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Using Incremental Conductance for Modeling of Maximum Power Point Tracking of a Photovoltaic cell in Baghdad-Iraq

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Abstract
Photovoltaic cells are one of the best alternatives to fossil fuels for electricity generation. These cells are affected by the surrounding atmosphere. The ambient temperature and the solar radiation intensity are the most important climatic factors affecting the photovoltaic power. Any change, even a small fraction of these factors, directly changes the current and voltage of the solar panel, leading to changes in the I-V and P-V curves. In these curves, there is a point called MMPT representing the maximum power produced by the photovoltaic cell.
In this study, one of the main methods of MMPT was studied to reach the maximum power point (MPP) of the PV panel. The studied method is Incremental Conductance (INC). This method was subjected to the conditions of temperature and solar radiation for the city of Baghdad, Iraq for the purpose of examining the conditions and response time, and was investigated the flexibility of the response of this method when solar radiation in the range of 300 W / m to 1000 watt / m 2 while changing the temperature in the range of 0°C to 70 °C. For the studied method INC, the generated power curve reached maximum value without oscillation, and the manganese stabilized after 0.15 seconds. The data used in the model is the data of the city of Baghdad – Iraq. The results of the study indicate that the method INC provides better and faster stability.

Keywords: MMPT, Incremental Conductance, climatic conditions, solar radiation, temperature

Introduction
Energy today is the engine for the advancement of societies and the more the society is advanced, the greater the energy expenditure [1]. Most of the energy produced today is from fossil sources such as coal, crude oil, and natural gas [2]. Most of these sources were consumed during the last two centuries and began to count the days for their depletion [3, 4]. This idea pushed to new balance of powerful countries based on the available capacity of production of energy. But, even these countries began to suffer from the fluctuation of oil prices during the last two decades [5]. The concentrated reliance on fossil fuels has caused high pollution to the environment, resulting in serious problems such as climate change and global warming [6]. The shift towards renewable and environmentally friendly energy sources has become the goal of all countries in the world to reduce the damage caused by human activities resulting from the burning of fossil fuels [7].
Solar energy is considered to be the most environmentally friendly renewable energy. Many applications have been using solar energy successfully and for decades. For example, solar water heaters spread throughout the world and are quite successful in heating water for domestic and industrial purposes [8, 9]. The air is heated for comfort and heating of rooms and homes using solar air heaters [10, 11], and the Trombe wall has been used for this purpose successfully for years [12, 13]. Thousands of years ago, the Babylonians and ancient Egypt relied on the distillation of solar water to obtain potable and healthy water [14, 15]. Today, solar distillers took many forms and were used in the construction of various materials, including paraffin wax and nanoparticles [16, 17]. Graduate salty solar ponds have been used to store heat in large quantities, which can be used to amplify glass houses or to connect them to solar distillers for the purpose of increasing their productivity [18, 19].

Solar applications have been recently created to generate electricity, such as solar chemises that heat the air in their collectors and then run through the chimney, which is located in the middle of the solar collector [20]. As hot air rises to the top, air turbines move and produce electricity [21]. Today, concentrated solar power stations are being used with high efficiency in many parts of the world [22-24]. The most important solar applications that have expanded across the world are photovoltaic cells that convert solar radiation into electricity [25, 26]. The low cost of producing energy from solar cells and their ease of manufacture, installation and high flexibility in the possibility of deployment in all the plant, desert or rural arid and semiarid make it a global favorite and spread quickly and confidently [27-33].

Photovoltaic cells are affected by weather conditions such as temperature [34], solar radiation [35], and relative humidity [36], and wind [37], dust plus tilt angle [38-40]. High cell temperature causes low electrical productivity because the bulk of solar radiation turns into heat [41-44]. New research has begun to look for a new way to cool the cell, whether by air, water, nanomaterials, and variable-phase materials [45-48]. The dust reduces the radiation of the cell and causes a kind of disinformation that reduces the productivity of the cell [49]. Several factors interfere with the amount of air deposited from the physical and chemical properties of dust [50], wind speed [51], dust source type [52], and relative humidity [53].

The temperature of the atmosphere and the intensity of solar radiation are the most important climatic factors that affect the productivity of the PV cell. As any change even a small proportion of these factors directly affect the current and voltage of the cell resulting in changes in the I-V and P-V curve [54]. In this curve there is a point called MMPT which represents the highest power produced by the photovoltaic cell [55, 56].

Many methods are used to determine the MMPT such as direct and indirect methods, connected to the Internet and not connected to the Internet methods. Each method differs from its counterpart, some of which are complex because of the high accuracy required. Each approach is characterized by its responsive response speed and responsiveness, as well as cost and traceability [57, 58]. The process of tracking solar radiation, which changes intensity from one moment to another and from one season to another and the use of a mechanism to control the direction of the solar cell to obtain the potential capacity of the solar panel and to increase the efficiency of electricity is very important in generating electricity [59, 60].

Load resistance is an important factor that can affect the energy generated by the solar cell and this resistance is variable and unstable. When the load resistance and the maximum energy produced by the solar cell match, the cell's output reaches the maximum value (Vop and Iop)[61]. To determine this ideal point of operation, a DC to DC converter is used between the battery or the load and PV array, which mean that the operation of a row of PV cells at MPP is done by connecting a controller to a DC / DC adapter and using the MPPT algorithm. In this case, the value of the input impedance of the transformer will be compatible with the change in solar radiation and temperature [62]. Thus, when the solar intensity or the temperature changes, the MPP curves change and the Vop and Iop move to a new location. This point corresponds to the highest voltage and current by changing the transformer cycle [63].

The Incremental Conductance (IC) method is used to track MPP point. The differentiation technique is used here to reach the energy generated by the cell relative to the voltage to zero. The IC method presses compare the direct connection of the panel to the discharge of the mounting panel. The voltage of the array is followed to satisfy = 0, which is MPP. IC uses a different algorithm than other methods that are easily implemented and are faster and more efficient [64, 65].

The Incremental Conductance (IC) method was selected in this study and applied to a model using radiation and temperature as input parameters. The impact of each parameter on time response by looking at data obtained from different locations in the city of Baghdad-Iraq was made. This study aims to evaluate the best MPPT method applied for Iraqi weathers.

Experimental Methodology

The Incremental Conductance (IC) method is used in photovoltaic systems for their high efficiency, shortening of the time required for tracking and use of fixed frequency. This method is characterized by high accuracy in tracking with great stability. The algorithm here calculates the new factors of the solar panel when weather conditions change. This method is based on the slope of the MPP (I-V and P-V) curves by increasing the value if the point is left on the MPP side and decreases the value if the point is on the right side of the MPP [66, 67]. The following equations explain this:

$$\frac{dp}{dv} = 0, \quad \text{at MPP} \qquad (1)$$

$$\frac{dp}{dv} < 0, \quad \text{Right of MPP} \qquad (2)$$

$$\frac{dp}{dv} > 0, \quad \text{Left of MPP} \qquad (3)$$

The differences between the minimum and maximum voltage is checked continuously by evaluating the value appeared while the voltage continued varying in the same direction or in the opposite one [68, 69]. Then, IC MPP point is derived by differentiating the PV power with respect to voltage and setting the result to zero [70, 71],

$$\frac{dP_{pv}}{dV_{pv}} = I_{pv}\frac{dV_{pv}}{dV_{pv}} + V_{pv}\frac{dI_{pv}}{dV_{pv}} = I_{pv} + V_{pv}\frac{dI_{pv}}{dV_{pv}} = 0 \tag{4}$$

$$\frac{-I_{pv}}{V_{pv}} = \frac{dI_{pv}}{dV_{pv}} \tag{5}$$

The left side of equitation 4 represents the opposite of direct conductance, $G=dI_{pv}/dV_{pv}$; while the right side of equitation represents the incremental conductance [72]. The incremental variations, dV_{pv} and $I_{pv,}$ can be approximated by using the parameters ΔP_{pv} and $\Delta I_{pv,}$ with measure real values of dV_{pv} and I_{pv} [73-75].

A tracking algorithm is used to measure solar cell voltage during two moments, t_1 and t_2, where ΔVpv and Ipv represent the difference between measured values during this period. After that, the produced voltage of the solar panel is increased.

Effect of Irradiance on incremental conductance (INC)

The expected radiation data from 300 W/m^2 to 1000 W/m^2 is used to verify the effect of radiation. From the model's graphs, the direct effect of radiation on the output power can be evaluated and the model starts from zero to 0.5 seconds for the x-axis. In contrast, the Y axis starts from zero to the top of the energy curve.

The Effect of Temperature on to incremental conductance (INC)

Temperature is the second major factor that directly affects the efficiency of the PV system. In this way, change the temperature and check the output. The effect of the temperature with the outside of the solar cell is linked to the inverse relationship, because when the temperature increases, the generated electricity will decrease.

Results and Discussions

Fig 1 shows the relation between time and power for the Incremental Conductance Irradiance Method. The figure shows that energy is affected by changes in the intensity of solar radiation with the method of continuous increase. The curve is stabilized after 0.2 seconds.

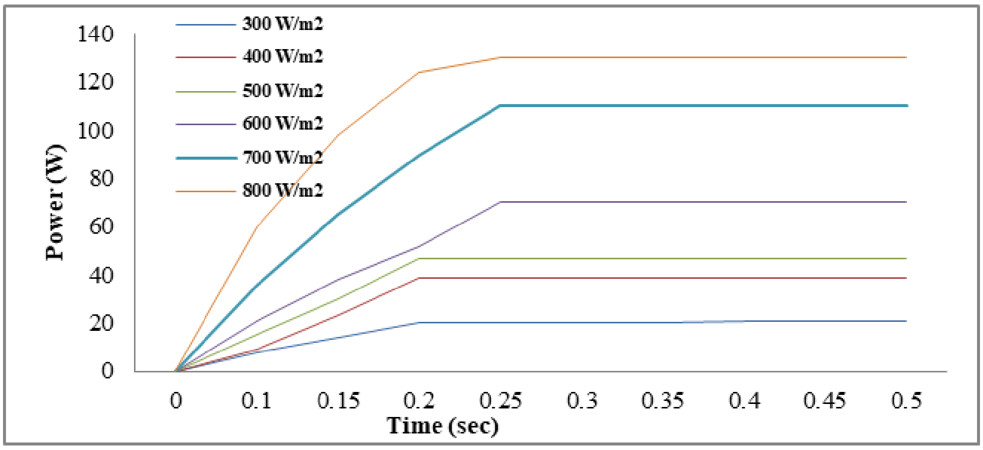

Fig. 1: Incremental Conductance method with irradiance range

Fig. 2 shows the resulted power when the INC method was used while the temperature was varied from zero to 70°C. The results show that the power was stabilized after 0.15 seconds. The minimum degree used achieved the maximum power while on the contrary the maximum temperature achieved the minimum power.

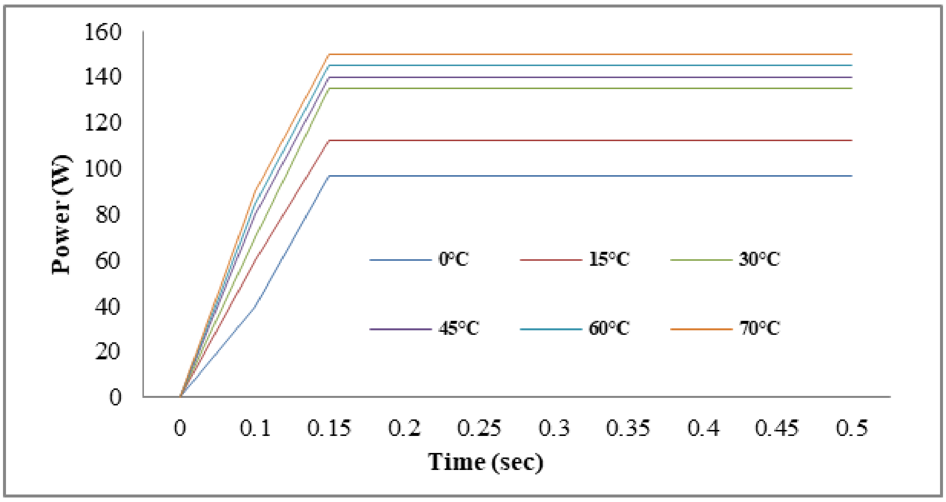

Fig. 2: The Incremental Conductance with temperature ranges

Iraqi weather conditions

The conducted model was tested using the average temperature and the irradiation of Baghdad-Iraq climate data conditions for different stations of the city.

Irradiation conditions

Iraq distinguish by its high solar radiation as it is located near the solar belt with minimum solar radiation intensity of 265 W/m2 in winter (January) and 890 W/m2 in summer (August). Also, the bright days more than 330 days per year, this means more than 3300 shiny hour. When the incremental continuity method is used with a radiation change from the highest value of 890 W / m 2, the power reaches 111 W and the lowest value at 265 W / m 2 with a power of 66 W. The energy curves were stabilized after 0.25 seconds.

Temperature Conditions

The variation in the ambient temperature in winter and summer in Baghdad - Iraq is about 25ºC, which is considered a semi-desert region. When the incremental continuity method is used with temperature changes, the maximum temperature in Baghdad generates the lowest capacity.

Conclusion

In the study the effectiveness of the INC method was assessed with temperature change and solar radiation to assess the maximum capacity generated from the solar panel. This study was applied to the same conditions and examined the response time and elasticity of this method when radiation and temperature change. The method was tested across a range of all expected radiation starting from 300 W / m to 1000 W / m, and the temperature range from 0 ° C to 70 ° C.

The results showed that this method fluctuated in the power generated around the maximum point and the curve stabilized after 0.15 seconds. Radiation data were applied to the city of Baghdad by taking the average solar radiation and the temperature of six stations in the city. Results showed that the INC method provides the best, best and fastest stability of the data produced.

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