15	0.25	15.84	13	205.92	51.4800
11:30	0.25	15.71	15	235.65	58.9125
11:45	0.25	17.89	31	554.59	138.6475
12:00	0.25	16.59	22	364.98	91.2450
12:15	0.25	17.56	28	491.68	122.9200
12:30	0.25	17.55	28	491.40	122.8500
12:45	0.25	17.49	27	472.23	118.0575

Table 3. Average Daily Energy

DAY	DAILY ENERGY GENERATED (Wh)
1	2518.305
2	2008.25
3	2433.9725
AVERAGE DAILY ENERGY	2320.1758

From results of the experiment, 640W_p generates average daily energy of 2320.1758 Wh, as partially

provided in **Table 3**. Thus, from (4), the value of PGF determined experimentally is 3.625.

From (5), the per cent deviation in PGF is determined to be 0.88 %.

6. CONCLUSION

From the study conducted, PGF obtained from the experiment is slightly higher than the PGF obtained analytically by a deviation of 0.88 %. The PGF determined experimentally is compared with the value obtained analytically and the deviation observed is sufficiently small, validating the experiment. The results availed for this report are interim, thus, the work is ongoing. This shows that further work needs to be done in other to provide technical support for offline offgrid design of solar PV systems in Nigeria without procurement of expensive foreign computational tools.

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