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Investigate the maximum power point of photovoltaic system at different environmental conditions

Khaleel Ali Khudhur[1], Nabeel Mohamed Akram Samad[1], Ghanim Thiab Hasan[2]
[1]Department of Electrical Engineering, Kirkuk Technical College, Northern Technical University, Kirkuk, Iraq
[2]Department of Electrical Engineering, Shirqat Engineering College, Tikrit University, Tikrit, Iraq

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ABSTRACT

The main objective of this work is to implement a circuit-based simulation model of a photovoltaic (PV) cell in order to investigate the electrical behavior of the practical cell with respect to some changes in weather parameters. The simulation model consists of three subsystems: photovoltaic cells, DC/DC converter and MPPT controller based logic fuzzy control. The maximum power control function is achieved with the appropriate power control of the power inverter. Fuzzy logic controller has been used to perform MPPT functions to get maximum power from the PV panel. The proposed circuit was implemented in MATLAB/Simulink. The obtained results show that the output sequence is non-linear and almost constant current to the open circuit voltage and the power has maximum motion to voltage for certain environmental conditions.

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Corresponding Author:

Ghanim Thiab Hasan
Department of Electrical Engineering, Shirqat Faculty of Engineering, Tikrit University
Salah-Aldeen, Tikrit, Iraq
Email: ganimdiab@yahoo.com

1. INTRODUCTION

After centuries of using fossil fuel power, today's global image is changing, and renewable sources are increasingly considered to be one of the key factors for the future development of the Earth [1]. The main source of energy is still fossil fuels that give 85-90% energy [2]. Oil is the most significant of 35%, while coal and natural gas are equally represented [3]. Almost 8% of the energy comes from nuclear power plants, and only 3.3% of energy comes from renewable sources [4]. Since we will have to meet all of our energy needs in renewable energy sources in the future, we need to invent a way to turn renewable resources into useful energy and thereby ensure the further advancement of mankind [5]. Therefore, the use of renewable energy sources has an increasing role in world energy production. Nature supplies us daily, free of charge, with large quantities of sun and wind [6]. On the other hand, there is less and less oil, coal and other exploited assets on our planet, whose cost is parallel to that fact [7].

Over the last few years, man is increasingly apparent that excessive utilization of fossil fuels has significantly and most probably irreparably damaged the living environment, not only himself, but also all species on Earth [8]. The conclusion is that by using the sun and the wind, we save the material to achieve the same goal we would achieve by using traditional means at a much higher costs [9]. In order to overcome this obstacle as soon as possible, new technologies, management methods and other elements that would contribute to the lower cost of energy produced are intensively explored [10]. Less than one sunny hour is enough to cover the total energy need of nearly 7 billion people living on this planet [11]. There are some studies on the design of solar system which conducted by some researchers such as Sundareswaran *et al.* [12], in their research, they developed a new hybrid algorithm for the maximum power point tracking controller (MPPT) which under partial shaded conditions that involves sequential integration of particle swarm optimization (PSO) and perturb and observe (P&O) algorithms. This algorithm has been evaluated validated through simulation and experimental results which show increasing in the tracking speed and improving the transient response. According to the new renewable energy policy, the 10th Malaysian Plan will be implemented in 2021. This designed renewable energy generator can be installed in homes with a dedicated network boot system [13].

Shivashankar *et al.* [14] in their paper, They tried to bring out the latest literature review on the problems associated when the intermittent photovoltaic system is connected to the grid and they focus on the methods of smoothing the output power fluctuation from this system. They also briefly discuss the control strategy built for the battery energy storage in the photovoltaic system. One of the oldest investigations was Park Albuquerque and the Recreation Department of New Mexico [15]. The system design uses two photovoltaic panels of 50 W with a 35 W sodium lamp. Standard systems will last six hours at night and are designed to use conventional conversion due to the maximum design of the racing force in the development phase. The results of the study showed the potential of solar energy to illuminate street lights and laid the foundations for future plans [16].

In the study [17], it had been shown how to build alternative energy systems, connect them to a traditional electricity network, and increase the volume or amount of energy resources to meet load needs. The influence of alternative energy on the traditional electrical network is also considered to improve the stability of the system [18]. However, most design rules are based on a "need for implementation" strategy instead of reliability. Alternatives, diseases and some results for assessing the reliability of energy systems [19].

The study conducted by Ganjuli and Singh [20] presented a novel method to measure the potential of solar electricity generation in Patiala on the basis of solar radiation data obtained from the weather station installed within the Thapar University campus. Further possible plant capacity is estimated for an arbitrarily chosen area. The results supported justify the method proposed. which is based on the system connected to a wider network by using a high-quality converter that converts direct current (DC) power to meet the electrical requirements of the network.

2. METHOD

The proposed photovoltaic system consists of a photovoltaic panel, DC/DC converter, regulator, and a load. Figure 1 shows the photovoltaic system implemented in the MATLAB/Simulink software package [21]. The input parameters in the model are the solar allowance *Gt*, the temperature of the cell *Tc* and the current of the *Ipv* panel, while the output parameters are the panel control voltage and the power of the panel *Ppv*. During the simulation, 3 photovoltaic panels winch arranged in a series manner. The simulation parameters are taken from the real SOLVIS SV215 photovoltaic panel [22]. The rotor drive role is together with the power-limiting regulator, ensures the operation of the photovoltaic panel at the maximum power point. In this work, the non-inverting DC converter had been used whose scheme is shown in Figure 2 [23].

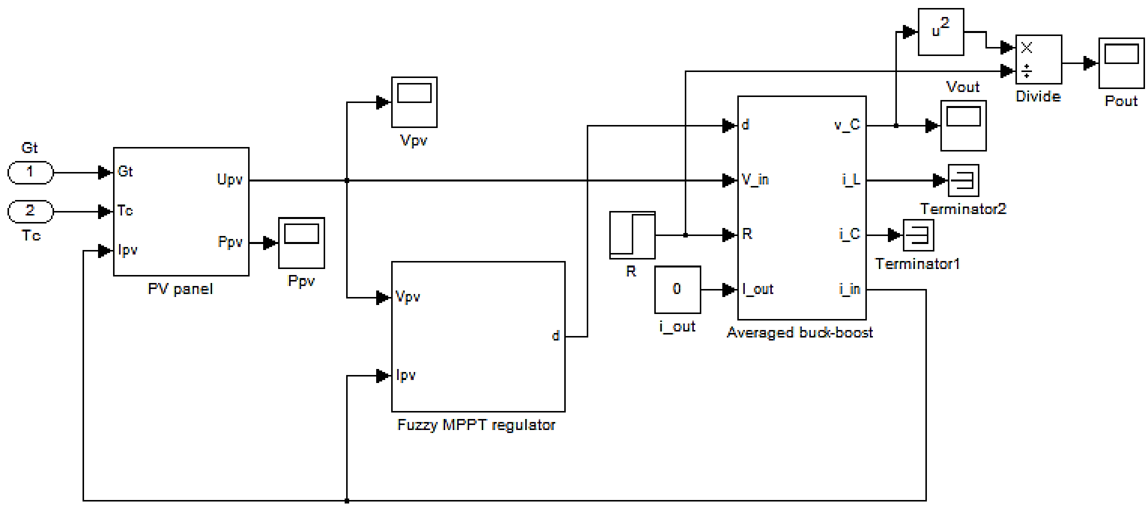

Figure 1. Photovoltaic model implemented in MATLAB/Simulink

The mathematical formulas describing descending-ascending DC converter without loss in elements are given by (1)-(4) [23]:

$$C\frac{dV_c}{dt} = (1-p)i_L - \frac{v_c}{R} - i_O \quad (1)$$

$$L\frac{di_L}{dt} = uv_{in} - (1-p)v_c \quad (2)$$

$$v_O = \frac{Rv_c}{R+R_c} + \frac{RR_c}{R+R_c}[(1-p)i_L) - i_o] \quad (3)$$

$$\frac{v_{out}}{v_{in}} = \frac{D}{1-D} \quad (4)$$

where, *D* is the Duty cycle.

$$I_{out} = \frac{P_{out}}{V_{out}} \quad (5)$$

$$R_{out} = \frac{V_{out}}{I_{out}} \quad (6)$$

Iin will be as (7), (8):

$$I_{in} = \frac{P_{out}}{V_{in}} \quad (7)$$

$$I_L = \frac{I_{in}}{D} \quad (8)$$

Inductance *L* will be [24]:

$$L = \frac{V_{in} \cdot D}{\Delta I_L \cdot f} \quad (9)$$

where, ΔI_L is the permissible coil current wavelength (20%), ΔV_{in} the permitted voltage wavelength (0.5%). The calculation results of the DC converter parameters are shown in Table 1.

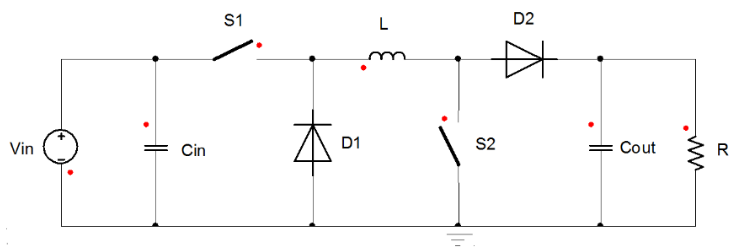

Figure 2. Non-inverting DC converter

Table 1. Calculation results of the DC converter parameters

Parameter description	Symbol	Value
Output current	I_{out}	8 A
Load resistance	R_{out}	6 Ω
Input current	I_{in}	8.6 A
Conductor factor	D	0.47
Coil current	IL	14 A
Inductance	L	521 µH
Capacitance	C	661 µF

The goal of the MPPT control is to bring the photovoltaic system to the maximum power point of the power and maintain it in the system regardless of the disturbance of the panel temperature changes, change the allowance or change the system load [25]. In Figure 3, the P-U characteristic is shown with the point of maximum power. The maximum power point is at the extreme point where the derivation is $\frac{dP}{dU} = 0$. On the left side, the derivative characteristics are positive, while on the right side it is negative.

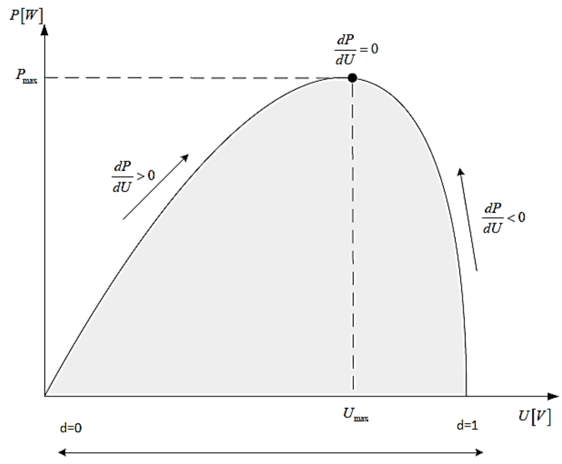

Figure 3. P-U characteristic with the point of maximum power [26]

Since the point of maximum power lies in the extreme point where it is valid:

$$\frac{dP}{dU} = o \tag{10}$$

We have:

$$\frac{dP}{dU} = \frac{d(U \cdot I)}{dU} = I \cdot \frac{dU}{dU} + U \cdot \frac{dI}{dU} = I + U\frac{dI}{dU} \tag{11}$$

$$\frac{dP}{dU} = 0 \Rightarrow -\frac{I}{U} = \frac{dI}{dU} \tag{12}$$

When the condition in (12) is met then the maximum power is achieved.

The fuzzy controller for monitoring the maximum power point in MATLAB/Simulink is shown in Figure 4. The entry into the fuzzy regulator is a condition in (12), and output is a change of the driving factor. The condition in (12) tells us which side the characteristics are, and the point of maximum power regulates depending on the distance from the center of the (fuzzy logic). Affinity function is defined for how much of the current power point deviates from the maximum power point.

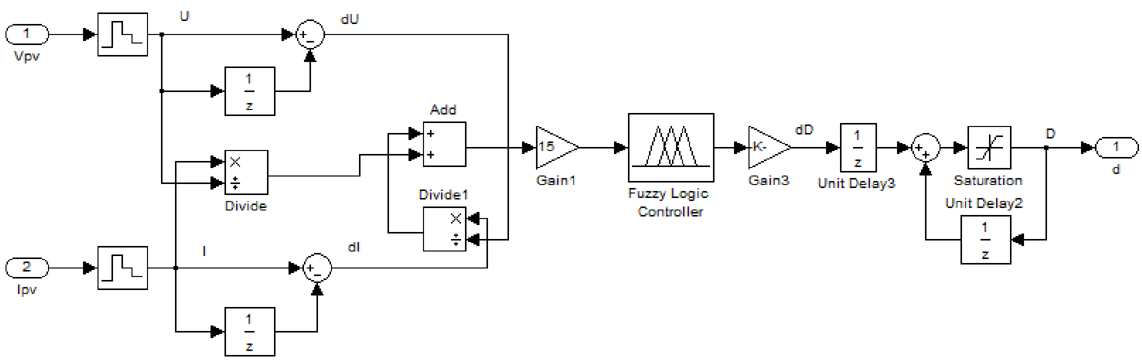

Figure 4. Simulated Fuzzy MPPT controller

3. RESULTS AND DISCUSSION

Figures 5-6 illustrate the responses to change of allowance are shown in the first case from 600 to 700 W/m^2 and in the second case from 600 to 500 W/m^2. In these two cases, the temperature Tc is stay constant and is approximately Tc=25 °C. So, the obtained results indicate that the allowance in these two cases is gradually drop.

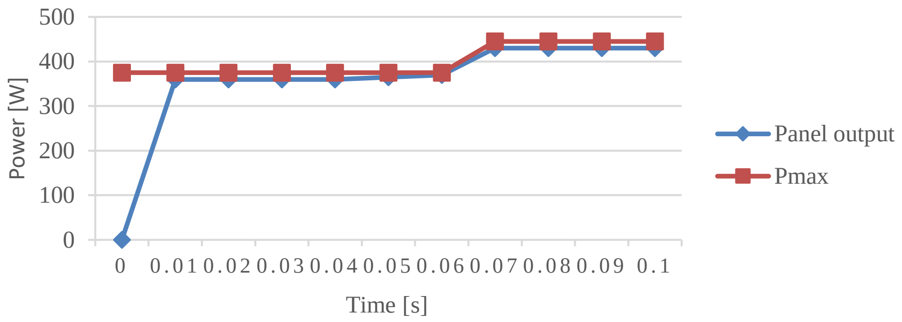

Figure 5. Response to change in power from 600 to 700 W/m^2

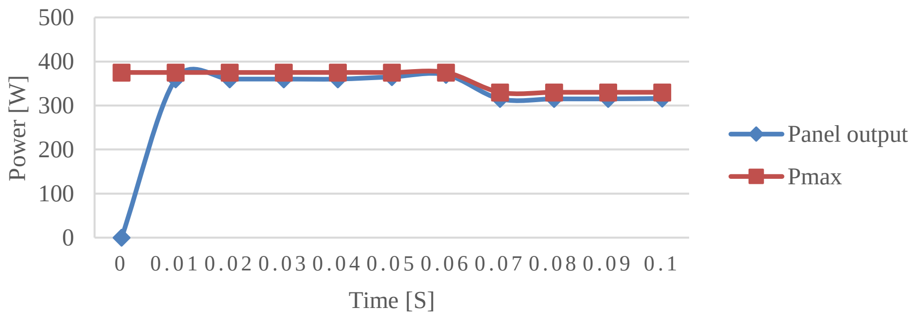

Figure 6. Response to change in power from 600 to 500 W/m^2

Figures 7 and 8 show changes in temperature, in the first case at 20 to 25 °C and in the other case at 30 to 25 °C, in both cases the allowance *Gt* is constant and is Gt=700 W/m^2. On the responses light blue is the maximum possible power that can be extracted from the photovoltaic system for the given amount and temperature. On the responses, we see that the power of the photovoltaic panel and the output power from the DC converter do not achieve the maximum amount of power available, but achieve the amount of power that is very close to maximum power. There is an uneven error in the input power, the regulator sometimes used to, and sometimes enter the area when it is. This depends on the workstation since the area is defined as a fuzzy set and the system is nonlinear.

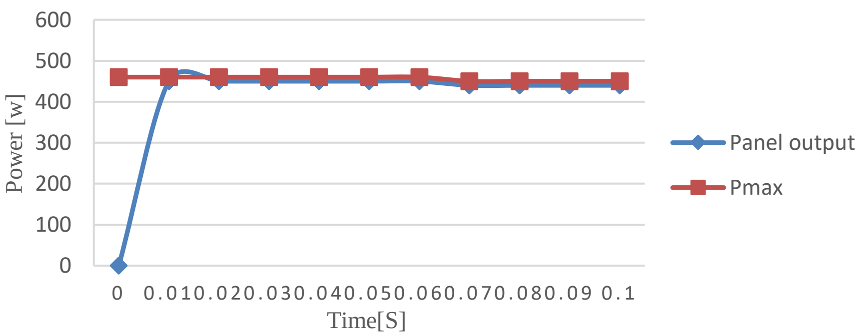

Figure 7. Response to temperature change from 20 to 25 °C

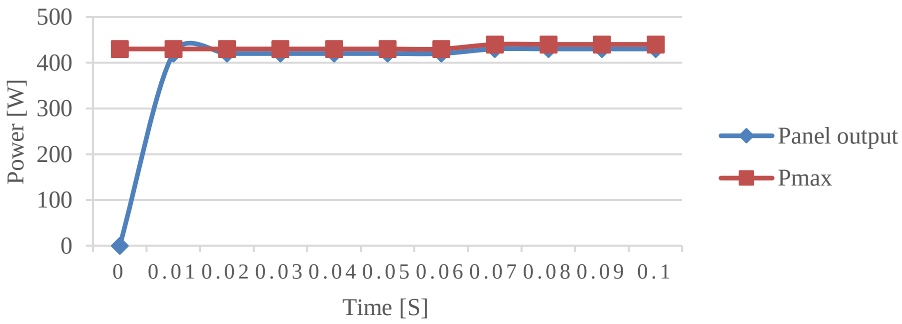

Figure 8. Response to temperature change from 25 to 30 °C

4. CONCLUSION

In this paper, a photovoltaic panel simulation and a controller for maximum power point monitoring at its current-voltage characteristics was conducted. It was designed to use the fuzzy logic controller to bring the photovoltaic system to the maximum power point of the power and maintain it in the system regardless of the disturbance of the panel temperature changes, change the allowance or change the system load .The operation of the photovoltaic model has been simulated by using the MATLAB/Simulink environment, which shows that the power of the photovoltaic panel and the output power of the inverter do not achieve the maximum amount of power available, but achieve the value of power that is very close to maximum power.

The simulation results show the non-linearity of the output array. The P-V characteristic shows an almost constant current to open a series of voltages and the characteristics of PV indicate that the power has increased relative to the voltage for certain environmental conditions. With changes in radiation cells, the actual changes are linearly happens because the voltage changes in the cells differ in the logarithmic, which is clear from the simulation equations. The proposed model can be used for research activities in the application of solar energy with a maximum power monitoring scheme for the photovoltaic system.

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BIOGRAPHIES OF AUTHORS

Khaleel Ali Khudhur Born in Kirkuk city, Iraq, holds a Bachelor’s degree in Electrical Engineering from the Technical Northern University. Technical college/Kirkuk/Iraq Republic of Iraq 2007, completed a master’s degree in electrical engineering in 2011, Faculty of Electrical Engineering, currently works as a lecture. Assist. in the Department of Electrical Engineering, published several scientific researches in his field of competence. He can be contacted at email: khaleel2012@ntu.edu.iq.

Nabeel Mohamed Akram Samad Born in Kirkuk, Iraq, holds a Bachelor’s degree in Electrical Engineering from the Technical Northern University. Technical college/Kirkuk/Iraq Republic of Iraq 2006, completed a master’s degree in electrical engineering in 2013, Faculty of Electrical Engineering, currently works as a lecture. Assist. in the Department of Electrical Engineering, published several scientific articles about research. He can be contacted at email: nabeelakram@ntu.edu.iq.

Ghanim Thiab Hasan He is an Associate Professor at the Department of Electrical Engineering, Al-Sherqat engineering college, Tikrit University, Iraq, where he has been a faculty member since 2006. He graduated with a first-class honors B.Eng. degree in electrical and Electronic Engineering from Belgrade University, Serbia, in 1984, and M.Sc. in Electrical Engineering from Belgrade University, Serbia in 1986. His research interests are primarily in the area of electrical and electronic engineering. He can be contacted at email: ganimdiab@yahoo.com.