



Experimental Determination of Panel Generation Factor for Apo Area of Federal Capital Territory in Nigeria

Jessica A. Onwuzuruike¹ and Maruf A. Aminu^{1*}

¹*Department of Electrical and Electronics Engineering, Nile University of Nigeria, Abuja, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Author JAO performed the literature search, developed the framework and wrote and performed the analytical experiment. Author MAA carried out the result analysis in addition to guiding author JAO for performing the experiment. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2019/v24i330157

Editor(s):

(1) Dr. Prinya Chindaprasirt, Professor, Khon Kaen University, Thailand.

Reviewers:

(1) Bankole Adebajji, Ekiti State University, Nigeria.

(2) Himanshu Dehra, American Institute-Industry Forum on Energy, Canada.

(3) A. Ayeshamariam, Khadir Mohideen College, India.

(4) M. Murali, Sona College of Technology, India.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/50680>

Original Research Article

Received 10 June 2019
Accepted 18 August 2019
Published 31 August 2019

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 experimentally 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.

*Corresponding author: E-mail: maruf.aminu@gmail.com;

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).

$$PGF_{analytical} = \frac{f_{PV}\bar{G}_T}{\bar{G}_{T,STC}} \tag{1}$$

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

$$E_{PV} = Y_{PV} \frac{f_{PV}\bar{G}_T}{\bar{G}_{T,STC}} \tag{2}$$

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 (\bar{G}_T). The derating factor in this case, f_{PV} , is given in (3).

$$f_{PV} = 0.85*0.95*0.95*0.9 = 0.69 \tag{3}$$

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).

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

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].

$$\%PGF_{deviation} = \frac{PGF_{experimental} - PGF_{analytical}}{PGF_{experimental}} \times 100 \tag{5}$$

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.

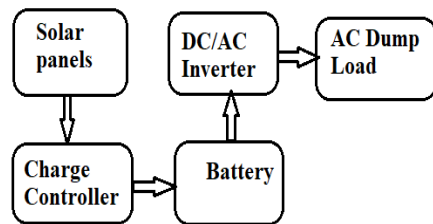


Fig. 1. Block diagram of the setup

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.



(a)



(b)



(c)

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

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

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Herbert A. Wade, solar photovoltaic systems technical training manual. France: United Nations Educational, Scientific and Cultural Organization; 2003.
- Lee K, Kang MG. Optimum design of dye-sensitized solar module for building-integrated photovoltaic systems. ETRI J. 2017;39(6):859–865.
- Damm CJ, Zloza WA, Staff SJ. Development of a web-based decision tool for selection of distributed energy resources and systems (DERS) for moving college and corporate campuses toward net-zero Energy. Proc. ASEE Annu. Conf. Expo. 2017;9393–9444.
- Barad JS, Chauhan MS, Barad DS, Parmar H. Calculation methodology and development of solar power generating system for household appliances; 2017.

5. Esan AB, Egbune D. Estimating the solar home system sizing for rural residential apartments using a panel tilt angle of 82 degrees: Ilorin, Kwara state as case study. *Electr. Comput. Eng.* 2017;1(3):90–96.
6. Swartz J, Ghofrani A, Jafari M. Sizing methodology for combined renewable energy systems. Presented at the 2017 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT). 2017;1–5.
7. Ballaji A, Ananda M, Swamy KN, Murthy V. Design, analysis and economic investigation of standalone roof top solar PV system for rural India. *Int. J. Appl. Eng. Res.* 2018;13(19):14461–14468.
8. Aya Ali Amer N, Joglekar, Tassneem Ahmed Zamzam, Iqbal A. Design and implementation of solar PV emulator using MAGNA DC power supply. *J. Electr. Eng.* 2018;11(4):1–8.
9. Khatib T, Ibrahim IA, Mohamed A. A review on sizing methodologies of photovoltaic array and storage battery in a standalone photovoltaic system. *Energy Convers. Manag.* 2016;120:430–448.
10. Hussin MZ, Omar AM, Shaari S, Sin NDM. Review of state-of-the-art: Inverter-to-array power ratio for thin – Film sizing technique. *Renew. Sustain. Energy Rev.* 2017;74: 265-277.
11. Fathima AH, Palanisamy K. Optimization in microgrids with hybrid energy systems – A review. *Renew. Sustain. Energy Rev.* 2015;45:431–446.
12. Chao-Rong Chen, Kartini UT. k-nearest neighbor neural network models for very short-term global solar irradiance forecasting based on meteorological data. *Energ.* 1996;1073(10):186.
13. Touafek K, Khelifa A, Boutina L, Tabet I, Haddad S. Theoretical study and experimental validation of energetic performances of photovoltaic/thermal air collector. *Int. J. Photoenergy*; 2018.
14. Pavithra CV, Vivekanandan C. Bidirectional three port converter for power flow management of PV/Battery-Fed elevator system. *J. Vibro Engineering.* 2018;20(1): 732-747.
15. Herb W. PV system sizing. *Solar PV Design Implementation O M. Marshall Islands*; 2008.
16. Global Solar Atlas. [Online]. Available: <https://globalsolaratlas.info/>
17. Maruf A. Aminu. Design of reactive power and voltage controllers for converter-interfaced ac microgrids. *Br. J. Appl. Sci. Technol.* 2016;17(1).

© 2019 Onwuzuruike and Aminu; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle3.com/review-history/50680>