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Determination of Number of Days of Autonomy for Battery Sizing in Lagos, Nigeria.

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Abstract

The study investigated the number of days of autonomy for sizing a photovoltaic cell (PV) panel and a battery bank in Lagos State, Nigeria. The calculations were based upon the data of monthly mean and daily mean global solar radiation obtained from Department of Physics, University of Lagos weather station (6.31ºN, 3.25ºE); over a period of 6 years (2007 to 2012). The global solar radiation on the horizontal surfaces from the weather station was analyzed using Microsoft excel and the average watt-hour radiation per day was obtained. The month with the worst solar radiation in the year was determined to be July with average daily solar radiation of 1435.07 Wh/m^2/day. This radiation value in the month of July was used in sizing the PV panel and the battery bank. For a PV system to comfortably supply the required energy load needed in Lagos State, the panel must be able to provide a minimum of 1435.07 Wh/m^2/day energy to the battery after a consecutive number of cloudy days. The number of days of autonomy for sizing a battery bank for a PV system was determined to be 5 days. Using this number in sizing the battery bank, the system is expected to power the load for consecutive five cloudy days without being recharged by the panels. It was found that the solar noon in Lagos is around 1.00PM and is expected that more load be channeled to the solar noon to safeguard the battery life.

Keywords**:** photovotaic panel; autonomy; battery bank; sizing;

Introduction

The frequent power failure in Nigeria today has necessitated the search for alternative energy sources for domestic and industrial uses. Considering the cost and environmental effect; the conventional energy source should be replaced by this alternative. Most of the standalone power generating stations or even the conventional grid require a backup for steady power supply to the load.

The power generation using renewable energy sources such as wind and solar are intermittent in nature. Hence, providing continuous supply of power to the load via the battery backup becomes essential (Manimekalai *et al.*, 2013).

It is also understandable while most of the alternative power sources available today need an

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external storage like battery bank. Many at times, the main source of power is not readily available, thus the need for an alternative source. A backup with a battery can fill this gap. One major problem confronting this system of power is determination of the number of batteries needed to maintain a steady power supply to the load. In the case of photovoltaic, (PV solar system), the sun is only available during the day, therefore creating a need for an alternative power source or a battery bank during the night or a cloudy day (Karafil *et al*. 2016; Li *et al*. 2017). Sometime during the rainy season (depending on the location of the site) the sun may not be available for days, putting the energy demand of the load on the battery. For the battery to meet this energy need, one has to consider the days of autonomy while sizing the battery. This is the maximum number of days the loads depend on the batteries for its energy needs without being recharged by the main power source (Rajeswari and Bhanu, 2013; Karafil and Özbay, 2018).

In a country like Nigeria where power supply from the power holding company of Nigeria, PHCN, (national grid) is not reliable, most of our standalone business outlets like automatic teller machine (ATM) and telecommunication mast, or remote systems such as satellite earth station and even the space satellite stations depend on alternative power for its energy requirements. It was estimated that as at 2012, more than 1.4 billion people all over the world lack access to electricity. About 42% of this people are from Sub- Saharan African, with over 76 million in Nigeria and some 69 million in Ethiopia and most of the rest in developing Asia (Modibbo, 2012; Musa *et al*. 2013). Ishaq *et al.* (2013) asserted that rural electricity can be improved in Nigeria if decentralized off-grid electricity is considered making use of solar PV. They assumed 4 days as the number of days of autonomy for mounting a solar panel in Wudil, Kano State.

Since diesel generator is not an alternative, battery storage is needed to backup energy for future use. In sizing the number of batteries needed to supply the required energy to the load; it is important for the engineers to know the number of days of autonomy for the place where the site is located. This will help the engineer in designing a system that will not fail in the case of a prolonged cloud-day. Guda and Aliyu, (2015) assumed the number of days of autonomy for sizing a solar panel in Bauchi state, Nigeria to be three (3). This assumption was made without proper research work to verify if the assumed number is correct. Krishnan and Sanukrishna, (2013) arbitrary assumed an average of 5 and 10 days as number of days of autonomy for non-critical and critical applications, respectively.

If the number of days of autonomy is wrongfully assumed, it is likely that the system will fail after sizing. A failed system may create more problems especially for a load that needed constant power supply. For a small value of days of autonomy, exhaustive comparison of all possible combinations of array size and battery capacity can be made. As the number increases, however, it becomes difficult if not impossible to consider all combinations (Woldehanna, 1998).

In battery sizing, there is need to consider the depth of discharge (DoD). Most batteries are rated in terms of charge cycle. A charge cycle is the required time it takes a fully charged battery to discharge and recharge fully again, if a certain amount of energy is constantly drawn from the battery to the load (Divya and Ostergaard, 2009).

According to Chendo and Obot, (2011) the dry season run from October to March, while the rainy season run from April to September each year. The solar intensity is high during the dry season than the rainy season. This is because of frequent cloud cover experienced during the rainy season. As a result, a solar cell is expected to generate more than enough energy during the dry season than the rainy season. It is also important for the engineers to know the number of days of autonomy for a particular site in question. The knowledge of this will help the engineers to determine the accurate number of batteries and PV panels needed for the project. Therefore, the aim of this study is to determine the number of days of autonomy for battery sizing in Lagos.

Materials and Methods

The radiation data for this work was obtained from the Department of Physics, University of Lagos weather station (6.31^{o}N, 3.25^{o}E); over a period of 6 years (2007 to 2012). These data were analyzed using Microsoft excel to calculate the average daily and monthly solar radiation for the twelve months in the year for all the years considered in this work. To analyse the solar radiation in order to get the average hourly radiation, solar radiation value was multiply by the number of the hours; in this case by 11 hours. This value gives the radiation in watts-hours. And then, determine the month that offered the worst solar radiation for the year. The radiation for the month of worst solar radiation must meet the required energy for the load, each month of the year. Eleven hours was used since the sun rises around 7 am and sets around 6 pm, as a result, the calculation was done considering radiation from 7am to 6pm. The total global solar radiation is made of the direct, the diffused and the ground reflected solar radiation. The data collected is for horizontal surfaces, direct and diffused radiation. No ground reflected radiation. The combination of the two gives the required global solar radiation. To determine the worst month for solar radiation in the year, a chart of global solar radiation was plotted against months of the year. The worst month of the solar radiation which occurs at the pick of the rainy season was determined. The average solar radiation for this month gives the minimum solar radiation energy required to power the load for that month. The number of days in a roll with solar energy less than that of the average solar radiation for the month is the number of days of autonomy for that particular site. To determine this, a chart of average daily global solar radiation against the days was plotted; the highest number of days with energy less than that of the average monthly global solar radiation in a roll is the number of days of autonomy. This number will be used while sizing the battery banks for a PV system designed to operate in that location. In sizing, the battery is calculated to supply energy to the load for the particular days of number of autonomy without being recharged.

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Results and Discussion

Solar intensity is observed to be high during the dry season than the rainy season as shown in Fig 1. As dry season approaches from August, the radiation intensity begins to increase till around November, when the harmattan starts. During this period, the radiation received on earth begin to reduce, and drastically in December and January. Thus, there is reduction in solar radiation between the months of November and February due to the dust particles associated with harmattan.

In March/April, the harmattan has gradually abated and the sky is clear as the rainy season approaches. Hence, the radiation intensity is highest in the month of April. As such, solar panel is expected to generate maximum power output. Therefore, to avoid energy wastage more load should be used as well as provision of energy storage facilities. On the other hand, it essential to ensure that the solar panel will be able to generate enough energy during the worst month of solar radiation in the year (July), or make provision to store the excess energy generated during the period of pick solar radiation to compliment that of the worst month, which is done by sizing the battery using the month of July (worst month for solar radiation). Sizing the battery requires the knowledge of days of autonomy for this month, which is determined by the average daily solar radiation for the worst solar radiation month for the year. Table 1 shows the average daily solar radiation for each months of the year. The worst solar radiation month for the year (July) has an average daily solar radiation of 1435.06 Wh/m^2/day. Thus, the system must be sized in such a way that it can meet the energy required for day to day powering of the load.

Table1: Monthly average radiations on horizontal surface between 7 am to 6 pm

Units	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
W/m^2	186.01	234.58	305.36	320.81	273.53	185.71	130.46	190.31	217.96	276.81	245.09	191.15
Wh/m^2 /day	2046.2	2580.4	3359.04	3529.0	3008.9	2042.8	1435.0	2093.4	2397.6	3044.9	2696.0	2102.7

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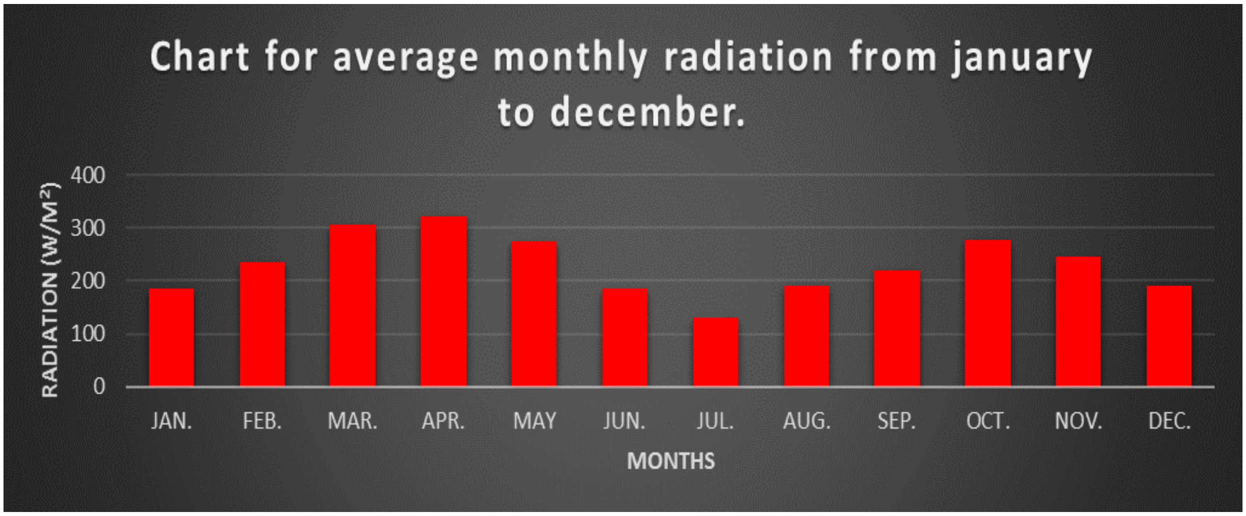

Figure 1: The average monthly solar radiation from January to December

The above Fig. 2 represents the average hourly radiation from 7 am to 6 pm and from 8 am to 5 pm for the month of July. The chart showed the sun rise to be around 7 am and get to its pick sometime around 1 pm, and gradually goes down around 6 pm. It is clear from the chart that our solar noon did not occur exactly at 12 noon but somewhere in between 12 pm and 1 pm and very close to 1 pm. Significantly, the sun came out around 7 am and set 12 hours later around 7 pm. This is a clear indication that our solar noon is near 1 pm (in between 12 pm and 1 pm).

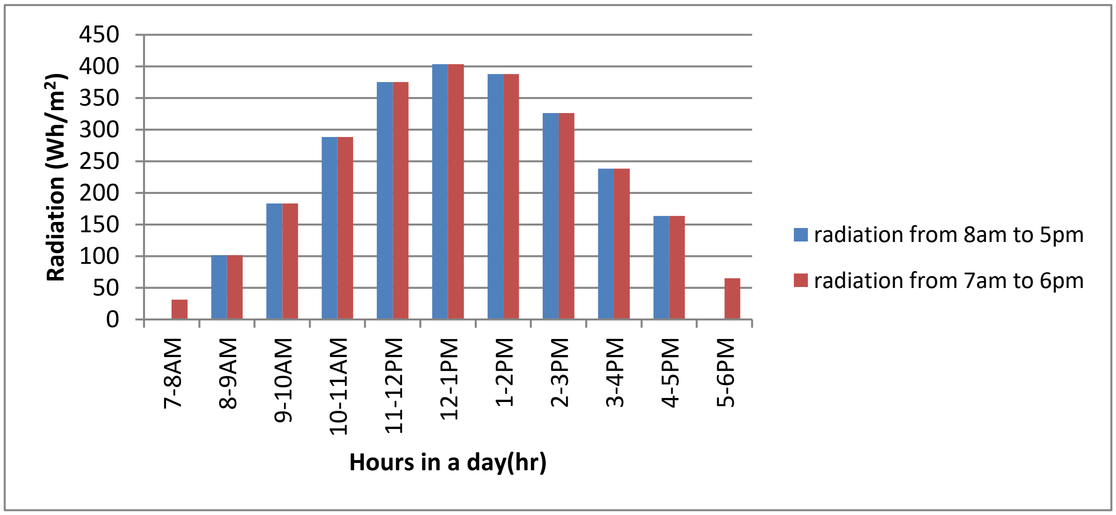

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Figure 2: The average hourly radiation for a year from 7AM to 6PM

Figure 3 showed that sun rise was not by 6 am in Lagos, this also buttressed the point that the solar noon in Lagos is not 12 noon but around 1 pm. Hence, energy loss for the solar radiation collected between 7 am to 7 pm is not significant compared with that of solar radiation collected between 6 am to 7 pm. If the sun rises around 7 am, it is expected to set 12 hours later; which is around 7 pm. In that case the solar noon is around 1pm.

To get the number of days of autonomy for the month of July (the worst month for solar radiation), the average solar radiation for the month of July was calculated. Table 1 presented the average daily solar radiation for the twelve months of the year. From table 1, the average daily solar radiation for the month of July (the worst month for solar radiation in a year) is 1435.0 Wh/m^2/day.

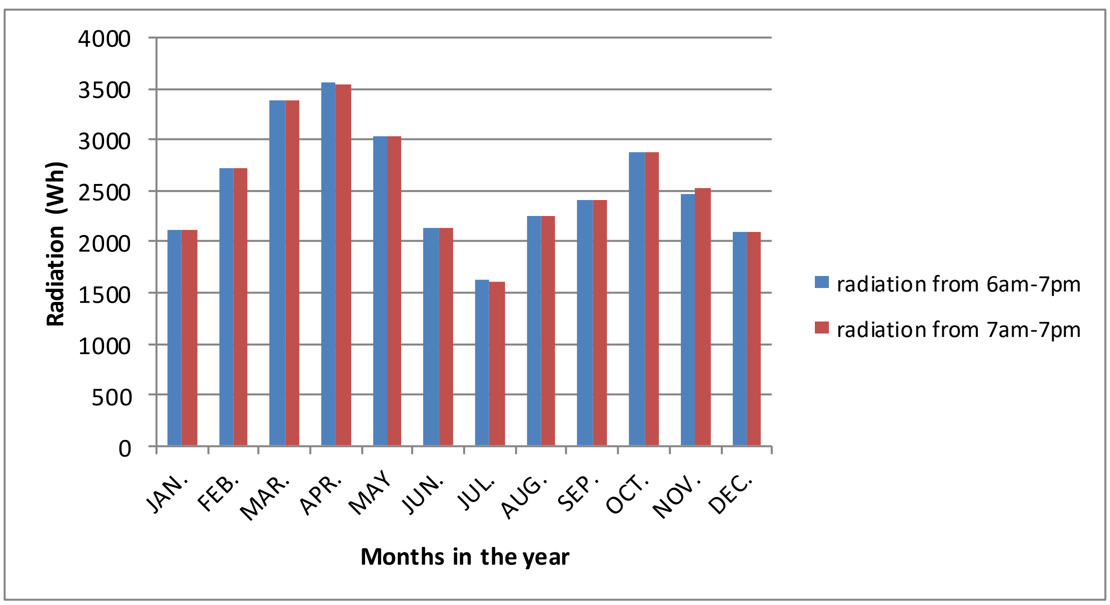

Figure 3: The average monthly radiation from 6 am to 7 pm and from 7 am to 6 pm

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The number of days in a roll that has a solar radiation less than 1435.0 Wh/m^2/day from days 5 to 9 in the same month (July) and also from day 11 in the month of July to day 15 in the same month is shown in figure 4. This indicates that the number of days of autonomy for the month of July is 5 (five) days. Since the month of July is the worst solar radiation month for the year, this number is chosen as the number of days of autonomy for battery sizing in the whole year at the site in question.

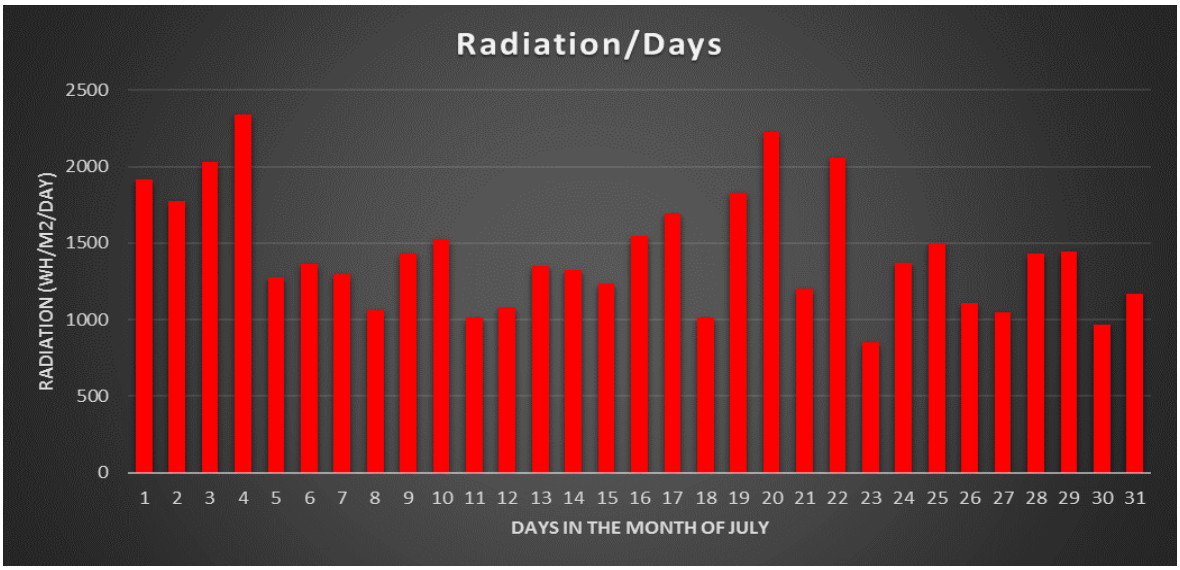

Figure 4: Average daily radiation for each day in the month of July (worst radiation month).

Conclusions

The month that offers the worst solar radiation in a year for Lagos (6.31^{o}N, 3.25^{o}E) is July. In sizing a PV system, this month will be used. Also, the number of days of autonomy for sizing a PV system in Lagos State, Nigeria is five (5) days. The sunrise hour in Lagos is around 7 am, while the sunset is around 7 pm. The solar noon is around 1 pm, as a result more loads should be channelled around this time to safeguard the life of the batteries.

References

Divya, K.C. and Ostergaard, J. (2009). Battery energy storage technology for power systems—*An overview, Electric Power system Research*, **79**, pp. 511–520.

Guda, H.A. and Aliyu, U.O. (2015). Design of a Stand-Alone Photovoltaic System for a Residence in Bauchi. *International Journal of Engineering and Technology*, **5**(1): pp.34-44.

Ishaq, M., Ibrahim, U.H. and Abubakar, H. (2013). Design of an Off-Grid Photovoltaic System: A Case Study of Government Technical College, Wudil, Kano State. *International Journal of Scientific & Technology Research* , **2**(12): pp. 175-181.

Karafil, A., Ozbay, H. and Kesler, M. (2016). Temperature and solar radiation effects on photovoltaic panel power. *Journal of New Results in Science*, **5**(12): 48-58.

Karafil, A. and Özbay, H. (2018). Design of Stand-Alone PV System on a Farm House in Bilecik City, Turkey. *El-Cezerî Journal of Science and Engineering*, **5**(3): pp.909-916.

Krishnan, R. S. and Sanukrishna, S.S. (2013). Modelling and Performance Optimization by Simulation of a Stand-alone Solar Photovoltaic system. *International Journal of Advanced Research*, **1** (6), pp. 346-355.

Li, C., Zhou, D., Yu, W., Wang, H., Zhu, D., Sun, M., Li, G. (2017). Performance of off-grid residential solar photovoltaic power systems using five solar tracking modes in Kunming, China. *International Journal of Hydrogen Energy*, **42**(10): pp. 6502-6510.

Manimekalai, P., Harikumar, R. and Raghavan, S. (2013). An Overview of Batteries for Photovoltaic (PV) System. *International Journal of Computer Applications*, **82**(12): pp. 28-32.

Modibbo, M. (2012). Improving Energy Access: Costs and Benefits of Solar PV in Nigeria. *An Article Published by The Mix: Oil and Water,* **33** (22) , 1898-1920.

Obot, N.I. and Chendo, M.A.C. (2010). Sizing of a stand Alone Photovoltaic system using rule of thumb. *Nigeria Journal of solar Energy*, **20**, pp.84-89.

Musa, I., Haruna, I. U. and Haruna, A. (2013). Design of an off grid photovoltaic system: A case study of government technical college, Wudil, Kano State", *International Journal of Scientific & Technology Research*, **2**(12): pp.175-181.

Rajeswari, R. L. and Bhanu, K. C. V. (2013). Design of Stand- Alone Photovoltaic System. *International Journal of Engineering Research and Applications* (IJERA). **3**(2), pp.510-515.

Woldehanna, F. (1998). The Generalised Reliability Approach for Array-Battery Sizing of Photovoltaic System. *Journal of EAEA*, **15**, pp. 35-39.

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