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Design of MPPT PV using Particle Swarm Optimization Algorithm under Partial Shading Condition

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ABSTRACT

Fossil energy sources experience a decrease each year when the demand increases significantly. In the case of environmental issues, renewable energy sources (RES) can be energy alternatives. The photovoltaic module is RES with unique characteristics, especially partial shading conditions. This condition leads to the PV characteristic curve experiencing multiple peaks. The paper conducted the simulation of the PV solar panel module using MATLAB Simulink. The Maximum Power Point Tracking (MPPT) PV is also described based on a particle swarm optimization (PSO) algorithm. The proposed algorithm can address multiple peak curve problems due to partial shading conditions. For comparison, the conventional algorithm, perturb & observe, is presented. The PV module is divided into three group cells with irradiance differences for each group to illustrate the partial shading condition. The result shows that the PSO algorithm guarantees optimal and fast response for the operating PowerPoint. It needs about 0.04 seconds to maintain at the optimal power point, 129 Watt, compared with the perturb and observe algorithm performance that only kept at the lower operating power point, 67 Watt at 0.06 second. Thus, the PSO algorithm can tackle the partial shading condition with a fast response to maintain the maximum PowerPoint. Therefore, the PSO algorithm is the proper solution for tracking the optimum operating power point under partial shading conditions.

Keywords: Maximum Power Point Tracking; MPPT; PV; Irradiance; Particle Swarm Optimization.

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I. INTRODUCTION

When demand increases significantly, fossil energy sources decrease each year [1][2]. Therefore, many sectors use renewable energy sources as an energy alternative. Renewable energy (RE) sources are the most used as low-cost energy. Moreover, t utilization of RE can reduce pollution [3]. The most attractive attention of renewable energy consumption is the clean environmental problems that people mainly care about friendly-environmentally. One renewable electrical resource used as an alternative energy source is photovoltaic (PV) solar cell energy. Using solar energy as a source of power generation as an alternative energy source can cut electricity bills and make it more cost effective [4]. Moreover, solar energy has many other benefits, such as generating power without any emissions during operation, so its benefits lead to an interesting issue in dealing with global warming problems [5].

Converting solar energy into electrical Photovoltaic materials can be used to generate electricity directly without the need for mechanical conversion. Photovoltaic (PV) technology is made of semiconductor materials called PV panels. The efficiency of the photovoltaic panel varies due to non-linear characteristics, which are influenced by both temperature and solar radiation. Therefore, photovoltaic generation must be controlled to achieve the high efficiency of solar energy. In order to achieve the maximum energy from solar photovoltaic modules, PV modules need to be operated at maximum power point (MPP) [6]. The process can be achieved using the maximum power point trackers (MPPT) technique. These Maximum Power Point Tracking controller devices are used to configure the DC-DC Converter so that the solar panel module extracts the maximum amount of solar energy [7]. The photovoltaic panel system shows the power-voltage characteristic curve and the current-voltage characteristic curve. As a result, voltage and current are essential variables used as a reference for controlling a boost converter. The boost converter has the primary function of increasing voltage and providing impedance between the PV solar system and the load.

In a PV system, each PV array consists of numerous PV panels connected in series and parallel to generate high voltage and high current to increase the output power of PV generators. A solar power system contains two types of diodes: bypass diodes and blocking diodes. Blocking diodes are used to prevent the backflow of electricity, and bypass diodes inhibit the heating effect of hot spots and reduce the power loss due to shading. This situation is defined as a Partial Shade Condition (PSC). PSC is described as a situation in which each panel receives and experiences At the same time, differing sun irradiations and temperatures [8]. There

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are algorithms used to track the maximum power point, such as conventional algorithm, Incremental conductance (IC), Perturb and Observe (P&O), and artificial intelligent algorithm group. This study selected the particle swarm optimization algorithm to set up the pulse width modulation (PWM) to get the best energy output from the PV solar module. The software implementation of the MPPT charge controller is designed and tested for the PV charging system. The results will be compared to conventional charge controllers such as the perturb and observe (P&O) algorithm. The PSO algorithm can track the global peak of the PV curve with multiple peaks under partial shading conditions. However, conventional algorithms, such as the P&O algorithm, track the optimum PowerPoint at the local peak under partial shading conditions.

II. METHOD

The PV system has two outputs, voltage and current. The product of those outputs is the power which shows the dynamic character as the non-linear curve. Its characteristic curve depicts the output power variation to the output voltage. The output power characteristic curve has one peak as the maximum PowerPoint. In the case of partial shading conditions, the characteristic curve will have multiple peaks. This complex condition needs a controller to maintain the operating PowerPoint at the maximum power range to high efficiency. Simulation in this study is implemented in Simulink MATLAB 2020a.

A. Photovoltaic system

The entire photovoltaic (PV) system discussed in this article comprises PV solar modules, voltage sensors, current sensors, maximum power point trackers (MPPT), DC to DC converters, gate drivers, and resistive loads. This is illustrated in Figure 1. A solar panel with a capacity of 250 watts is broken up into three groups of cells, each receiving a distinct amount of light. It illustrates the partial shading condition.

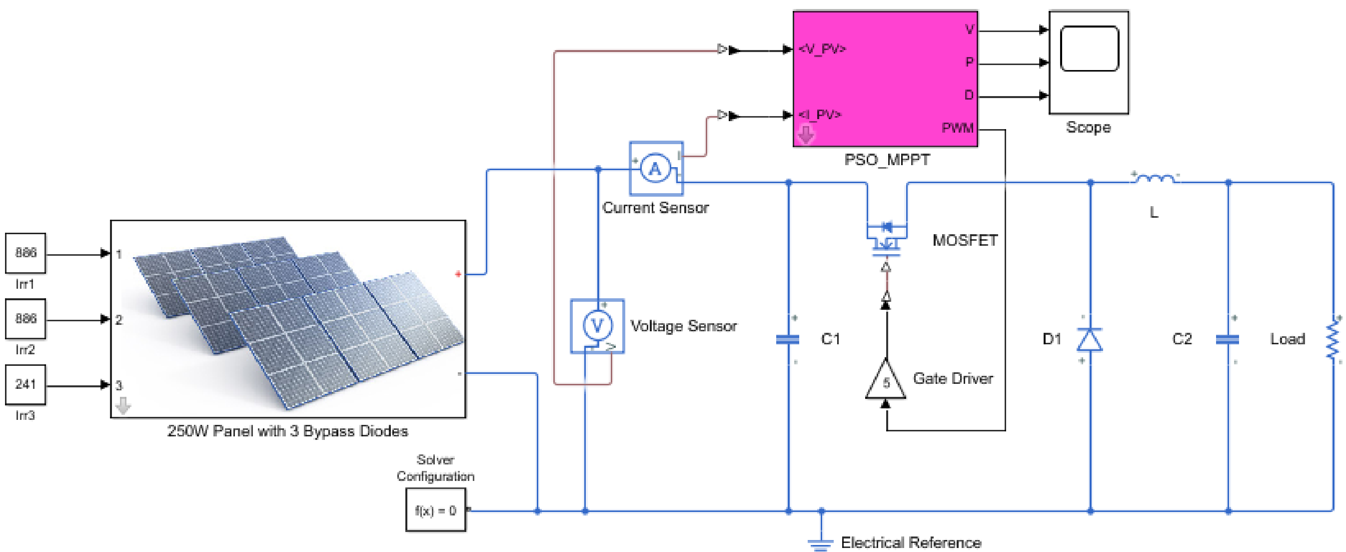

Fig. 1. PV system model in Simulink

The PV module is made from semiconductor technology which generates DC electricity. The equivalent circuit is the most implemented solar cell model. Its PV model consists of a current source, a diode, and a shunt resistor, R_{sh}, connected in parallel, while the resistor R_s is connected in series, as shown in Fig. 2. The Equation of the output current in the equivalent circuit is given as Equation (1) [9].

$$I_{out} = I_{ph} - I_{s,0}\left(\exp\left(\frac{V + IR_s}{aV_t}\right) - 1\right) - \frac{V + IR_s}{R_{sh}} \tag{1}$$

Where I_{ph} as the photocurrent of the solar cell model (A); $I_{s,0}$ as the saturation of reverse current (A); V as the voltage output of the solar cell (V); a is the ideal diode factor of the solar cell; and V_t as the thermal voltage.

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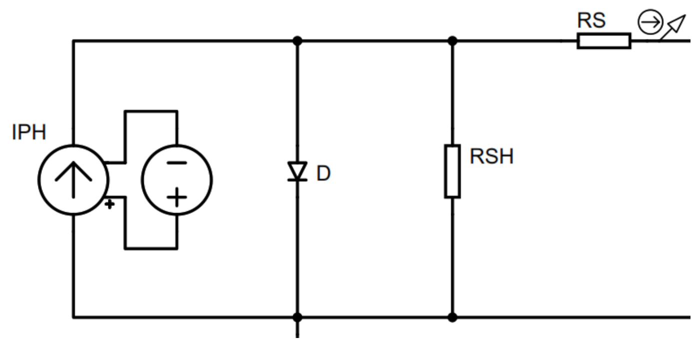

Fig. 2. The PV cell equivalent model

Fig. 3 explains the characteristic curve of P – V obtained from the I-V curve's characteristic curve. In this study, The PV solar panel has a characteristic at standard temperature conditions (STC), as explained in Table I.

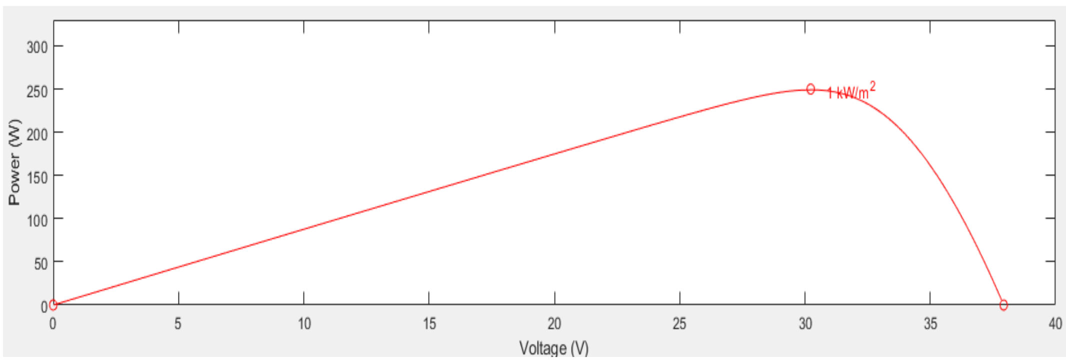

Fig. 3. The P-V Characteristic Curve

The P – V characteristic curve is based on the change of PV current (dP) and voltage (dV). Its PV characteristic curve shows the peak power known as the Maximum Power Point (MPP) [10].

TABLE I
THE PHOTOVOLTAIC SOLAR PANEL PARAMETERS

Parameters	Value
Short Circuit Current (A), I_{SC}	8.75
Open circuit voltage (V), V_{oc}	36.6
Total number of cells	60
Cell Temperature (DegC)	25
Ideality Factor	1.216

B. *Particle Swarm Optimization Algorithm*

The particle swarm optimization (PSO) algorithm is a metaheuristic optimization method influenced by bird flocking or fish schooling social behavior to find their goals in the search space. Each particle will change its position to time. the algorithm is led by local or personal experience (P_{best}) and other particle or overall experience (G_{best}) and decision of the particle to search next position in multidimensional search space. Thus, the PSO algorithm mixes the method of local search and global search [11], [12].

TABLE II
THE PSO PARAMETERS

Parameters	Value
Inertial weight, w	0.6
c_1	2.04
c_2	2.04
r_1	0.6
r_2	0.7

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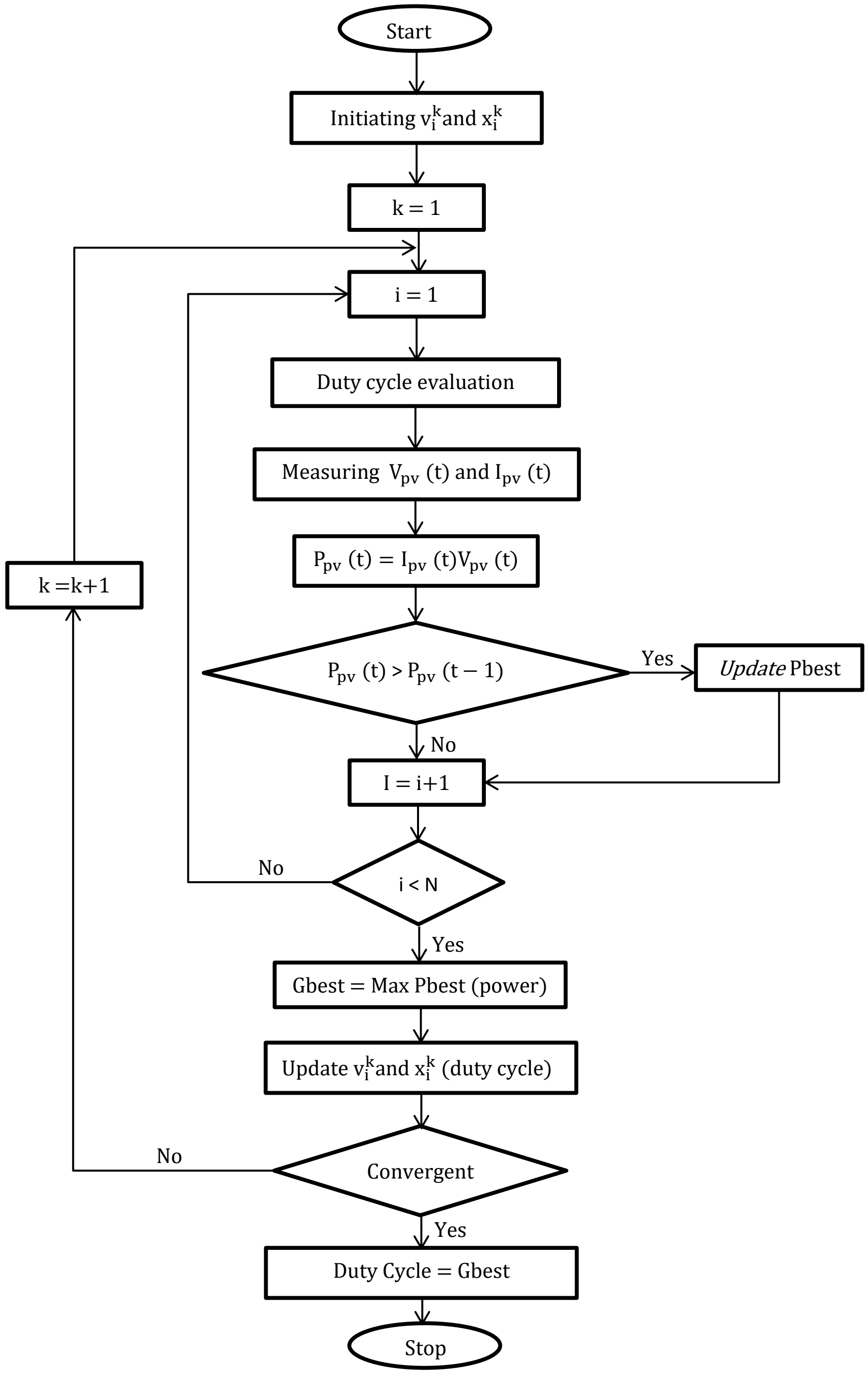

Fig. 4. PSO Algorithm Flowchart

The PSO algorithm is initiated by randomly deciding the first particle position and, following its particle, will look for the optimal value by updating the new position. For each iteration, each particle will update its position based on the best solution for the best local value (P_{best}) and the best solution based on the global population (G_{best}). After that, the velocity and position of particles will be updated using Equations (2) and (3). The parameters of the PSO algorithm are seen in Table II. Furthermore, the PSO algorithm flowchart is explained in Fig. 4.

$$v_i^k = wv_i^k + c_1r_1\left({p_{best}}_i^k\right) + c_2r_2({g_{best}}_i^k - x_i^k) \tag{2}$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \tag{3}$$

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Where the v_i^k variable is the velocity of i^{th} particle and k^{th} iteration, the x_i^k variable is a position of i^{th} particle and k^{th} iteration, the c_1,c_2 variable is acceleration factors, the r_1,r_2 variable is a random variable, between 0 and 1, and w variable is weight.

III. RESULT AND DISCUSSION

This research is designed to optimize the MPPT PV solar system with a PSO algorithm in Simulink MATLAB for the simulation approach. The output variables of performance results are duty cycle, output voltage, and output power from the PV module. The output power performance will be compared using the PSO and the conventional algorithms. One PV module is divided into three group cells, which experience different irradiance, 886 for two groups and 241 Watt/m^2 for another one.

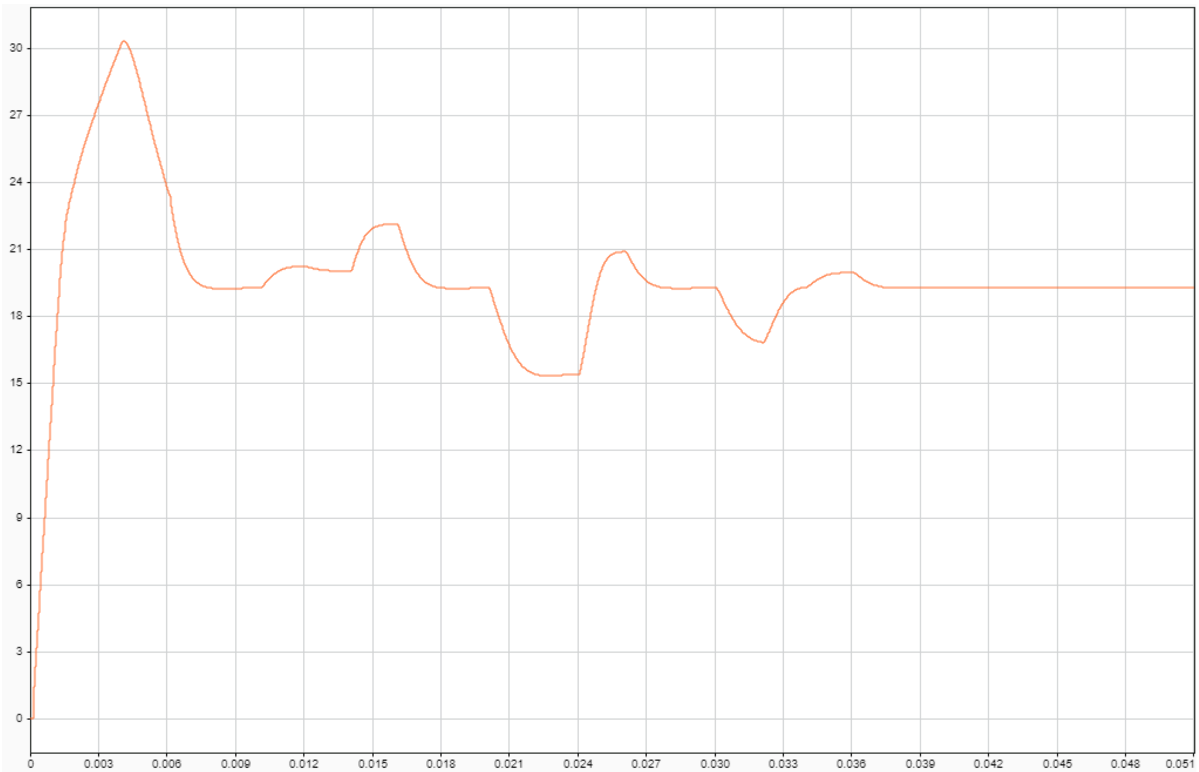

Fig. 5 The Voltage Photovoltaic (PSO)

The simulation approach uses a partial shading condition scenario representing an actual condition of a photovoltaic installation. Variation of Insulation on photovoltaic module surface can generate the multiple peaks of P-V curve characteristic. The proposed PSO and conventional algorithm Perturb and Observe (P&O) will be implemented. These performance results are analyzed and compared. The P&O algorithm described below is also explained. Figure 5 depicts the photovoltaic voltage, whereas the duty cycle performance result is illustrated in Fig.6. The duty cycle experiences the fast change to find the best position of the duty cycle that can maintain the operating PowerPoint at the maximum PowerPoint. This phenomenon will affect the output voltage change from photovoltaic solar panels. The duty cycle position varies before 0.04 seconds. Finally, the duty cycle maintains at about 0.84, and the output voltage is 19.3 volts.

The PSO algorithm begins population initialization by having position X (as duty cycle) and velocity v. In each iteration, the performances will be evaluated using a fitness of practices to find the best particles. Then, the best local performance will be updated, following the global value of the population. The iteration still works until the best performance of global value is reached. Therefore, the PSO algorithm can find PowerPoint global peak under partial shading conditions.

The PSO algorithm performance result is shown in Fig. 7. Although the operating power point experiences three peaks at the maximum power point, finally PSO algorithm can maintain the operating PowerPoint at 129 Watt after time is at 0.04 second in instances of partial shadowing. The PSO algorithm result is compared with the conventional, Perturb and Observe algorithm. The PSO algorithm shows good performance compared with the P&O algorithm. The P&O algorithm cannot find the global maximum PowerPoint. This algorithm operates at 67 Watt at 0.06 seconds, following a steady state. Thus, the PSO algorithm shows a fast response and high efficiency compared with the P&O algorithm.

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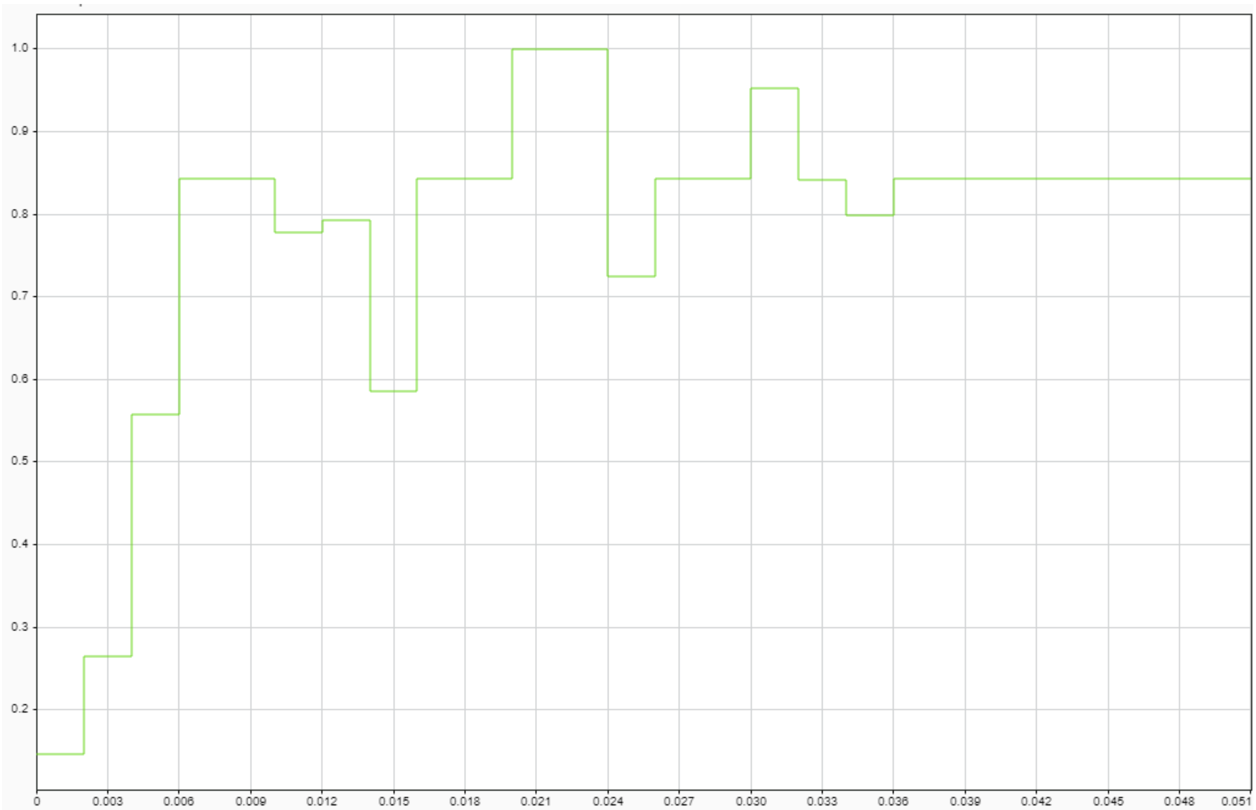

Fig. 6. Duty cycle (PSO)

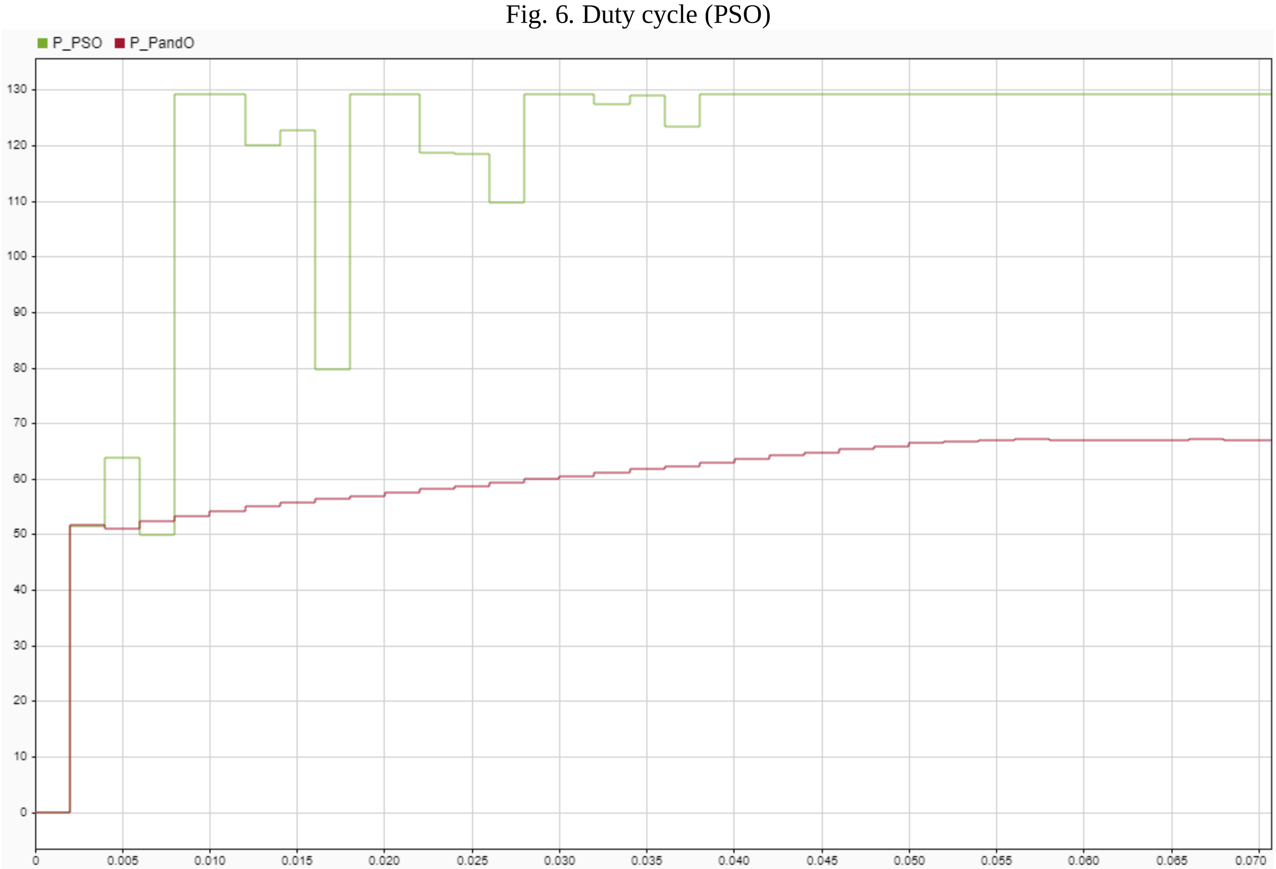

Fig. 7. The Performance Result of MPPT for PSO Compared With Perturb And Observe Algorithm

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IV. CONCLUSION

This research design consists of a PV solar panel module, DC to DC boost converter, MPPT, gate driver, voltage and current sensor, and resistive load. The simulation using Simulink MATLAB result is presented. The inclusion of MPPT PV system simulation results in the expected performance. The PSO algorithm shows the fast response and optimal PowerPoint with the high efficiency, which needs about 0.04 seconds to maintain at the optimal power point, 129 Watt, compared with the perturb and observe algorithm performance that only carries the output power at the lower operating power point, 67 Watt at 0.06 second. Thus, the PSO algorithm can tackle the partial shading condition with a fast response to maintain the maximum PowerPoint. Implementation of hardware and PV array configuration can be considered as future works.

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