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Effect of Air Pressure on the Output of Photovoltaic Panel and Solar Illuminance (or Intensity)

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Abstract
Experiments to probe and draw a verdict on the effect of air pressure on the output of photovoltaic panel and solar illuminance/intensity have been done. 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 (or open circuit voltage) and output current (or short circuit current) of the photovoltaic panel. Data analysis spells that solar illuminance/intensity, output current and voltage rise with increase in air pressure. The verdict is justifiable by the phenomenon that air pressure is the pressure exerted by the weight of air in the atmosphere of Earth, and it is proportional to the gravitational force. This force increases with decrease in altitude and exerts more downward pull on the particles of radiations from the sun as they fall and consequently it rises the solar illuminance/intensity and simultaneously the output current and output voltage.

Keywords: *Effect, Air pressure, Photovoltaic panel, Solar illuminance, Solar intensity.*

1. Introduction

Air pressure, sometimes also called barometric pressure, is the pressure exerted by the weight of air in the atmosphere of Earth (or that of another planet) [1] [2]. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point. Low-pressure areas have less atmospheric mass above their location, whereas high-pressure areas have more atmospheric mass above their location. Likewise, as elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure decreases with increasing elevation [2].

Also, air pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. The pressure at a point increases as the weight of the air above it increases. Thinking in terms of air molecules, if the number of air molecules above a surface increases, there are more molecules to exert a force on that surface and consequently, the pressure increases [3]. The opposite is also true, where a reduction in the number of air molecules above a surface will result in a decrease in pressure. Atmospheric pressure is measured with an instrument called a "barometer", which is why atmospheric pressure is also referred to as barometric pressure [3]. The common units of air pressure are: inches of mercury (inHg), atmospheres (atm), kilopascals (kPa) and millibars (mb). 29.92 inHg is equivalent to 1 atm and equivalent to 101.325 kPa with 1013.25 mb. In aviation and television weather reports, pressure is given in inches of mercury ("Hg), while meteorologists use millibars (mb), the unit of pressure found on weather maps [3].

The number of air molecules above a surface changes as the height of the surface above the ground changes [4]. For example, there are fewer air molecules above the 50 kilometer (km) surface than are found above the 12 km surface. Since the number of air molecules above a surface decreases with height, pressure likewise decreases with height. Most of the atmosphere's molecules are held close to the earth's surface by gravity [4]. Because of this, air pressure decreases rapidly at first, then more slowly at higher levels. Since more than half of the atmosphere's molecules are located below an altitude of 5.5 km, atmospheric pressure decreases roughly 50% (to around 500 mb) within the lowest 5.5 km. Above 5.5 km, the pressure continues to decrease, but at an increasingly slower rate (to about 1 mb at 50 km) [4].

The height of a given pressure surface above the ground varies with temperature. As an example, consider two identical columns of air (A and B). Since they are identical, the 500 mb surface is found at the same height in each column. Cooling column A and heating column B changes the height of the 500 mb surface in each column. Since colder air contracts, the height of the 500 mb surface in column A decreases, while in column B, the warm air expands, raising the height of the 500 mb surface. Therefore, where the temperatures are colder, a given pressure surface will have a lower height than if the same pressure surface was located in warmer air [5].

The principal science behind photovoltaic cell power technology is photo electricity. The photoelectric effect is the emission of electrons from matter upon the absorption of electromagnetic radiation, such as ultraviolet radiation or x-rays. Upon exposing a metallic surface to electromagnetic radiation that is above the threshold frequency or threshold wavelength (which is specific to the type of surface and material), the photons are absorbed and current is produced. Upon exposing a conducting or semiconducting surface to electromagnetic radiation that is above the threshold frequency or threshold wavelength (which is specific to the type of surface and material), the photons are absorbed and current is produced. This kind of current is called photo current [6]. No electrons are emitted for radiation with a frequency below that of the threshold, as the electrons are unable to gain sufficient energy to overcome the electrostatic barrier presented by the termination of the crystalline surface [6]. By conservation of energy, the energy of the photon is absorbed by the electron and, if sufficient, the electron can escape from the material with a finite kinetic energy. A single photon can only eject a single electron, as the energy of one photon may only be absorbed by one electron. The electrons that are emitted are often termed photoelectrons [6].

Photovoltaic cell power technology uses solar radiations. Solar radiation is radiant energy emitted by the sun, particularly electromagnetic energy (in the form of particles and waves). About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum [7]. Electromagnetic radiation can be considered to be a stream of photons; radiant energy can be viewed as the energy carried by these photons [8].

As earlier highlighted, the amount of photon determines the amount of electrons extracted and excited and invariably, the photo current. The weather affects the amount of these solar radiations comprising rivers (or streams) of photons that hit the earth surface. The air pressure is one component of weather that may likely affect this solar radiation amount. This paper probes and reaches a verdict on the effect of air pressure on photovoltaic cells' output and solar illuminance or intensity.

Result from experiment on radio waves against atmospheric pressure indicates that: the strength of the radio wave as it propagates through the atmosphere is inversely proportional to the air pressure [9]. This is because, the air pressure from the weight of the air pull down the particles that compose the radio wave. In other words, with distance away from a transmitter, these particles of radio waves fall under gravity as they propagate through the earth's atmosphere and reduce radio wave or signal strength. As stated above, we want to verify the impact of the particles of solar radiation or photons (or solar partickles) from the sun.

2. Experiment, Result and Analysis

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 a 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 (short circuit currenr and open circuit 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).

Figs. 1 to 5 show results obtained from the experiment.

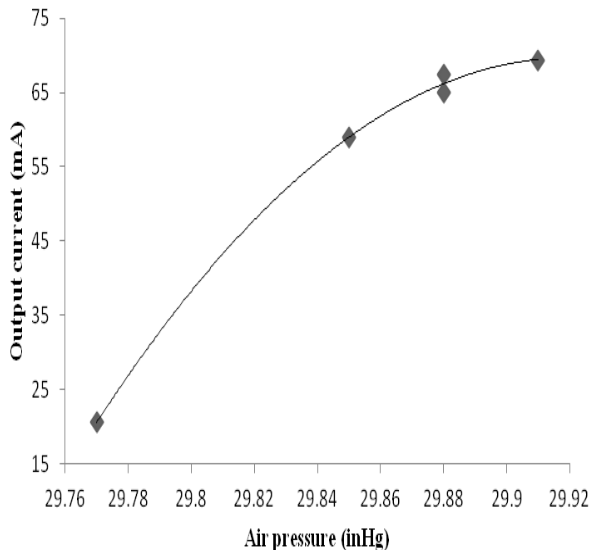

Fig. 1: Air pressure against Output current at near uniform air temperature: 72 ± 2 ^{0}F, relative humidity: 72 ± % , wind direction: WSW, wind speed: 7.5 ± 2.5 mph and solar illuminance/intensity

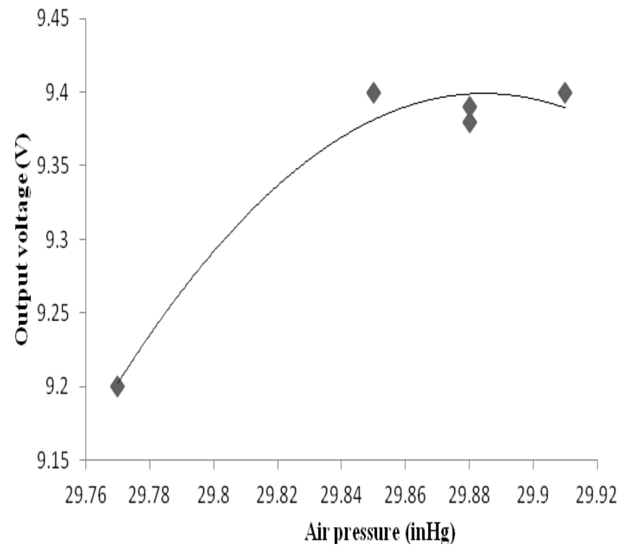

Fig. 3: Air pressure against Output voltage near uniform air temperature: 72 ± 2 ^{0}F, relative humidity: 72 ± %, wind direction: WSW, wind speed 7.5 ± 2.5 mph and solar illuminance/intensity

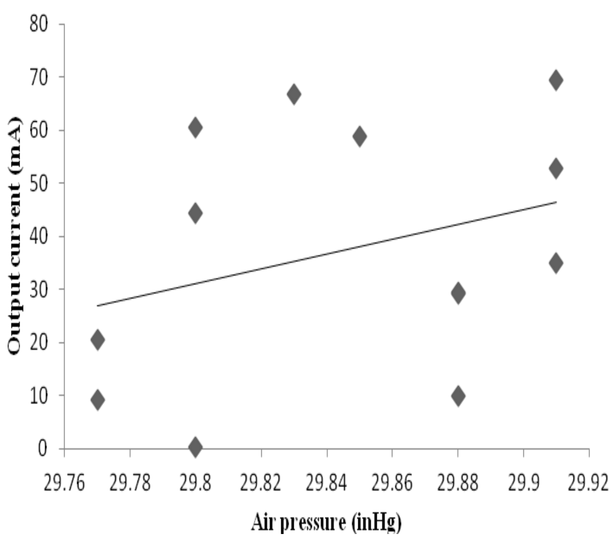

Fig. 2: Air pressure against Output current regardless of air temperature, relative humidity, wind direction (excluding speed) and solar illuminance/intensity uniformity

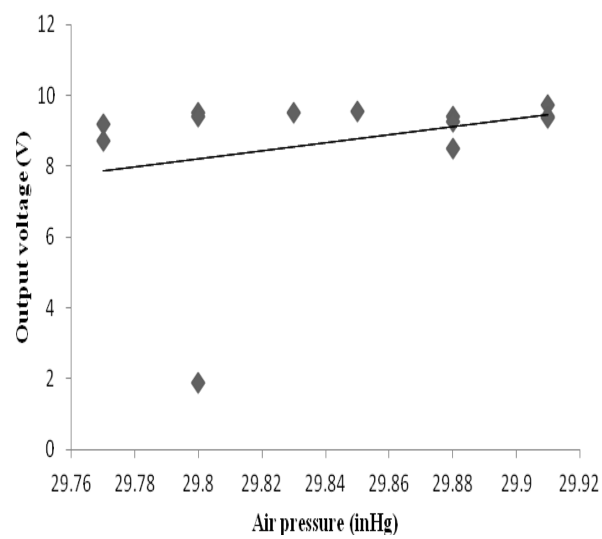

Fig. 4: Air pressure against Output voltage regardless of air temperature, relative humidity, wind direction (excluding speed) and solar illuminance/intensity

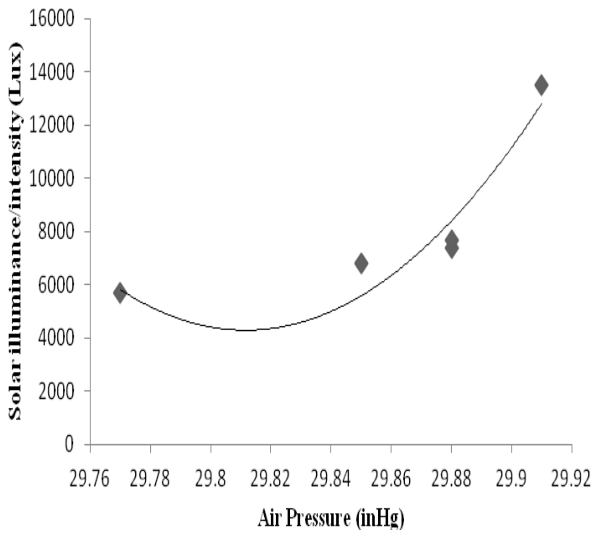

Fig. 5: Air pressure against Output current at near similar air temperature: 72 ± 2 ^{0}F, relative humidity: 72 ± %, wind direction: WSW, wind speed: 7.5 ± 2.5 mph and solar illuminance/intensity

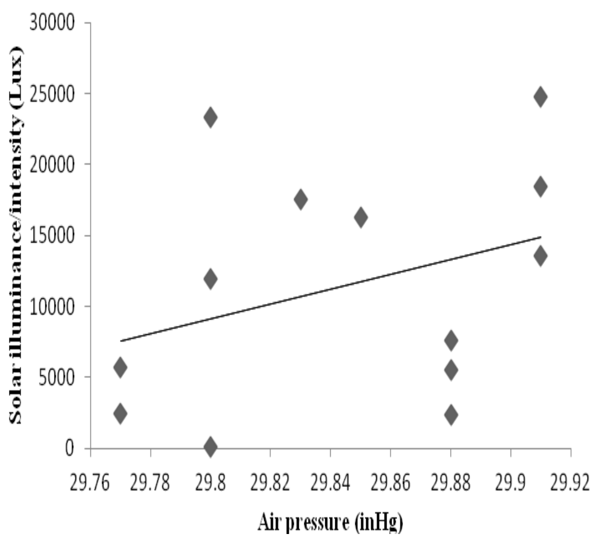

Fig. 6: Air pressure against Output current regardless of air temperature, relative humidity, wind direction (excluding speed) and solar illuminance/intensity uniformity

Fig. 1 shows that at near constant solar illuminance/intensity, air temperature, relative humidity and wind direction, the output current or short circuit current rises with increase in air pressure. The air pressure is the pressure exerted by the weight of air in the atmosphere of Earth [1] [2]. The weight of the air is a force acting downwards and it increases towards the earth surface, since air pressure increases with decreases in altitude or elevation from the earth surface. It implies that the downward force exerting on the falling or raining particles (or photons) of solar radiations increases since air pressure increases. This is why more particles (or photons) of solar radiations will rain on the photovoltaic cell, resulting in higher extraction and excitation of electrons and consequently higher photo current or short circuit current with increase in air pressure. In a sharp light, the air pressure is directly proportional to gravity ($P = \rho vg$; where ρ is air density, v is volume of air and g is the acceleration due to gravity) [10], hence: air pressure intensifies with decrease in height and simultaneously gravity.

Also fig. 2 fossilizes the above result, since buy and large, there is a rise in output current with increase in pressure from a larger data, regardless of constancy of solar illuminance/intensity, air temperature, relative humidity and wind direction.

Fig. 3 shows that there is an increase in output voltage or open circuit voltage with increasing air pressure at near constant solar illuminance/intensity, air temperature, relative humidity and wind direction. Fig. 4 shows that regardless of the solar illuminance/intensity, air temperature, relative humidity and wind direction for a large data, the establishment above is entrenched. Output voltage rises with increase in current, however, nonlinearly.

Figs. 5 and 6 show that air pressure rise result in increase in solar illuminance/intensity; this is true since the weight of the air is a downward force, influenced by gravity. It enables more particles (or photons) to rain on the earth. And since this gravitational force as a result of the weight of the air and simultaneously pressure increases towards the earth surface, the amount of particles (or photons) that falls down also increase. Hence: the illuminance/intensity of the solar radiation.

Finally at constant solar illuminance (or intensity), atmospheric temperature, relative humidity and wind speed and direction:

$I = KP^2$ (1)

$V = KP^2$ (2)

$SI = KP^{-2}$ (3)

$IV = KP^2$ (4)

Where; I is output current, V is output voltage, SI is solar illuminance (or intensity), P is pressure and K is a constant.

3. Conclusion

Output current (or short circuit current) and voltage (or open circuit voltage) rise with increase in air pressure. Air pressure is the pressure exerted by the weight of air in the atmosphere of Earth, and the weight of air is gravitational. This force increases with decrease in altitude and exerts more downward pull on the particles (or photons) of radiations from the sun and consequently it rises the solar illuminance/intensity and simultaneously the output current and voltage, since they are directly proportional, but non-linearly.

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Author's Profile

Joseph Amajama earned a Bachelor of Science degree (2008) in Electronics and Computer Technology and a Master of Science degree in Engineering Physics (2015) both from the University of Calabar, Cross River State, Nigeria. He had taught Mathematics and Physics in: Sambo Secondary School Gusau, Zamfara State (2008-2009), Emilis Secondary School, Calabar, Cross River State (2010-2012) and Early Steps Secondary School, Portharcourt, Rivers State (2014-2015), all in Nigeria. He was a part-time lecturer at the Lagos Aviation, Maritime and Business School (LAMBS), Calabar Branch (2010-2012). He is currently a part-time consultant lecturer at the Dorben Polytechnic, Bwari, Niger State and an academic staff of Electronics and Computer Technology Unit, Physics Department, University of Calabar, Cross River State, Nigeria. He is a member of the Nigerian Association of Technologists in Engineering

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