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Effect of Tilt Angle and Temperature on PV Performance

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ABSTRACT

The studies improved that the temperature has an impact on the PV as well as the solar radiation. In this article, we try to find the relation between the tilt angle and the temperature resulted. The practical experiments were conducted in the lab using a solar cell simulator to find this relation and to evaluate the impact of this relation on the panel's outcomes. The results indicated that the PV module temperature increases as a result from the increase of the solar intensity with increasing the tilt angle. The increase in the PV module temperature caused an increase in the voltage, a decrease in the current, and finally, increased the power.

Introduction

Sunlight (solar energy) is the main source for the lightening of each part in the earth. It is affecting the earth immediately if the sun light changed [1]. Also, it is controlling the climate generally which means that it is handling the dust, pressure and humidity so it is important to study the effect of the solar power on our plant and to know how much we can make it useful rather than make it harmful for the plant [2].

Solar radiation can be used in many solar applications to generate heat or electricity [3]. For instance the solar radiation can be used to heat water for domestic purposes [4]-[5]. It can be used for air heating in cold weathers [6]-[7], or to heat up Trombe walls for comfort conditions [8]-[9]-[10]. Heat can be stored in huge quantity in solar ponds, to be used for any other applications as heating the greenhouses or for enhancing distillating process [11]-[12]. Soar energy is used efficiently in distillation of brackish water especially in rural areas [13]-[14]-[15].

One of the uses of this energy is producing electricity [16]. Solar electricity can be achieved from direct and indirect applications. The indirect solar electricity applications are the solar chimney [17]-[18], concentrated solar power stations (CSP) [19]-[20]. As for direct solar electricity, it comes from using the photovoltaic systems [21]. These systems are being used today in many applications as pumping water for agricultural purposes [22]-[23]-[24], providing cities' street lights with electricity [25], and maintain electricity for the telecommunication systems in remote areas [26], as well as car parking [27].

The radiation occurs between the earth and the sun is a matter of motion of particles and it is considered as electromagnetic waves [28]. Radiation can occur as a long microwave waves or small waves and both are transporting the energy through a vacuum at a constant light speed which is equal to 300000 km/s, the wave length of the micro-magnetic waves can be determined using Wien's displacement law [29]. Small wavelengths have more energy per photon than long waves [30]. In the 19th century, Maxwell stated that the electromagnetic waves can make a continuous range of wavelengths called electromagnetic spectrum which is consisting of radio waves which are longer than gamma-rays by 121 times [31]. Solar radiation is emitting micromagnetic waves which cover a very large range of wavelengths which containing 9% ultraviolet, 45% of the solar radiation is visible band and 46% is infrared radiation [32].

Electricity is an electric charges flow which gives the effect of lights, electric current, and static electricity and so on [33]. Electricity is produced by using nonrenewable sources such as, fossil fuels but after certain years these sources will finish and there will be no more production for the electricity [34]. Due to this renewable resources started to be used as extra permanent sources [35]. Solar energy (solar PV) is the most source used in many countries all over the world because of its efficient in producing electricity; the PV arrays production increased 370 times than in 1992 [36]. The output of PV is affected by several climatic parameters such as temperature, solar radiation, air mass, humidity, and wind speed these conditions [37]. The standard conditions for PV output are, the panel temperature of 25°C, solar radiation of 1000W/m^2, air mass of 1.5 and wind speed of 2 m/s [38]. Because of the huge demand on the electricity the scientist discovered that there are another factors that affecting PV performance [39]. Perhaps the most affecting parameter that can limited the use of PV modules are the air humidity [40]-[41], dust [42]-[43], and wind speed [44]-[45].

PV devices are used widely everywhere [46]. For example, air conditioners, refreezes, electric lights and more of such these electric devices [47].

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The PV (photovoltaic) main part is the semiconductors [48]. These semiconductors have electrons that can pass through electric circuits, powering electrical devices or sending electricity to the grid by making these electrons free using solar energy [49]. These electronic processes which occur naturally in the semiconductors are the direct sources for the PV when sunlight is used [50]. These solar panels are made from crystalline silicon which is expensive but, they have more efficiency to produce electricity [51]. On the other hand, thin-film semiconductor materials are cheaper and can be also used to produce solar panels but with less abilities to produce electricity [52]. A unique type of solar panels - called multi-junction or tandem cells used for the applications which requires very light productions with high ability to produce electricity such as, satellites, military applications [53].

The temperature is changing continuously through the day and this permanent changing effect the PV performance as soon as the temperature changes [54]. These changes can affect the electric devices used and if the fluctuation in the temperature becomes more the PV output will be also fluctuated so the device can be destroyed [55]. Moreover, the PV output is increasing with decreasing the temperature so the resultant will be good for the device used since we need more PV output to make the devices work well [56]. The impact of the increased temperature is affecting the band gap of the semiconductors by reducing it [57]. This reduction in the band gap is expressed as an increasing in the electrons of the material and due to this motivation; the bond will be easily broken [58]. The most affected variable of the solar cell by the temperature is the open-circuit voltage [59]. The PV arrays efficiency decrease at high temperatures which means that the increasing of the temperature is decreasing the PV outcomes and the results will be not sufficient [60].

Solar radiation is affecting the general performance of PV including the efficiency of the system [61]. Unlike the effect of temperature on the PV performance, the solar radiation is directly proportional to the PV output [62]. As the solar radiation increases the PV output increases and the results being more sufficient [63]. In addition, the efficiency of the PV output increases if the PV arrays temperature stays constant at 25°C [64]. Many studies proved practically and theoretically that increasing solar radiation intensity increases the PV arrays temperature and resulting in reducing the PV power [65]. The solar radiation divided into two parts when it reaches the PV surface, the small part will be used to generate electricity while the signivicant part will heat the PV body causing higher temperature leading to a reduction in the PV efficiency [66].

Solar cells have introduced many researchers into a warning to make sure they work satisfactorily in volatile but well-known weather conditions [67]. So many researchers have used computational programs to predict the output of the solar cell with changes in temperature and solar radiation, both at the level of one day or one year [68]-[69]. These sports programs have led solar cell manufacturers and processors to deliver optimal services to the consumer [70].

Several techniques have been proposed to eliminate the effect of high temperature solar cells resulting from high solar radiation [71]. Perhaps the most important of these techniques is the use of the PVT system using a nanofluid as coolant [72]-[73]. These systems benefit in the production of electricity with greater capacity as a result of cell cooling as well as the heat derived from the cell in other heating applications [74].

To increase the efficiency of the system more, phase change materials (PCM) can be added, and by mixing it with nanoparticles to enhance the thermal conductivity of the PCM [75]. These techniques proved useful at the experimental level and remained to be used on wider scales.

There is strong public opposition to the use of solar cells in Iraq resulting from a failed street lighting experience [76]. However, this does not prevent us from ascertaining what happened and identifying the mistake, especially if we know that the atmosphere of Baghdad and the rest of Iraq's cities are severely contaminated by the burning of fossil fuels to generate electricity in personal and public generators [77]. The increase in cars and heavy traffic has exacerbated this problem [78]-[79]. Today, the only solution is to use photovoltaic cells to produce electricity both in the roofs of houses and government and private departments or by setting up power plants with capacities exceeding 100 megawatts [80].

This paper aims to study the effect of the temperature and solar radiation of the PV panel on the output power and efficiency of the PV panel. The practical tests were conducted in Baghdad City-IRAQ. Baghdad climate is characterized by its high solar radiation and high ambient temperature at summer season, and moderate temperature at winter. The relative humidity is low and didn't exceed 30% in most the year, especially the time of the field tests.

Experimental Setup

In this practical research work, the DL 9032 solar system, which is shown in figure 1, was used to evaluate the effect of the PV panel temperature and solar radiation on the PV efficiency. The system is a power source with one input and two distinct outputs, as represented in figure 2. The input terminal is a 230 V potential in respect to the ground. Power cable used to connect DL 9032 to the electrical outlet (230 V, 50 Hz). One module output is AC voltage source that has the same characteristics as module input, i.e. 230 V and 50 Hz. It is used to provide AC voltage for DL modules that require one. There is also a green terminal which is used for protective grounding of various DL modules that require grounding. Moreover, the other output is a 12 V DC voltage source. 12 V DC voltage source is obtained by transforming 220 V AC voltage to 12 V DC voltage using AC/DC converter.

In addition, for module DL 9032 to work properly, power cable must be connected to wall outlet (220 V, 50 Hz) and power switch must be turned to ON position. The red LED is turned ON (glows red) when voltage is present. For safety reasons wall outlet, must not be used if residual current device is not installed in electrical circuit that contains wall outlet.

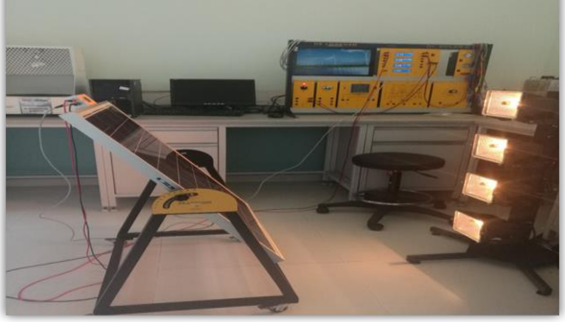

Fig. 1. Solar Radiation System.

The residual current device in wall outlet circuit must also be tested before DL 9032 is used. If residual current device does not work as it should, do not use DL 9032 module.

The solar panel used in the tests incorporates a module of (85 W, 12 V). It contains a sensor for the Irradiation and Temperature. These sensors are Red and Black; to provide the solar panel power output. Also, the 5-pin terminal provides irradiation and temperature data. To make it easy to be handled, the light weight solar module is placed on wheels. Side of the panel contains a meter for measuring the angle of the solar panel inclination towards the horizontal surface.

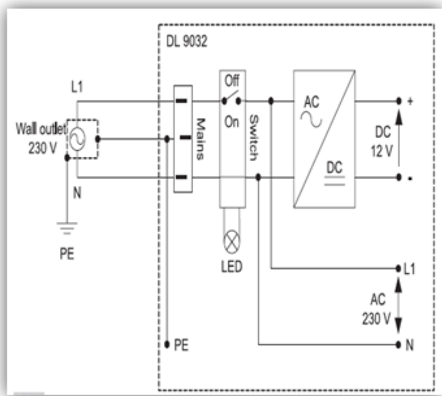

Fig. 2. Circuit diagram of DL 9032 Module.

Fig. 3. The solar Panel used in the tests.

The solar irradiation intensity and the PV temperature sensors used in the tests were type DELLENZO (Fig. 4). These sensors are used to transfer the heat and the irradiation from the Solar Source using the connections to the DL Solar device.

Fig. 4. Irradiation and Temperature Sensors.

Results and Discussions

Effect of Power on Voltage performance

Power and Voltage are directly proportional to each other. This relation is affected with the Elevation angle which makes it more stable as it is increasing. Fig. 5 shows the relation between Power and Voltage. As the Elevation angle increased the light intensity increase. The relation is starting with low Voltages at vertical case of the receiver and it becomes steadily increasing. However, as the Solar panels become more vertical, the starting Voltage value becomes higher and the increment became more stable near to constant state. The maximum power values were achieved at tilt angle =0° for voltage ranged from 0 to 17V. The other curves showed variable trends as their maximum power values achieved at voltage of 19 to 21 V. The figure indicates an obvious increase in voltage with tilt angle variation from 0° to 90°.

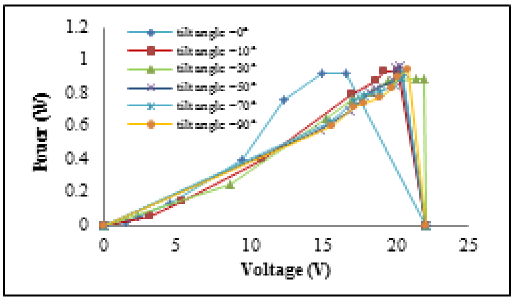

Fig. 5. The relation between the PV module power and voltage.

Maximum Power from IV characteristics

Fig. 6 shows the relation between the voltage and current of the tested PV module. The power is the production of multiplication of current with voltage values. The curves in the figure declare that increasing tilt angle from 0° to 90° the power will be increased. From the IV characteristics curves, the maximum value for the Power is at the point at which the volt and current has the maximum value before the Current drop.

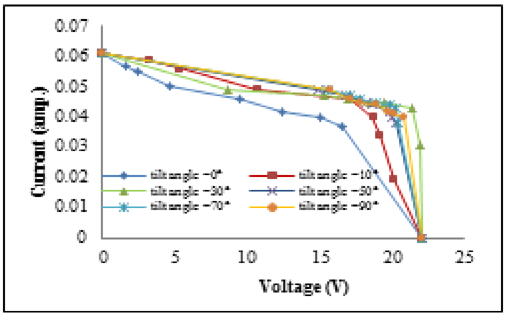

Fig. 6. the relation between the PV module current and voltage.

Effect of Temperature on Voltage

Fig. 7 represents the effect of tilt angle on the PV temperature, and the impact of temperature variation on the PV module's voltage. The Voltage has high record when the panel was directed at 90° to the Light source. The relation between the Voltages with the Temperature may not be obvious in the figure as the PV panel temperature variation was limited. At different Elevation Angles, the module temperature was increased. The curves show a small starting value of the Voltage and the flexible increasing of both Voltage and Temperature as the Light intensity and the Elevation Angle were increased.

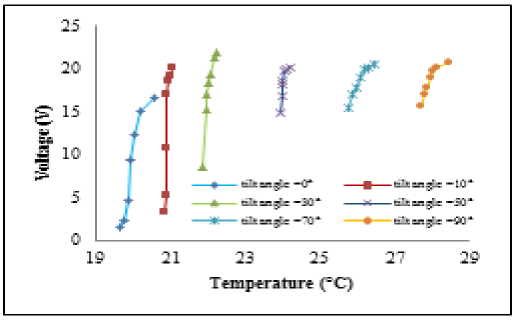

Fig. 7. The relation between the PV module temperature and voltage.

Effect of Temperature on Current

Fig. 8 represents the relation between the Current and Temperature at different Inclination Angles. The Current-temperature behavior is on an inverse manner compared with temperature-voltage relation. The current became more stable as the Elevation Angle increases but it keeps decreasing at the same time. The decrement can be noticed more when the Solar Panels are horizontal and it is stable when the Solar Panels direct to the Light source. The Light intensity is kept increasing during changing the tilt angle that cause the PV temperature to increase. The temperature increase caused the reduction in the PV current.

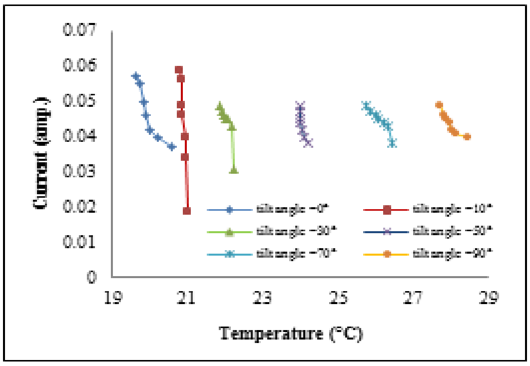

Fig. 8. The relation between the PV temperature and current.

Effect of Temperature on Power

Fig. 9 represents the relation between the PV module output power with temperature and tilt angle variation. As the resulted curves indicate, the increasing in the Light intensity due to the increase in the inclination angle made the Power directly proportional to the Temperature. However, the increment of the Power with the Temperature is differing from one Elevation Angle to another. The related graphs show that as the Inclination Angle increases the stability of the Power with the Temperature become more.

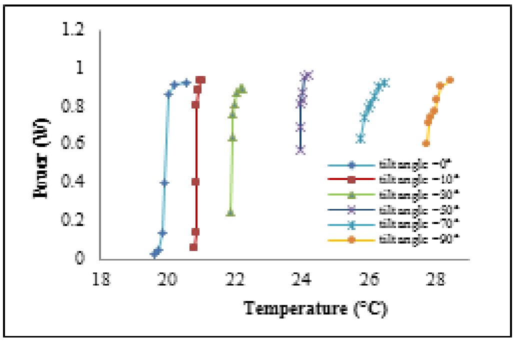

Fig. 9. The relation between the PV module power and temperature.

Conclusions

In this paper, the experimental tests were conducted in the lab using a solar cell simulator to find the effect of varying the tilt angle on the PV module temperatures and the impact of this variation on the panel's outcomes. The results indicated that increasing the tilt angle will increase the solar intensity and this increase will cause higher temperature. The increase in the PV module temperature caused an increase in the voltage, a decrease in the current, and finally, increased the power.

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