Optimization of solar photovoltaic efficiency using angular inclination: Effect on surface temperature distribution

Emetere M.E., and Adeyemo N.

1 Department of Physics, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria.
2 Department of Mechanical Engineering and Science, University of Johannesburg, APK, South Africa

E-mail: emetere@yahoo.com

Abstract. Temperature distribution over the surface of a solar photovoltaic (PV) panel is essential as over heating lowers the efficiency of the PV module. There have been multiple solutions towards cooling the PV surface during extremely hot sunshine. The mechanism is envisaged to be expensive to construct and maintain. In this research the PV panel was inclined at various degree to determine the best inclination that would allow convective cooling. It was observed that at an inclination of 45°, the convective cooling from surrounding wind was able to regulate the surface temperature. Hence, the sinusoidal trend of thermal heating was distorted significantly-signifying that the convective wind was able to mitigate the PV surface heating.

Keywords: energy, solar, temperature, solar energy, renewable energy

1. Introduction

Renewable energy serves as a source of clean and environmentally friendly energy to reduce the level of climate change and combat the anticipated scarcity of conventional energy. Solar energy offers one of the best alternative energy sources. The effect of energy as one of the key factors for economic growth and social development cannot be overemphasized. As a result, renewable energies that have the potential of providing the needed energy at little or no adverse effect to the environment are constantly being developed. Photovoltaic (PV) system (Figure 1) is one of the means of obtaining renewable energy [4]. Solar photovoltaic (PV) modules, a common type of solar energy utilization technology, which converts radiations from the sun into useable electricity, is widely in use due to its potential of providing clean and green energy continuously [3]. In 1839, Edmond Becquerel a French scientist discovered photovoltaic power. This has evolved through the years with a wide range of PV cell technologies and applications. The three generations of PV cell technologies based on the basic materials used are; crystalline silicon, thin film and concentrated photovoltaic and organic material [1]. Teo et al., [5] and Rahman et al., [6] reported that incident solar radiation on PV systems generates about 15 to 20% electrical energy and 75 to 80% thermal energy resulting in overheating of the PV system and a reduction in its efficiency. This is due to the fact that operating temperature affects the performance of a PV module even when other factors are controlled. Van et al., [7] reported that PV modules lose up to 7% power at higher temperatures due to decrease in voltage. Though increased solar intensity increases PV power, it decreases it’s efficiency due to the change in the temperature of the cells. Renewable energy target, that requires electricity retailers to source a certain proportion of the total electricity sale from renewable energy sources is currently 0% in...
Nigeria and the country aims for a 7% target by 2025 [2]. This research could provide a possible means of actualizing this target.

Researchers have proven that photovoltaic (PV) efficiency of solar cells is inversely proportional to their operating temperature [8-11]. Hence, the temperature distribution in a PV module will also give rise to thermal stresses within the module. In this research, we examine the influence of PV inclination on the temperature distribution on the PV module.

2. Experimental Design, Materials and Methods
A manual logger was designed to measure the temperature and current simultaneously [12]. 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 1: Typical photovoltaic system

Figure 2: Condition 1 (0°)
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. It is observed that the sinusoidal pattern which depicts high concentration of heat on the surface of the PV panel (Figure 6) allows the current production drop.
Figure 5: graph of current against time for 0°

Figure 6: graph of temperature against time for 0°

The graph in figure 6 shows a step sinusoidal plot of time against temperature. Temperature changes with time but is constant at certain point for a little period of time before it changes again hence the step form. The current production of the PV module describes a stepwise negative parabola (Figure 7) that makes it clear that the temperature distribution (Figure 8) produces high heat energy. 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. The step sinusoidal form of the graph in figure 8 indicates the variation in temperature and points in time at which the temperature remained constant for a short period of time. Figure 9 shows that the PV inclination supports the convective wind system to cool the surface of the PV panel (Figure 10).
Figure 7: graph of current against time for 30°

Figure 8: graph of temperature against time for 30°

Figure 9: graph of current against time for 45°
Figure 10: graph of temperature against time for 45°

4. Conclusion

From the experimentation, it was proven that temperature distribution had significant influence on the current production of the solar PV panel. The solar collapse at high temperatures hence the need for PV cooling in extreme weather. It was observed that at an inclination of 45°, the convective cooling from surrounding wind was able to regulate the surface temperature. Hence, the sinusoidal trend of thermal heating was distorted significantly-signifying that the convective wind was able to mitigate the PV surface heating.

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