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Experimental Evaluation of the Effect of Temperature on Polycrystalline and Monocrystalline Photovoltaic Modules

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Abstract:*This paper presents the evaluation of the effect of temperature on output power of polycrystalline and monocrystalline photovoltaic modules. This research was carried out by monitoring the variation in power output of the Photovoltaic (PV) modules with temperature of the chosen area in Nigeria during raining season. The results show that within the capacity of a photovoltaic panels, increase in temperature favours output current (i.e short circuit current I_{SC}) of the PV modules while temperatures greater than 42^0C do not favour high performance with the electrical efficiency of the PV modules also drops with the rise in temperature.*

Keywords:*Efficiency,monocrystalline, photovoltaic module, polycrystalline, temperature*

I. Introduction

With the increase in the use of solar panels in diverse sectors such as hospitals for cooling vaccines, institutions for cyber cafes (Information and Telecommunication Technology Unit), Laboratories as alternative source of energy, at homes and offices (as substitute for electric power failure). It is germane to know the effects of meteorological parameters such as relative humidity, temperature and light intensity on the stability of power generated from solar panels(PV modules). As the rate of energy consumption per capital has become a criterion of success in developing countries, providing the growing society with constant energy (Zafer*et al*., 2007). Fossil fuels reserves which provide the most part of energy sources of the world are limited and generally decreasing with environmental problems. The unsustainability of the present production-consumption energy model highlights the finite nature of conventional energy sources. The environmental degradation occasioned by the emission currently generated by the use of fossil fuels are the serious environmental problems, such as acid rain, greenhouse effect and ozone layer depletion, which in many cases are irreversible, (Dincar, 2003). Hence, the need to develop an efficient and safer means of generating energy.

Researches are ongoing for developing a more efficient way of producing energy from alternative sources which are harmless to the environment. Researchers have developed more efficient way of producing energy from alternative sources. The increasing use and promotion of renewable energy technologies such as biomass, wind, hydroelectricity solar thermal and solar electricity, seem to be a viable solution to environmental problem caused by other energy sources.

Solar energy is becoming more popular since sunlight is by far the largest carbon-free energy source on the planet. (El-Shaer,2014). Solar energy is one of the most promising renewable energy since it provides an unlimited, clean and environmentally friendly energy (Cuce E, *et. al.*, 2013). Having known this, solar energy cannot be used directly but needs to be converted into a usable form. The conversion of solar energy to electrical energy occurs by solar modules. Solar module is a collection of Photovoltaic cells, PV (solar cells) which is a device that converts the sunlight directly into direct current (DC) of electrical energy by the photovoltaic phenomena. The Si solar module among other various types of solar module devices was the first to be developed and is still the most widely used photovoltaic device, occupying more than 90% of the solar market nowadays. This is because of the advantages of the Si material over any other materials which include martial stability, high crystal quality, non-toxicity and lots more. Also, crystalline form has an almost ideal band gap for solar energy conversion, i.e. Eg=1.11 eV.

Photovoltaic, PV cells (solar cells)are devices which convert photons into electric potential in a Positive-Negative (PN) silicon junction (or other material). A PV cell is a basic unit that generates voltage in the range of 0.5 to 0.8 volts depending on the cell technology being used. Light of certain wavelengths is able to ionize the atoms in the silicon material and the internal field produced by the junction separates some of the positive charges (holes) from the negative charges (electrons) within the PV device. The holes are swept into the P-layer and the electrons are swept into N-layer. Although these opposite charges are attracted to each other, most of them can only recombine by passing through an external circuit outside the material because of the internal potential energy barrier. There are essentially 3 different types of PV Panels, Crystalline Silicon, Amorphous Silicon and other Thin Film technology PV Panels. Crystalline Silicon panels are the oldest, most reliable and highly efficient PV panels in the market today. Crystalline Panels can be further divided into Mono-Crystalline and Poly-Crystalline panels.

The purpose of this study is to experimentally investigate the effect of one of the meteorological parameters (Temperature) on the effective performance of PV modules to determine which type of the solar panels used for collecting solar insolation is more efficient.

II. Materials And Methods

The instruments used in this research are the T720 Digital Mutimeter for measuring the temperature, Reed CM-9930 200A True RMS AC/DC clamp meter for measuring the short circuit current (I_{sc}),1 monocrystalline photovoltaic module and 1 polycrystalline photovoltaic Module. The instruments used for this research work include 2 multimeters for measuring the ambient temperature and voltage, 1 clamp meter for measuring the current and 2 photovoltaic modules.

This research work was carried out at Owode area of Ogbomoso, Oyo state, Nigeria for a period of one month. The research work was performed by placing the monocrystalline and polycrystalline solar panels horizontally side by side on a specially designed stand of 2m height. A Multimeter was connected in series with each of the solar panels so as to take measurements of the maximum output voltage. Also, a clamp meter was connected in parallel to the solar panels so as to take measurements of the maximum current, I_{sc} when shunt occurs (at the point when the voltage is zero).

Secondly, the meteorological parameters, ambient temperatures were recorded. Data were collected at interval of 30 minutes between the hours of 9.00am to 3.00pm for a period of one month to ensure effective and accurate data record. The photovoltaic module and the meteorological sensors were placed on the same horizontal test plane at a height 2m facing the sun.

III. Results

Results showed that as the temperature increases, there is no significant effect on the open circuit voltage (Voc) of both photovoltaic modules, (Fig. 1 and 2). Also increase in temperature resulted to an increase in the short circuit current (Isc), (Fig. 3 and 4). Increase in the output power produced by both photovoltaic modules were recorded as the time of the day increases, but the peak was recorded for both photovoltaic modules between 11:00am and 1:30pm beyond which there is a drop in the output power produced, (Fig. 5 and 6).

Results showed that increase in temperature leads to increase in the output power of the photovoltaic modules but the peak values were recorded when the temperature was around 32°C - 42°C for monocrystalline photovoltaic module while the peak was recorded when the temperature was around 34°C - 39°C for polycrystalline photovoltaic module beyond these points, the output power begins to drop, (Fig. 7 and 8).

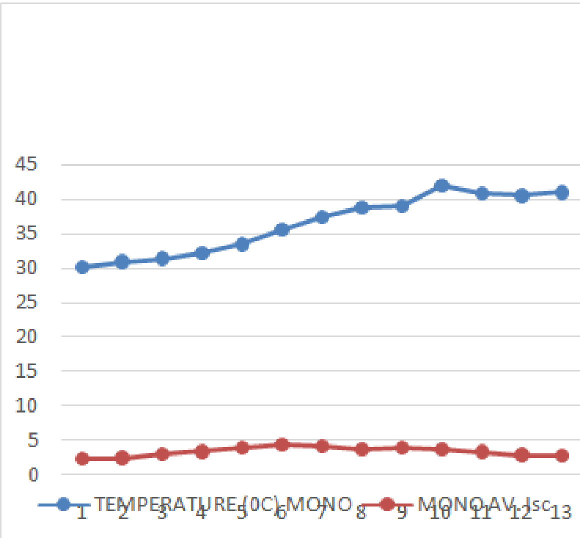


Fig.1: Temperature Against Output Voltage For Monocrystalline PV

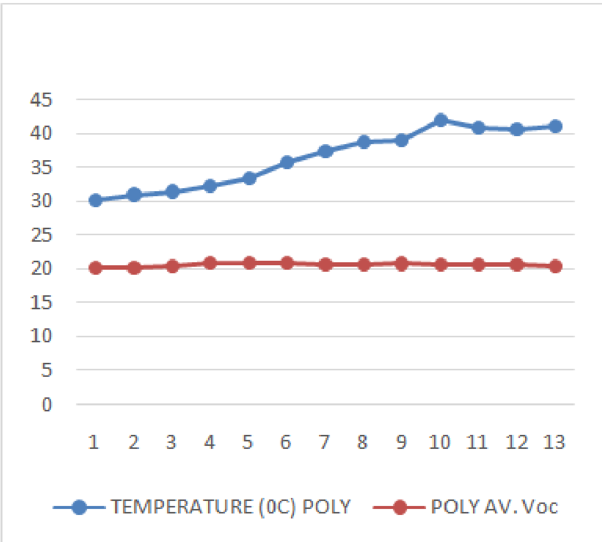


Fig.2: Temperature Against Output Voltage For Polycrystalline PV

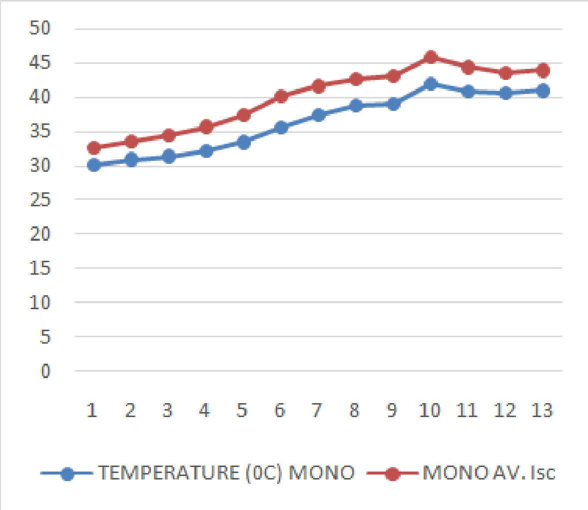


Fig 3: Temperature Against Current For Monocrystalline PV

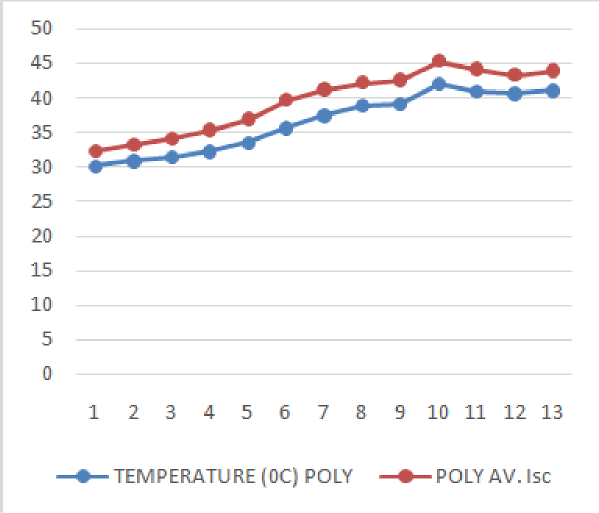


Fig 4: Temperature Against Current For polycrystalline PV

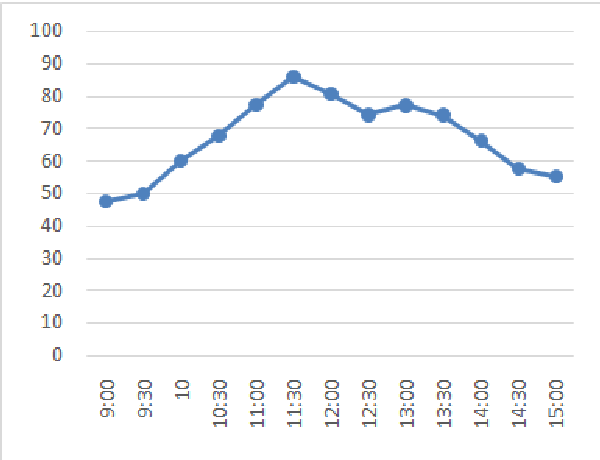


Fig 5: Output Power Against Time Of The Day for Monocrystalline PV

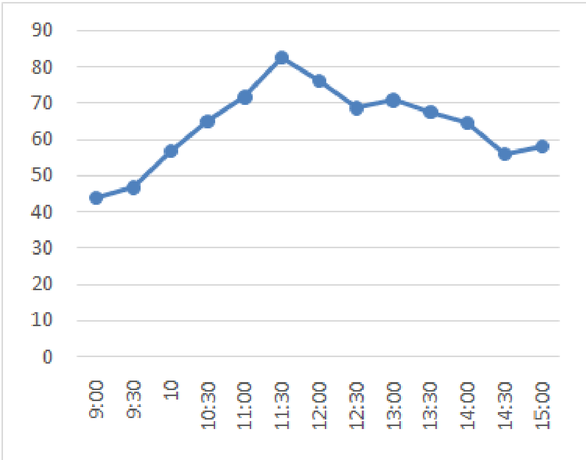


Fig 6: Output Power Against Time Of The Day forPolycrystalline PV

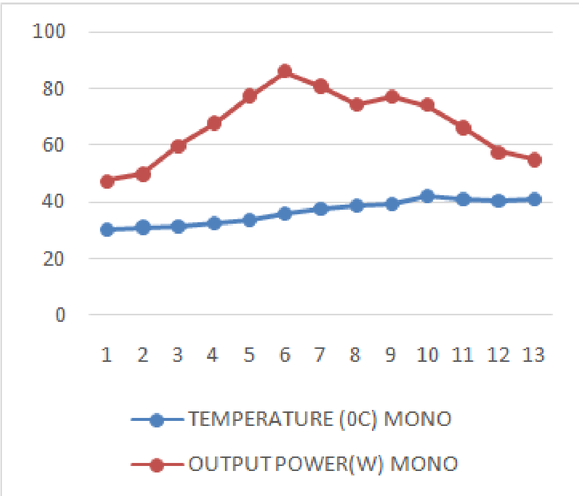


Fig 7: Variation Of Output Power With Temperature for Monocrystalline PV

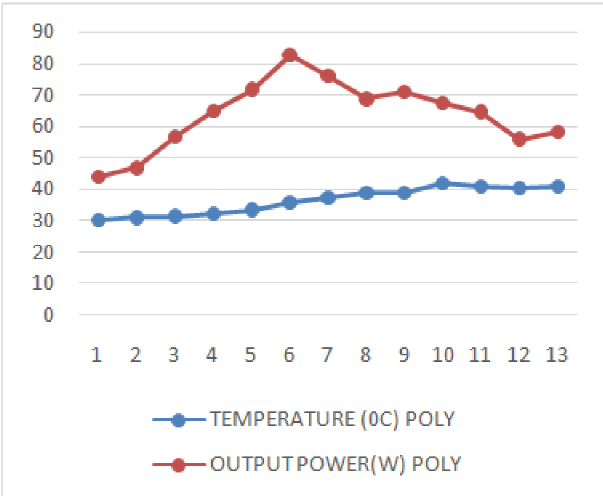
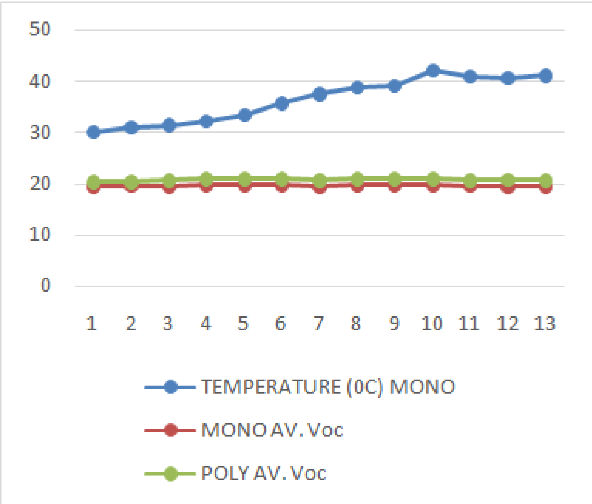


Fig 8: Variation In Output Power With Temperature for Polycrystalline PV

Comparing the two photovoltaic modules, it was shown from the results that even though there is no significant effect on the increase of voltage, the open circuit voltage (Voc) of polycrystalline photovoltaic module increases more with temperature than that of monocrystalline photovoltaic module, (Fig. 9). Fig. 10 shows that short circuit current (Isc) of monocrystalline photovoltaic module increases more than that of polycrystalline module as the temperature increases.

As shown in Fig. 11, results showed that the peak output power was recorded when the temperature was around 32^{o}C -42^{o}C for monocrystalline photovoltaic module while the peak was recorded when the temperature was around 34^{o}C -39^{o}C for polycrystalline photovoltaic module beyond these points, the output power begins to drop. Results showed that increase in temperature does not have a direct proportionality with increase in the output power of the photovoltaic modules but an increase was recorded when the temperature was around 32^{o}C -42^{o}C for monocrystalline photovoltaic module while the peak was recorded when the temperature was around 34^{o}C -39^{o}C for polycrystalline photovoltaic module beyond these points, the output power begins to drop, (Fig. 7 and 8).



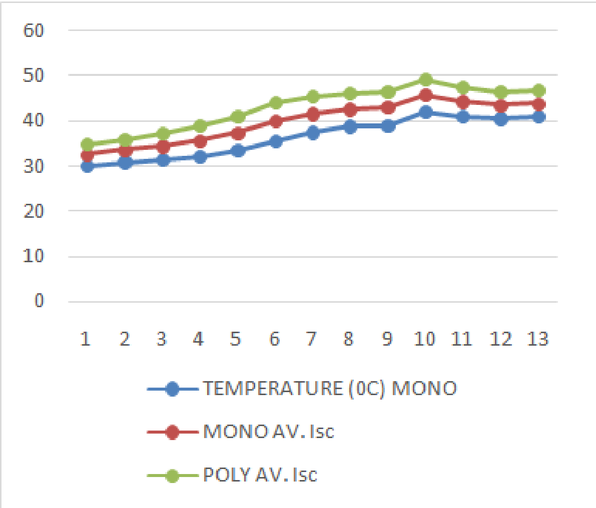


Fig 9: Comparison of Output Voltage And Temperature

Fig 10: Comparison of Maximum Current And Temperature

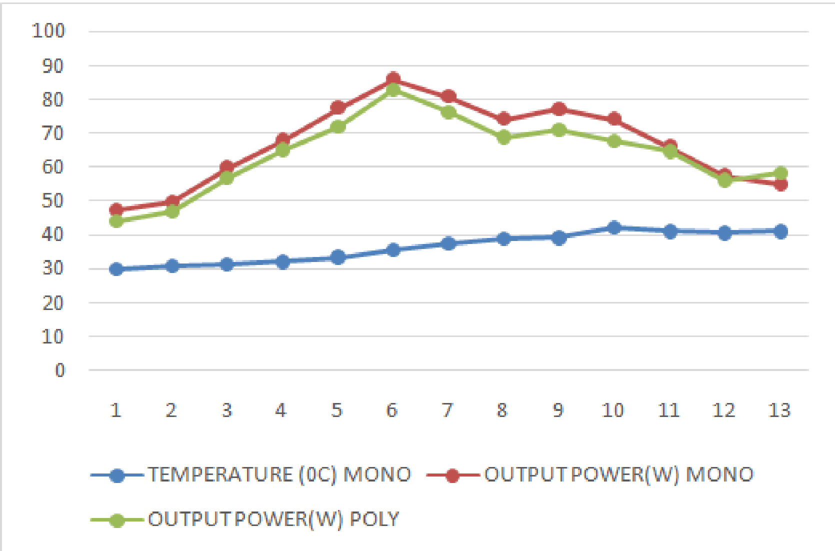


Fig 11: Comparison of Output Power with Temperature

IV. Discussion

This study presents the study of the evaluations of the effect of temperature on polycrystalline and monocrystalline photovoltaic modules. From our results, it was shown that as the temperature increases, there is no significant effect on the open circuit voltage (Voc) of both photovoltaic modules. The Voc increases slightly after which it becomes steady as it approaches the peak value. (Fig.1 and 2), this is in agreement with the result of Amajama and Mopta (2016) in effect of Air temperature on the Output of photovoltaic panels and its relationship with Solar illuminance/intensity where it was concluded that that the output voltage (or open circuit voltage) rises with increase in air temperature, but gradually get steady as the peak voltage is approached. However, in a research work titled Performance evaluation of polycrystalline solar photovoltaic module in weather conditions of Maiduguri, Nigeria by Mustapha *et al.*(2013), results showed that module voltage decreased by 0.05 Voc with increase in temperature. Also, our findings is not in agreement with Abdelkader*et al*. (2010), in their study of A comparative Analysis of the Performance of Monocrystalline and Multi-crystalline PV Cells in Semi Arid Climate Conditions: the Case of Jordan where they concluded that As the ambient temperature increases cell temperature increases, the open circuit voltage decreases.

The study shows that increase in temperature resulted to an increase in the short circuit current (Isc), (Fig. 3 and 4), this is in agreement with the result of Mustapha *et al.* (2013) in their research work titled Performance evaluation of polycrystalline solar photovoltaic module in weather conditions of Maiduguri Nigeria, where it was found out that module current increased by 0.1^{o}C with increase in temperature. Likewise in a study by Omubo-Pepple and Tamunobereton-ari (2013)on Influence of Meteorological Parameters on the Efficiency of Photovoltaic Module in some cities in the Niger Delta of Nigeria, resultsshowed that as the solar panel temperature increases so also the output current. Result by Abdelkader*et al*. (2010), in their study of A comparative Analysis of the Performance of Monocrystalline and Multiycrystalline PV Cells in Semi Arid Climate Conditions: the Case of Jordan also shows that As the ambient temperature increases cell temperature increases, the short circuit current become slightly higher to reach the maximum output current.

Further results in this study shows that increase in the output power produced by both photovoltaic modules were recorded as the time of the day increases, but the peak was recorded for both photovoltaic modules between 11:00am and 1:30pm beyond which there is a drop in the output power produced, (Fig. 5 and 6). This agrees with the conclusion made by Omubo-Pepple and Tamunobereton-ari (2013)on Influence of Meteorological Parameters on the Efficiency of Photovoltaic Module in some cities in the Niger Delta of Nigeria that time dependent efficiency with maximum efficiency recorded between 10am and 3pm of the day.

Results showed that increase in temperature leads to increase in the output power of the photovoltaic modules but the peak values were recorded when the temperature was around 32^{o}C - 42^{o}C for monocrystalline photovoltaic module while the peak was recorded when the temperature was around 34^{o}C - 39^{o}C for polycrystalline photovoltaic module beyond these points, the output power begins to drop, (Fig. 7 and 8). This was also reported by Mustapha *et al.* (2013) in their research work titled Performance evaluation of polycrystalline solar photovoltaic module in weather conditions of Maiduguri, Nigeria that power increased with increase in temperature.

V. Conclusion

Experimental evaluation of effects of temperature on polycrystalline and monocrystalline photovoltaic module was investigated. The result shows that within the capacity of a photovoltaic panel, increase in temperature favours output current (i.e short circuit current I_{SC}) and relatively has little or no effect on the voltage (i.e open circuit voltage V_{0C}). The results also shows that monocrystalline photovoltaic modules should be installed at a place where they receive temperature that ranges from 32^{o}C - 42^{o}C and polycrystalline photovoltaic modules should be installed at a place where the temperature received should be within the range of 34^{o}C - 39^{o}C less than 42^{0} to aid constant supply of high output power.

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