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DESIGN OF MAXIMUM POWER POINT TRACKING (MPPT) CONTROLLER BASED ON PARTICLE SWARM OPTIMIZATION ALGORITHM FOR PHOTOVOLTAIC SYSTEM IN PARTIAL SHADING CONDITION (PSC)

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ABSTRACT
Fossil energy still dominates the energy supply, even though fossil energy is non-renewable energy whose supply is decreasing yearly. Fossil energy has a bad impact on the environment, especially on global warming. The use of renewable energy sources for power generation is increased, such as solar photovoltaic systems that convert solar radiation into electrical energy. Non-linear changes in solar radiation intensity (insolation) and panel surface temperature are the main problems of photovoltaic systems for effective energy conversion. Besides temperature and insolation, partial shading condition (PSC) also greatly influences solar cells characteristics. This partial shading condition (PSC) causes the output characteristics of the PV module to become more complex and shows several peaks in its characteristic curve. The controller is needed to keep photovoltaic operating at its highest maximum power point in partial shading conditions. In this paper, the Maximum Power Point Tracker (MPPT) method with particle swarm optimization (PSO) algorithm is used to maximize power output to be at the maximum area (Maximum Power Point). The parameters of the PSO algorithm will be set in such a way that it can reach the MPP point in a relatively short time. This paper depicts that the PSO algorithm can maintain power at 15 W at 0.6 seconds under partial shading conditions. Therefore, the PSO algorithm is the right solution to track the optimal operating power point under partial shading conditions.

Keywords:
Renewable Energy Source (RES), Solar Photovoltaic Systems, Partial Shading Condition (PSC), Maximum Power Point Tracker (MPPT), Particle Swarm Optimization (PSO)

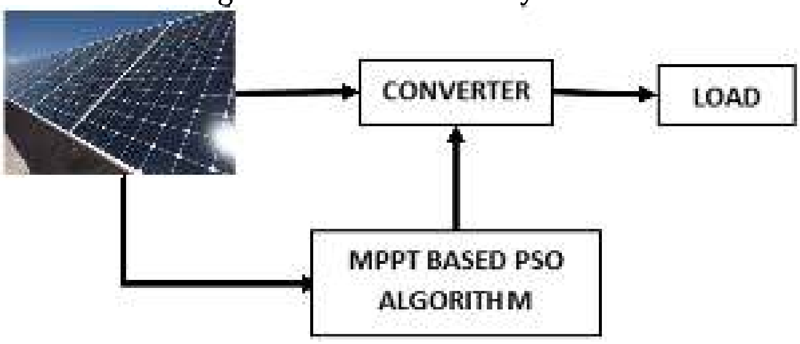
INTRODUCTION
Indonesia has big challenges in energy management, especially challenges in implementing renewable energy sources (RES). Fossil energy still dominates the supply of energy, even though fossil energy is a non-renewable energy whose supply is decreasing every year and has a negative impact on the environment, especially regarding global warming. Therefore, the use of RES as an alternative to non-renewable energy is considered very important in managing domestic energy. The government is intensifying the application of RES to minimize the use of fossil energy and its negative impact on the environment. RES is the purest energy because it comes from nature and its supply is very abundant in the universe. For example: sun, wind, river, plants and so on.

The need for electricity in Indonesia increases significantly every year. Even though in 2020 the need for electricity had decreased by 7% due to the COVID-19 pandemic, after 2021 the need for electricity has increased again and expected to continue to increase in accordance with economic growth, population, energy prices and government policies. Currently, coal dominates the utilization of fossil energy as the main supplier of electricity generation in Indonesia. To reduce dependence on fossil energy and minimize the environmental impacts, the use of renewable energy source (RES) for electricity generation must always be increased. One of RES that will be analyzed in more deTAIL is increasing the utilization of solar power plants (Dr. Edi Hilmawan dkk., 2021).

The Indonesian government has taken several steps to increase the use of renewable energy. One of them is by adding new power generation based renewable energy source (RES) after the Indonesian economy recovers as usual. Mainly in the providing of cheap and clean electricity such as Solar Power Plants. Solar Power Plants consist of a solar panel system or photovoltaic (PV) system that converts solar radiation into electrical energy. Non-linear changes in solar radiation intensity (insolation) and panel surface temperature are the main problems of photovoltaic systems for effective energy conversion. Besides temperature and insolation, partial shading also shows a major influence on the characteristics of solar cells. When more than one PV module is connected and one of them is exposed to partial shading, the insolation received by the two modules will be different. This partial shading condition causes the output characteristics of the PV module to become more complex and shows several peaks in its characteristic curve. To overcome the non-linear PV system and the complex output characteristics of PV modules, needed a PV controller using the Maximum Power Point Tracker (MPPT) method with an algorithm that can keep photovoltaic operating at its highest efficiency point (Afroni Mohammad Jasa et al., n.d.; Verma et al., 2016; Wirateruna et al., 2022).

This research discusses a control system that can maximize the photovoltaic system capabilities by using the Maximum Power Point Tracker (MPPT) method, which is a method that works by tracking the highest output power point of the photovoltaic system. The MPPT control system will manage the power of the photovoltaic system through a converter that controlled by a PWM (Pulse Width Modulation) signal from the duty cycle resulting from the MPPT algorithm operation. One of the MPPT algorithms is Particle Swarm Optimization (PSO) algorithm. MPPT optimization using the Particle Swarm Optimization (PSO) algorithm is a programming method used to maximize power output to be at the maximum area (Maximum Power Point). The parameters of the PSO algorithm will be set in such a way that it can reach the MPP point in a relatively short time.

Figure 1 The MPPT PV System



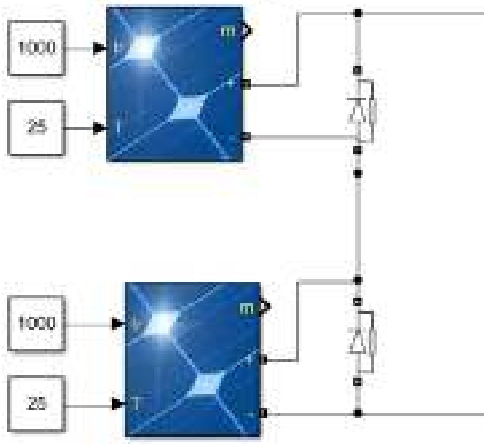
The MPPT PV system process starts from the resources to the load part of the system which consists of four main parts, namely the source (photovoltaic), converter, MPPT with the PSO algorithm and load. The MPPT PV system block diagram is shown in Figure 1 above.

METHOD

Design of PV

The PV module that used in this research is a polycrystalline PV type from Staryu products. The modeling that used in this study is the MATLAB R2020a simulink. The PV array consists of 2 PV modules arranged in series to form 1 string as shown in Figure 2.

Figure 2 Array PV model



The specifications for the PV module on the MATLAB simulink are shown in Table 1:

Table 1 PV Module Specifications

Modul PV	***P-10W***
Maximum Power (Pmax) (W)	*10*
Maximum Power Voltage (Vmp) (V)	*17.5*
Maximum Power Current (Imp) (A)	*0.571*
Open Circuit Voltage (Voc) (V)	*21*
Short Circuit Current (Isc) (A)	*0.64*
Maximum System Voltage (VDC)	*1000*
Cell Temperature (DegC)	*25*

Design of The MPPT Method

One of the MPPT algorithms is Particle Swarm Optimization (PSO) which was first introduced by Dr. Eberhart and his colleague Dr. Kennedy in 1995. PSO is a search optimization algorithm based on animal populations that look for food sources such as fish and bird populations. This optimization technique starts with a random population or is called a particle. In general, population-based optimization techniques seek an optimal point or solution using the population of its own particles. The search for optimal solutions in PSO includes a solution space that contains optimization variables (Eberhart & Kennedy, 1995)

The PSO algorithm starts by generating random particles and then each particle moves through the search space to find the best solution value. This collection of particles (swarm) continues to move and update the position of the particles until it reaches the best solution. Each particle has two values: the first is the local best value (Pbest) and the second is the global value (Gbest). The position of a particle is changed in several iterations with a certain speed based on the experience of the particle and the group. After that, the velocity and position of the particle will be updated using Equations (1) and (2).

$$v_i^k = \omega . v_i^k + c_1 . r_1 \left(p_{best}{}_i^k - x_i^k \right) + c_2 . r_2 \left(g_{best}{}_i^k - x_i^k \right) \quad (1)$$

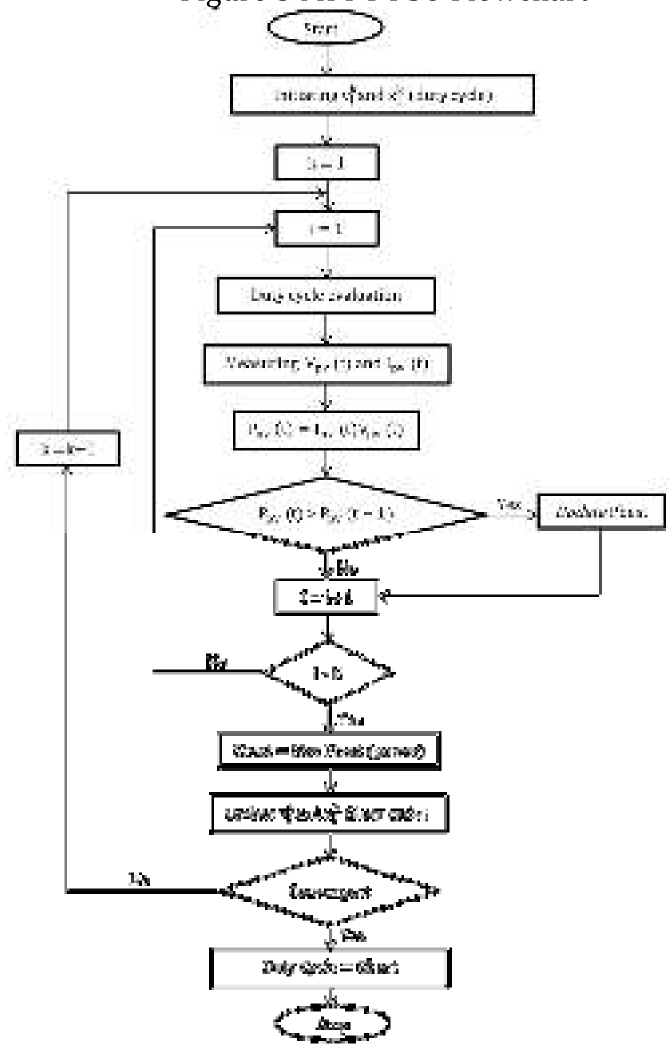
$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (2)$$

Where the variable v_i^k is the velocity of particle i in iteration k, variable x_i^k is the position of particle i in iteration k, variables c_1 and c_2 are acceleration parameters (acceleration factor), variables r_1 and r_2 are random numbers spread in the range between 0 to 1 and the variable ω is a constant number called the inertia parameter (Mubarok & Whiancaka, 2020; Wirateruna & Millenia, 2022).

In this study, MPPT with the PSO algorithm was used to find GMPP (Global Maximum Power Point) with reference to the output power of the PV and the output of the controller (duty cycle). Implementation of Maximum Power Point Tracking using the Particle Swarm Optimization (PSO) algorithm on simulink is shown in Figure 3 below. In designing the PSO algorithm for MPPT, particles are likened to the duty cycle of the PWM signal. The PSO algorithm expresses the position and velocity of the particles as the value of the duty cycle.

The input of the PSO algorithm is the multiplication of the current and voltage values from the PV to find the power used to get the duty cycle value that will be entered into the converter. After entering the duty cycle value into the converter, the output voltage and current values of the converter will produce a power value which is then analyzed to determine the local maximum value and optimal output power. The PSO algorithm flowchart is shown in Figure 3.

Figure 3 MPPT PSO Flowchart



Design of Boost Converter

The boost converter is the main component of the MPPT PV system. The boost converter can operate in on-state condition and off-state conditions, these operation conditions are based on the switching of PWM produced by the MOSFET driver. The comparison of the output voltage Vo and the input voltage Vin is explained in the following equation to generate the duty cycle D.

$$\frac{V_o}{V_{in}} = \frac{1}{1-D} \tag{3}$$

To calculated the inductance using equation 4. Where: R is the resistive load and the $fmin$ is the minimum frequency.

$$L_{min} = \frac{D(1-D)^2 R_{max}}{2 f_{min}} \tag{4}$$

To filter the output voltage in the stable voltage, the boost converter needs to calculate the minimum capacitance (Irkham dkk., 2018).

$$C_{min} = \frac{D}{\%V_r . R . f_{min}} \tag{5}$$

Table 2. The boost converter specification

Parameter	Nilai
The input voltage	17,5
The output voltage	50
Resistor	100 Ω
Induktor	120,6 μH
Kapasitor	19,7 μF
Frekuensi switching	33kHz

RESULT AND DISCUSSION

The purpose of designing a PV system with simulink matlab is to find out how the performance of the PV system is and to see the response performance of the MPPT with the PSO algorithm on matlab simulink under various conditions, in Figure 4 the results of the MPPT PV system design are shown. The first condition is during normal conditions when PV is in a Standard Test Condition (STC) state (temperature of 25ºC and a light intensity of 1000 W/m^2). The I-V P-V characteristic curve under normal conditions in the simulation is shown in figure 5. Based on Figure 6 it shows that the voltage graph starts to stabilize at a fairly fast time, namely 0.6S. Figure 7 shows that the output power of the tracking results using MPPT PSO has a good level of accuracy and relatively fast tracking, which is around 0.6S to reach a stable state.

Figure 4 PSO ALGORITHM

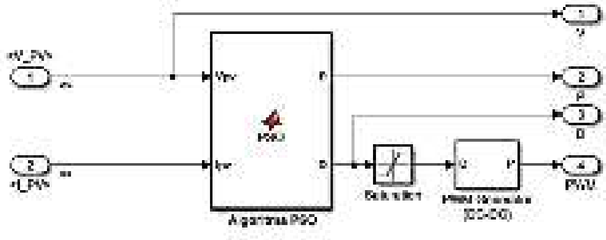


Figure 5 Simulink simulation of the PV MPPT system

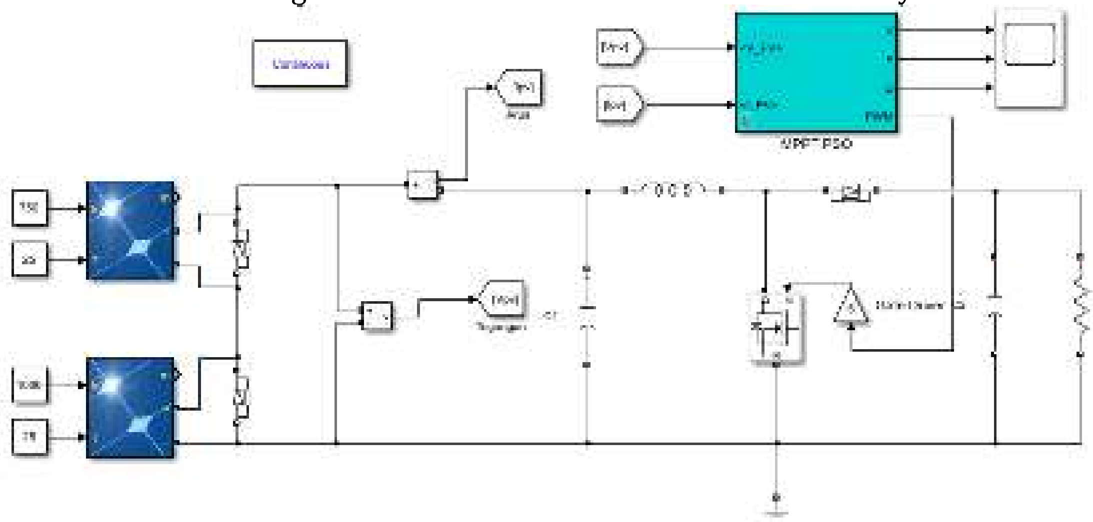


Figure 6 The I-V P-V curve in normal conditions

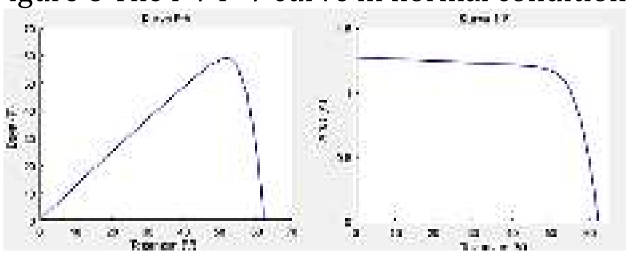


Figure 7 the Graph of (V)-(t) in normal conditions

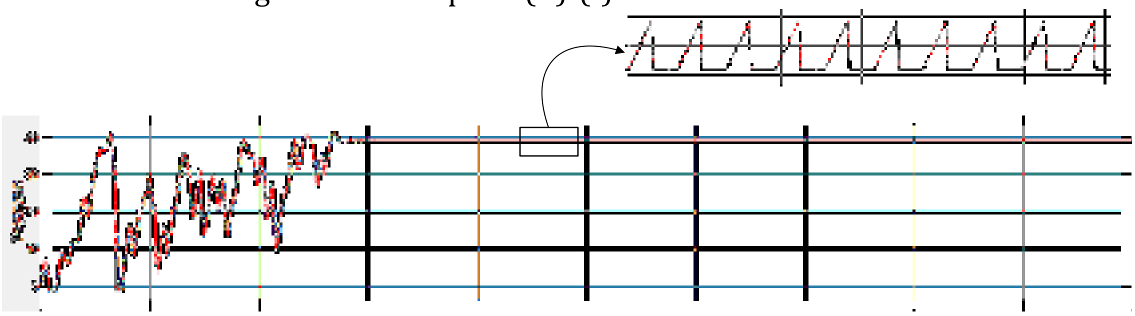


Figure 8 the Graph of (P)-(t) in normal conditions

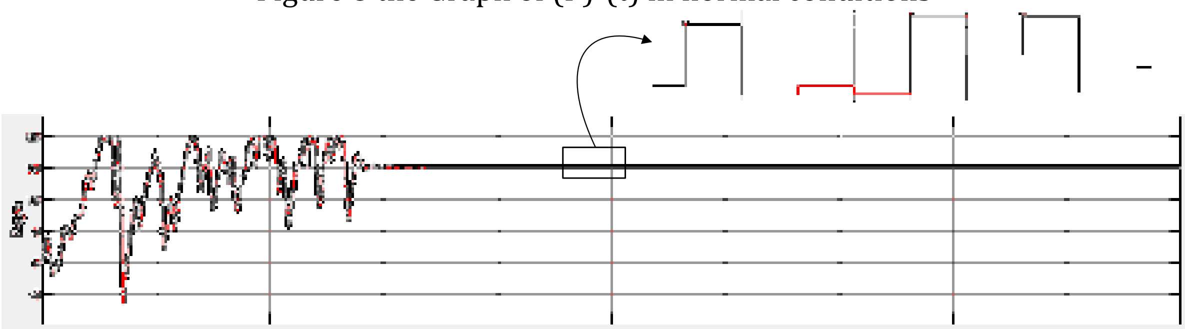


Figure 9 The I-V P-V curve in partial shading conditions

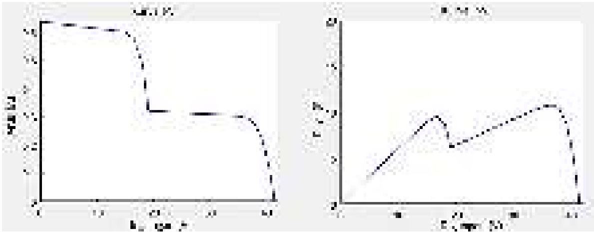


Figure 10 the Graph of (V)-(t) in partial shading conditions

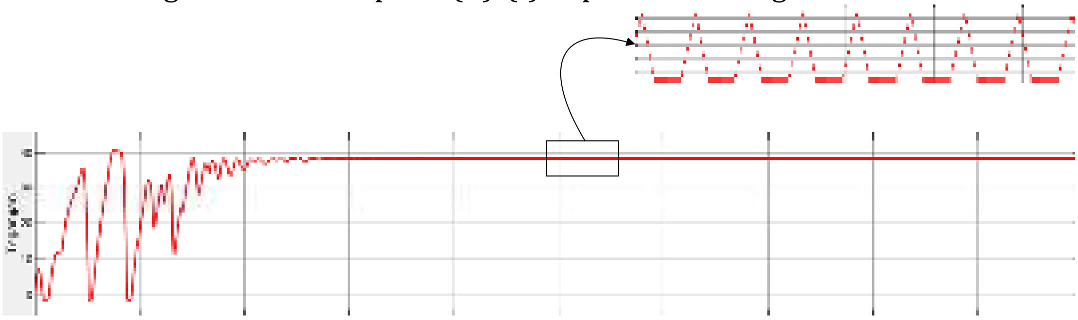
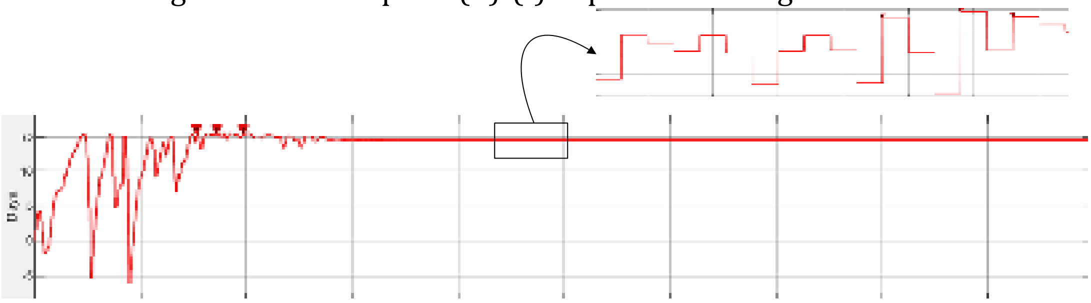


Figure 11 the Graph of (P)-(t) in partial shading conditions



MPPT testing based on the PSO algorithm under partial shading condition (PSC) when the PV is partially shaded. The I-V P-V characteristic curve under partial shading conditions in the simulation is shown in figure 8. Based on Figure 9 it shows that the voltage graph starts to stabilize in a relatively short time, namely 0.58S. Figure 10 shows that the output power of the tracking results uses MPPT PSO.

CONCLUSION

The MPPT PV system consists of the PV module 20 WP in series, the DC-DC boost converter, MPPT controller, and the resistive load. The simulation results of the MPPT PV system based on PSO algorithm using a boost converter show a good performance, it can reach the MPP point in a relatively short time. This paper depicts that the PSO algorithm can maintain power at 15 W at 0.6 seconds under normal and partial shading conditions.

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