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Effect of Air temperature on the Output of photovoltaic panels and its relationship with Solar illuminance/intensity

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Abstract
The effect of air temperature on a photovoltaic panel's outputs and its relationship with solar illuminance/intensity has been established with some mathematical models. Experiments conducted show that within the capacity of a photovoltaic panel, air temperature favours outputs. For the current, the output builds up rapidly with increasing illuminance/intensity at beginning and afterwards but slowly towards the ending. Further increment in illuminance after exceeding the capacity of the photovoltaic panel may reduce the efficiency of the output current, due to irregular motion of extracted and excited electrons (holes). This irregular motion, results in collision and reduction of drift speed. However, for voltage it builds up to a maximum with increasing illuminance until it reaches its peak and stagnates afterwards. Illuminace/intensity of solar radiation favours the extraction and excitation of electrons (holes) and it is accompanied by heat, giving rise to increase in air temperature (illumination/intensity is a function of temperature).

Keywords: *Effect, Air temperature, Output, Photovoltaic panel, Solar illuminance/intensity.*

1. Introduction

In the world today, there is a climatic change resulting in an unfriendly globe due to some harmful human activities. More so, now more than ever before there is a greater demand for power. Nearly every technological apparatus requires power for its optimal performance. Old harmful/hardazous/ecoenemy power technologies today are folding up due to their devastating byproducts e.g. nuclear power, geothermal and gas power generating technologies [1].

Today, friends of the globe are seeking renewable, safe and even low cost efficient technologies to generate power. Every hour new power technologies are innovated in our scientific universe. Most of these technologies are for small or medium power production, to solve perenial power problem. One of the renewable and safest technologies of producing power is solar power technology using solar panels constituted of solar solar cells [1].

Solar cells convert sunlight into energy due to the photovoltaic effect. These cells are made from photovoltaic semiconductor materials. These semiconductor materials behave as insulators under normal conditions but become conductors of electricity when exposed to light. The common types of solar cells are: *Monocrystalline* solar cells which have high power output efficiency but are difficult to produce and expensive. *Polycrystalline* solar cells which have a lower production cost and are therefore less expensive but they are less efficient due to inherent crystalline defects. *Amorphous* solar cells ?which have lower production costs than the other 2 types mentioned above. However the power output efficiency is also the lowest amongst these three types of cells. Solar energy is a clean and environment friendly way of generating power. The generation of solar power does not cause any pollution to the atmosphere. It also does not result in deforestation nor does it drain the earth of its natural resources [2].

Solar energy in one form or another is the source of nearly all energy on the earth. Humans, like all other animals and plants, rely on the sun for warmth and food. However, people also harness the sun's energy in many other different ways. For example, fossil fuels, plant matter from a past geological age, is used for transportation and electricity generation and is essentially just stored solar energy from millions of years ago. Similarly, biomass converts the sun's energy into a fuel, which can then be used for heat, transport or electricity. Wind energy, used for hundred of years to provide mechanical energy or for transportation, uses air currents that are created by solar heated air and the rotation of the earth. Today wind turbines convert wind power into electricity as well as its traditional uses. Even hydroelectricity is derived from the sun. Hydropower depends on the evaporation of water by the sun, and its subsequent return to the Earth as rain to provide water in dams. Photovoltaics (often abbreviated as PV) is a simple and elegant method of harnessing the sun's energy. PV devices (solar cells) are unique in that they directly convert the incident solar radiation into electricity, with no noise, pollution or moving parts, making them robust, reliable and long lasting. Solar cells are based on the same principles and materials behind the communications and computer revolutions, and this CDROM covers the operation, use and applications of photovoltaic devices and systems [3].

Like all other semiconductor devices, solar cells are sensitive to temperature. Increases in temperature reduce the band gap of a semiconductor, thereby affecting most of the semiconductor material parameters. The decrease in the band gap of a semiconductor with increasing temperature can be viewed as increasing the energy of the electrons in the material. Lower energy is therefore needed to break the bond. In the bond model of a semiconductor band gap, reduction in the bond energy also reduces the band gap. Therefore increasing the temperature reduces the band gap. In a solar cell, the parameter most affected by an increase in temperature is the open-circuit voltage. The open-circuit voltage decreases with temperature because of the temperature dependence of the output current. Also, The short-circuit current, increases slightly with temperature, since the band gap energy, decreases and more photons have enough energy to create electron-hole pairs [4], [5].

Air temperature is one of the major weather parameters and it is majorly a function of the intensity of the sun. The search light of this research is condensed on the air temperature effect on solar panels, since temperature has a bearing on the performance of solar cells and weather as well has some force on electromagnetic waves (solar radiations).

2. Methodology

The four major weather parameters: air temperature, air pressure, relative humidity and wind speed and direction were measured intermittently in the course of daylight and simultaneously with solar illuminace/intensity and output voltage and output current of the photovoltaic panel.

The photovoltaic panel is the mono-crystalline cell type with 1.5 W, 12V rating. The dimension of the photovoltaic plate, excluding the metallic frame of the panel is 45 cm by 14.5 cm. The panel was mounted on a platform of about 105 cm and exposed to direct sunlight. The outputs of the photovoltaic panel (current and voltage) were measured with the aid of a multi-metre and the solar illuminance/intensity was measured with a Digital Illuminance Meter (DT-1309 model).

3. Results and Analysis

After measurements, the results are as expressed graphically in Figs. 1, 2, 3, 4, 5, 6, 7 and 8. Figs. 1 and 2 show Output current versus Air temperature at near constant Air pressure, Relative humidity and Wind direction (exception of speed) and Output current versus Air temperature at non-constant Air pressure, Relative humidity and Wind speed and direction in sequence. Figs. 3 and 4 show Output voltage versus Air temperature at constant Air pressure, Relative humidity and Wind direction (exception of speed) and Output voltage versus Air temperature at non-constant Air pressure, Relative humidity and Wind direction speed in that order. Figs. 5 and 6 show Solar Illuminance/Intensity versus Air temperature at constant Air pressure, Relative humidity and Wind direction and Solar Illuminance/Intensity versus Air temperature at non-constant Air pressure, Relative humidity and Wind direction respectively. Finally, Figs. 7 and 8 show Output voltage versus Solar Illuminance/Intensity at near constant Air pressure, Relative humidity and wind direction and Output voltage versus Solar Illuminance/Intensity at non-constant Air pressure, Relative humidity and wind direction.

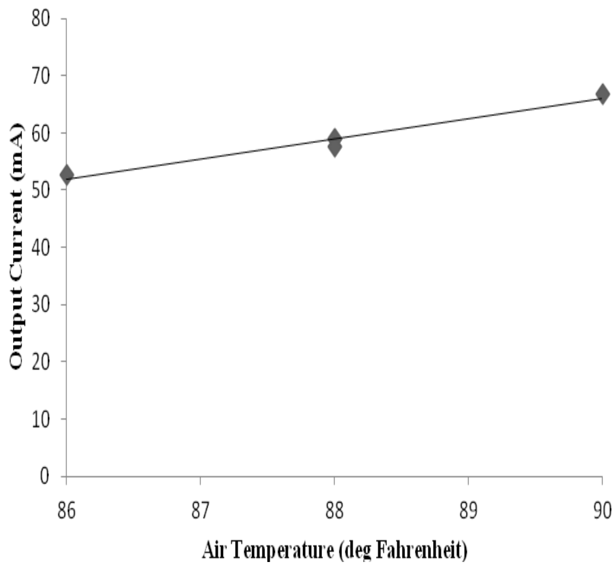

Fig. 1 Output current versus Air temperature at near constant Air pressure (29.88 ± 0.3 inHg), Relative humidity (70 %), Wind speed (7 ± 2 mph), Wind direction (WSW) and Solar illuminance/intensity (15 ± 3 Klux)

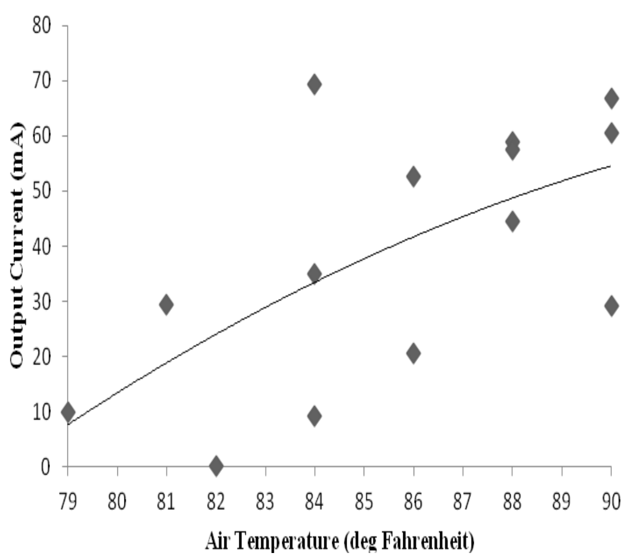

Fig. 2: Output current versus Air temperature at non-constant Air pressure, Relative humidity and Wind speed and direction

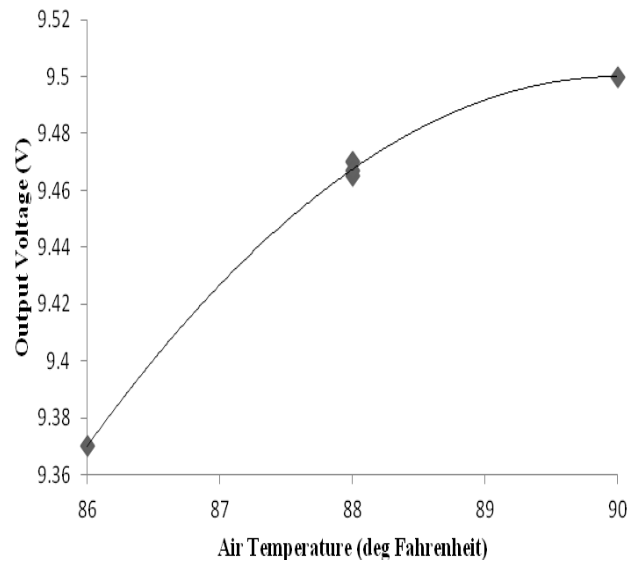

Fig. 3: Output voltage versus Air temperature at near constant Air pressure (29.88 ± 0.3 inHg), Relative humidity (70 %), Wind speed (7 ± 2 mph),Wind direction (WSW) and Solar illuminance/intensity (15 ± 3 Klux)

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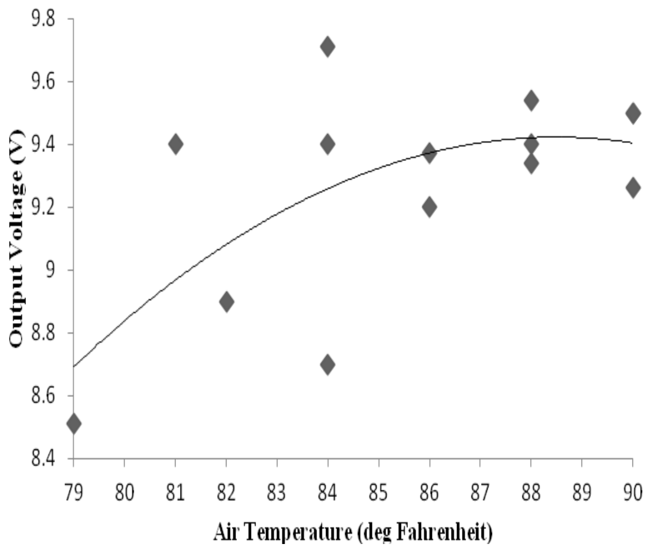

Fig. 4: Output voltage versus Air temperature at non-constant Air pressure, Relative humidity and Wind direction speed

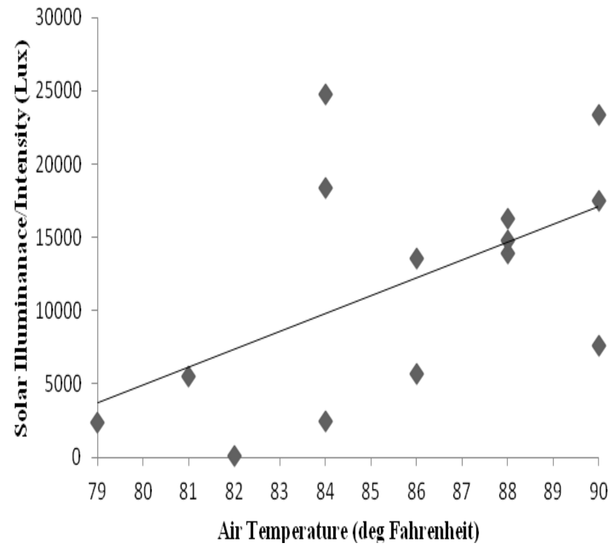

Fig. 6: Solar Illuminance/Intensity versus Air temperature at non-constant Air pressure, Relative humidity and Wind direction

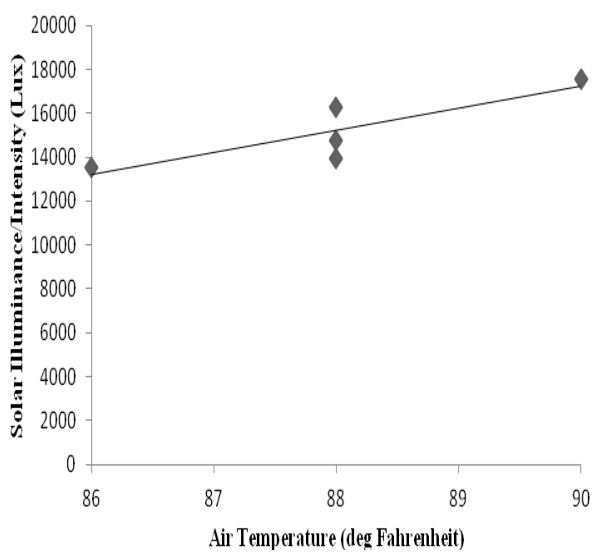

Fig. 5: Solar Illuminance/Intensity versus Air temperature at near constant Air pressure (29.88 $\pm$ 0.3 inHg), Relative humidity (70 %), Wind speed (7 $\pm$ 2 mph) and Wind direction (WSW)

Fig. 1 shows that output current (or short circuit current) rises with increase in air temperature, since temperature reduces the band gap energy. The steepness of the slope decreases with increase in air temperature, in other words, there is a gradual depreciation in the rise of output current with appreciation in air temperature. However, to some extent beyond the capacity of the photovoltaic panel, increment in air temperature becomes detrimental, due to randomized flow of electrons (or holes); leading to excessive collision and reduction in drift velocity, invariably current. Solar radiations are energetic particles; it is difficult to separate them from the heat they convey that rises the air temperature. Also, Fig. 2 buttresses the phenomenon above, despite not bringing to account the other weather parameters: air pressure, relative humidity and wind. The graph shows that there is a gradual increase in the output current with increase in air temperature. A point worthy of note is that a higher amount of solar radiation will generate more heat, hence rises the air temperature.

Fig. 3 shows that the output voltage (or open circuit voltage) rises with increase in air temperature, but gradually get steady as the peak voltage is approached. The shape of the curve is logarithmic. Similarly fig. 4 establishes the erection above, since despite non-consideration to the other major weather parameters: air pressure, relative humidity and wind, the same result was replicated.

Fig. 5 shows that air temperature rises with illuminance (or intensity) at constant air pressure, relative humidity and wind direction. Also Fig. 6 result parallels that of fig. 5 despite not bringing to bear the aforementioned weather parameters. As earlier highlighted, the energy of the radiations from the sun is in the form of heat. It is absorbed by the air around which results in rise in air temperature. The higher the rain of radiations from the sun: the higher the illuminance; the higher the intensity; and the higher the air temperature.

4. Conclusions

The better your paper looks, the better the Journal looks. Thanks for your cooperation and contribution. This study has shown that within the capacity of a photovoltaic panel, air temperature favours output current and voltage (i.e short circuit current and open circuit voltage). For current, the output builds up rapidly with increasing illuminance/intensity at beginning and afterwards but slowly towards the ending. Further increment in illuminance after exceeding the capacity of the photovoltaic panel may reduce the efficiency of the output current, due to irregular motion of extracted and excited electrons (holes). This irregular motion, results in collision and reduction of drift speed. Current is a regular flow of electrons or (holes) and the flow speed enhance it. However, for voltage it builds up to a maximum with increasing illuminance until it reaches its peak and stagnates afterwards.

Illuminace/intensity of solar radiation favours the extraction and excitation of electrons (holes) and it is accompanied by heat, giving rise to increase in air temperature. Some literatures have reported that temperature (or air temperature) is not favourable to photovoltaic panel output, but solar illumination or intensity does. They opine that a cool and sunny day will favour photovoltaic panel output. This is quite untrue, since solar radiations are energetic and convey energy in the form of heat, resulting in rise air temperature. The amount solar radiation raining or level of illuminance/intensity determines whether a day is sunny or not. This research has shown that increase in illumination/intensity is a function of temperature. It is difficult to have a cold sunny day. None the less, the humidity of the atmosphere may affect absorption and reflection of terrestrial/infrared radiations back into space, resulting in some slight difference in temperature on a sunny day.

The following models were deduced: $(IV)^2 = KT$ where I is the Output current (short circuit current), V is the Output voltage (open circuit voltage), T is the Air temperature and K is a constant: under the condition that solar illuminance/intensity, air pressure, relative humidity, wind speed and direction are constant and the output capacity of the photovoltaic panel is not exceeded and $L = KT$, where L is the solar illuminance/intensity, T is the atmospheric temperature and K is constant: under the condition that air pressure, relative humidity, wind speed and direction are constant and the output capacity of the photovoltaic panel is not exceeded.

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