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Optimization of solar photovoltaic efficiency using angular inclination: Effect on voltage output

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Abstract. The physical optimization processes of maximizing the solar photovoltaic (PV) panel via the angular adjustment of PV inclination to the sun were examined. The efficiency may vary within geographic locations. In this study, the measured dataset of a location in the tropical region of Nigeria was examined with the inclination ranging from 0° to 45°. It was observed that at 30° in the south –east direction yielded a more stable result that is essential basically for the stability of the solid state content of the PV panel. Though there were spikes of higher voltage in the 30°, it is recommended that PV users in the region to adopt 30° to enhance efficiency and longevity of the PV panel.

Keywords: energy, solar, voltage output, solar energy, renewable energy

1. Introduction

Over the years, the need for the generation of power has given rise to various means of harnessing energy. The implementation of windmills, gas turbines, hydroelectricity and so much more have become answers to the provision of the highly sought power. The adoption of renewable energy in low-income countries is encouraging because energy source never gets depleted. A good example is solar energy -energy that never runs out, readily available as soon as the sun rises. The photovoltaic cells are a solar-based device that converts solar energy into electricity [1-2].

The use of solar power has spread so wide that it is now used as an alternative source of power in workplaces, schools and so on. It is used to power large areas via solar farms (an area also known as a power station where a large-scale photovoltaic system is designed to supply merchant power into the electricity grid). These solar farms need to be put under observation so that there are no fluctuations in the output power generated. Manually testing each panel to determine its efficiency can be very tedious, and this is where the essence of the data logger comes in. The data logger is designed to automatically detect the current and voltage a panel is generating under hot, cold or humid conditions and determines when the efficiency of a panel reduces by analysing its output current and voltage [3-4].

The photovoltaic effect is a process which, when exposed to sunlight, produces voltage or current in a photovoltaic cell. It is composed of solar cells or different semiconductors, the p - type and the n - type semiconductorare combined to create a p - n junction. By joining these semiconductors, in the junction region where electrons move to the p-side and holes move to the n-side, an electric field is formed. The field causes particles positively charged to move in one direction and particles negatively charged to move in the other. Light comprises of photons that are electromagnetic radiation quantities [5]. A solar cell can absorb these photons. In the p-n junction, energy from the photon is transferred to an atom of the semiconducting material when light of an appropriate wavelength is incident on these cells. This induces the electrons to jump to a higher state of energy called the conduction band. This leaves a "hole" behind in the valence band from which the electron jumped. Electrons hold the semiconducting material together when unexcited by forming bonds with surrounding atoms that disable their movement. However, these electrons are free to move through the material in their excited state in the conduction band. Electrons and holes move in the opposite direction because of the electrical field that exists as a result of the p-n junction. The freed electron tends to move to the n-side rather than being attracted to the p-side [6]. This electron motion creates in the cell an electrical current. There's a "hole" left after the electron moves. This hole can move as well, but it moves to the p-side instead of moving to the n-side. It is this process that creates a cell current.

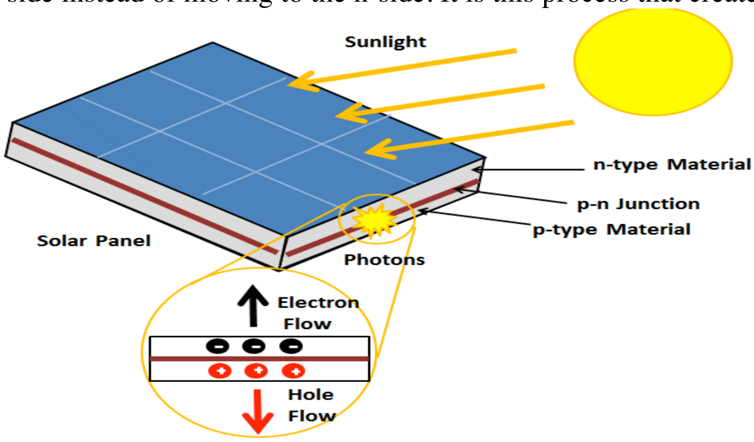

Figure 1: visual representation of the photovoltaic effect [7]

The focus of this study is to determine the best direction for optimal solar energy generation. From literature, we understand that the best direction is the south-east direction [8]. Hence, the angular inclination of the solar cell was investigated with the aim of determining the most stable voltage generation direction to elongate the lifespan of the PV panel.

2. Experimental Design, Materials and Methods

A manual logger was designed to measure the voltage and current simultaneously [3]. A polycrystalline 10V solar panel was used for the experiment. The PV panels were connected to the logger facing the south-east direction. The direction was determined using a GPS hand-held device. The angle of inclination was 0°, 30° and 45° as presented in figures 2-4 below. The dataset was processed using the MATLAB software.

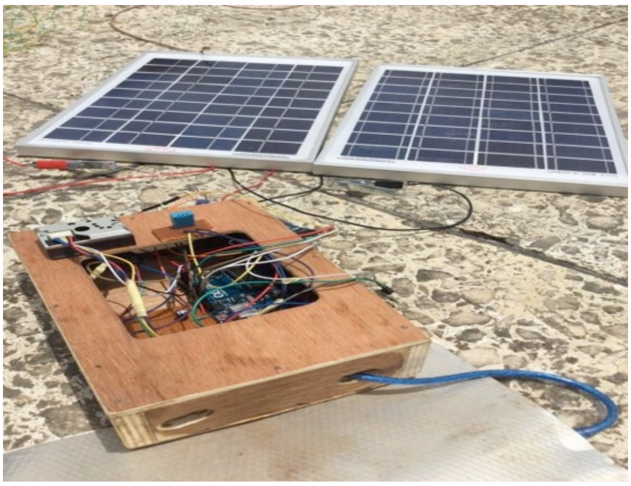

Figure 2: Condition 1 (0°)

Figure 3: Condition 2 (30°)

Figure 4: Condition 3 (45°)

3. Results and Discussion

The current versus time plot for 0° is presented in Figure 5. It is observed that the current generation was optimal at great part of the day. However, the current drop suggests that the solar radiation dropped.

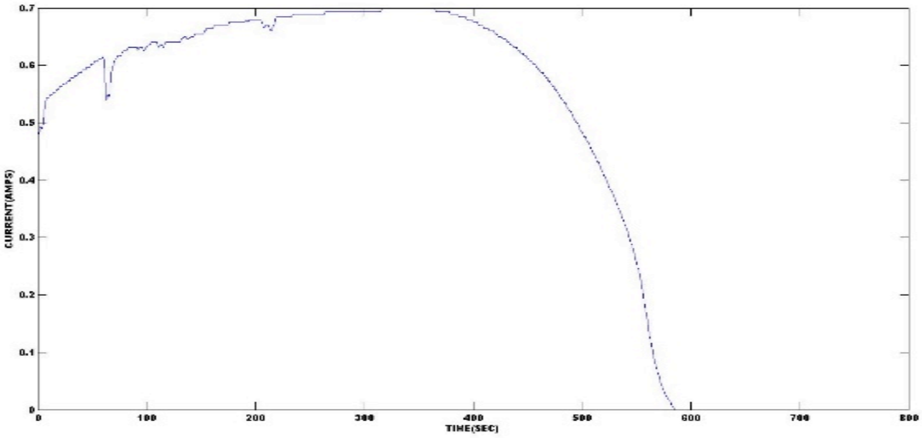

Figure 5: graph of current against time for 0°

The parabolic nature of the plot shows that current depreciates at higher time due to solar irradiance of the geographical region and the time of the day. The voltage generated is presented in Figure 6.

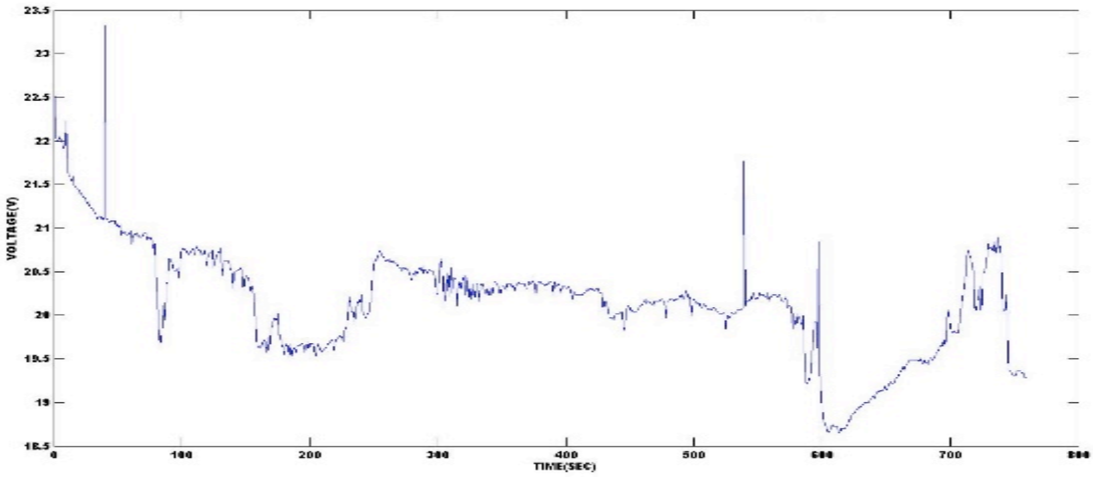

Figure 6: graph of voltage against time for 0°

The graph in Figure 6 shows the plot of voltage against time, the spectral nature of the graph simply shows the rise and fall in the voltage of the panel as affected by the rise and fall of solar irradiance. This scenario affects the solid-state arrangement of the PV panel [8].

The current versus time plot for 30° is presented in Figure 7 below. The graph in Figure 7 above shows the graph of time against current that exhibits a step sinusoidal form. The form taken by this graph indicates that at certain points in time, current was constant.

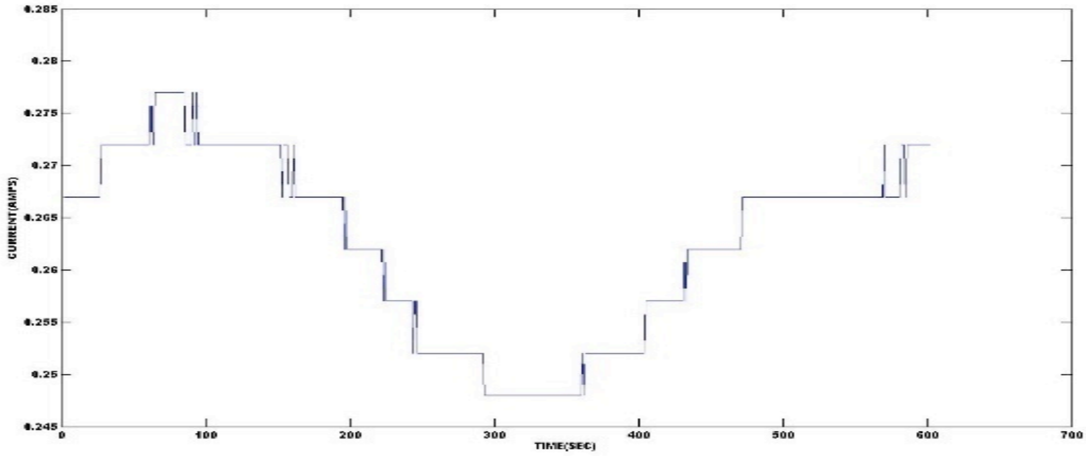

Figure 7: graph of current against time for 30°

The voltage generated is presented in Figure 8. This plot indicates that the voltage rises and drops considering factors such as solar irradiance, temperature of the panel and time of day. The voltage production was almost uniform for tewo-third of the experimentation time. This result is particularly interesting because the solid-state operation in the PV panel would not be over-burdened by abnormal excitations.

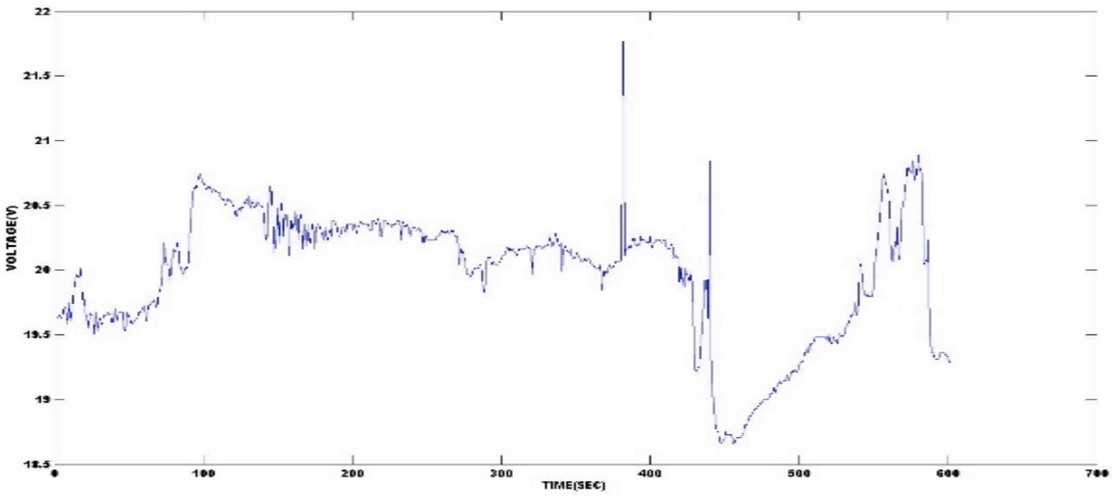

Figure 8: graph of voltage against time for 30°

The current versus time plot for 45° is presented in Figure 9. It shows the spectral form that explains that current rises and drops at certain points in time due to variations in solar irradiance.

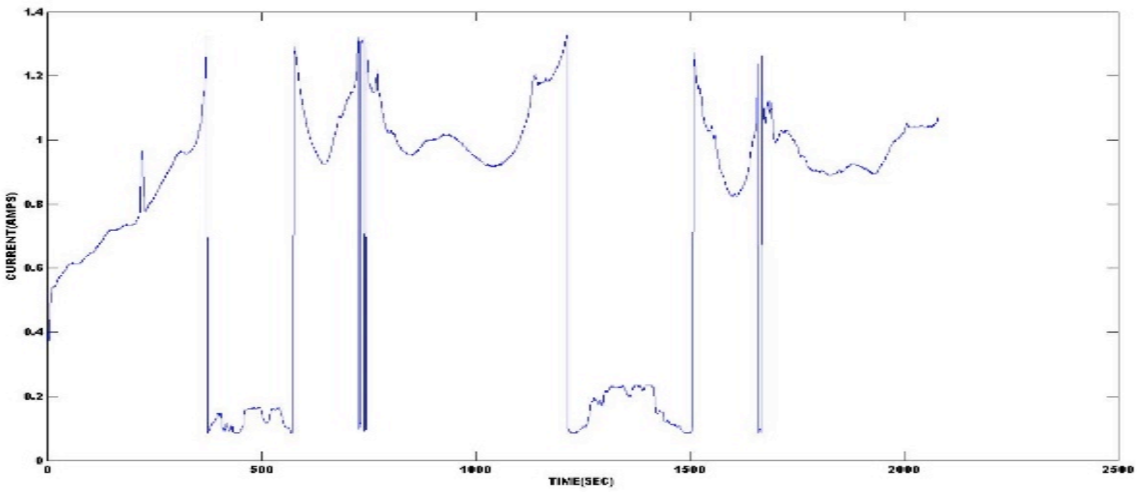

Figure 9: graph of current against time for 45°

This emerging current production, leads to the voltage production as presented in Figure 10. Aside that the spectral form of this graph indicates the rise and drop of the panel voltage as it reacts to solar irradiance, it is interesting to not that the abnormal voltage spikes is dangerous for the PV panel.

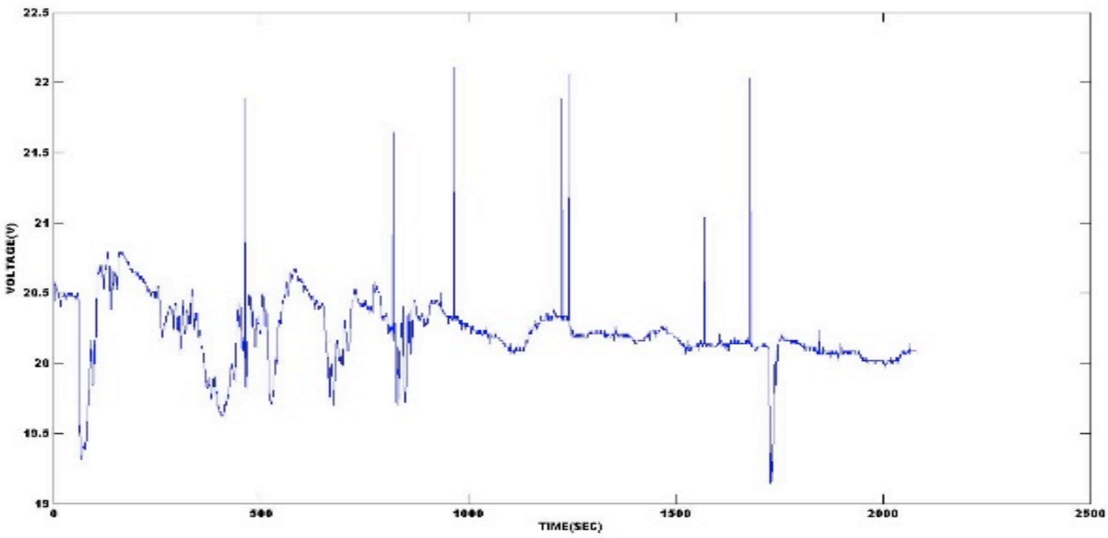

Figure 10: graph of voltage against time for 45°

4. Conclusion

From the experimentation, it was proven that the maximum voltage in a solar PV panel is not as important to the longevity of the panel. The efficiency of a solar panel should be measured with respect to the voltage stability and the duration of voltage stability. It was observed that at 30° in the south –east direction yielded a more stable result that is essential basically for the stability of the solid state content of the PV panel. Though there were spikes of higher voltage in the 30°, it is

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recommended that PV users in the region to adopt 30◦ to enhance efficiency and longevity of the PV panel.

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5. References

[1]. Moses E. Emetere, Marvel L. Akinyemi, and Etimbuk B. Edeghe, (2016). A Simple Technique for Sustaining Solar Energy Production in Active Convective Coastal Regions, International Journal of Photoenergy 2016, 3567502, 1-11, http://dx.doi.org/10.1155/2016/3567502
[2]. Emetere M.E., & Akinyemi M.L., (2015) Prospects of Solar Energy in the Coastal Areas of Nigeria, 2015 PIAMSEE: AIP Conference Proceedings, 1705 (1), 020035
[3]. K. N. Akposionu, and A. O. C Nwokoye (2012), Design and Fabrication of A Low-Cost Data Logger for Solar Energy Parameters, Journal of Energy Technologies and Policy, Vol.2, No.6, ISSN 2224-3232
[4]. Pratik Painjan, Rahul Nangare, Anupsing Pardeshu, "Design of Solar Insolation Level Detector and Data Logger", International Journal of Current Engineering and Technology E-ISSN 2277-4106, P-ISSN 2347-5161.
[5]. Cousera, https://www.coursera.org/lecture/solar-cells/semiconductors-udcqR (accessed 4/06/2019).
[6]. A.A.F. Husain, W.Z.W. Hasan, S. Shafie, M.N. Hamidon, S.S. Pandey, A review of transparent solar photovoltaic technologies, Renew. Sustain. Energy Rev., 94 (2018), pp. 779-791, 10.1016/j.rser.2018.06.031
[7]. Solar education (2012). https://energyeducation.ca/encyclopedia/Main_Page (accessed 4/06/2019).
[8]. M. Guo, H. Zang, S. Gao, T. Chen, J. Xiao, L. Cheng, Z. Wei, G. Sun, Optimal tilt angle and orientation of photovoltaic modules using HS algorithm in different climates of China, Appl. Sci., 7 (2017), p. 1028