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Implementation of Solar Panel Static Mppt on Partial Shading Conditions Based on the Boost Topology Converter with Firefly Algorithm

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Abstract

Indonesia has a large potential for new and renewable energy, one of which is solar energy. Solar energy can be converted into electrical energy using solar panels. The output power of a photovoltaic (PV) system is primarily affected by ambient temperature, solar irradiation, and the angle of incidence of the sun. Differences in the level of solar irradiation received by PV modules can be caused by cloudy weather, trees, buildings, and other objects that can cover the surface of the solar panels. When a PV module is partially shaded, the power output of the module becomes imbalanced. Unbalanced output power can cause multiple peaks on the PV characteristic curve, reducing overall output power. To obtain global-peak, a method for maximizing solar panel output power and an algorithm are required. The method is MPPT (Maximum Power Point Tracking). The goal of this research is to determine the maximum power point of PV in the condition of a partially shaded PV module and to design a boost converter. In this study, the MPPT control method with the Firefly algorithm is used to analyze solar panel output power in partially shaded conditions in order to avoid being trapped in the local peak. At 950 W/m2 irradiation and 35°C temperature, the maximum power output generated by the MPPT system on a 200 WP solar panel with the value of 56 Ω and 100 Ω loads is 82.85 W and 82.99 W. In partial shaded conditions on the solar panel by 25% at a temperature of 35ᴼC, the maximum power output generated by MPPT is 40.98 W and 40.82 W. In partial shaded conditions on the solar panel by 50% at a temperature of 35ᴼC, the maximum power output generated by MPPT is 38.81 W and 38.95 W. Partial shading conditions affect the maximum power point gain. The maximum output power of the panel will decrease as the panel surface is partially shaded.

Keywords: Boost converter, MPPT, Solar panel, Firefly Algorithm

1. Introduction

1.1 Introduce the Problem

Indonesia has a large potential for renewable energy, one of the highest potential is solar energy. Solar energy is one of the renewable energy sources with the highest potential, which is 207,898 MW, but the installed generating capacity is only 0.03% [Ditjen EBTKE, 2016]. The utilization of solar energy used in the last few decades is the Photovoltaic (PV) system which is a technology to generate direct current (DC) electric power measured in watts (W) or kilowatts

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(kW) from semiconductors when irradiated by photons [A. Luque and S. Hegedus, 1964]. PV output power is influenced by environmental factors, namely the presence of trees, tall buildings, clouds, and weather changes or what is called partial shadow on PV resulting in uneven irradiation on the surface of the solar panel so that the system output power will decrease drastically [M. Miyatake et al., 2011]. Therefore, a more inclusive tracking method is needed to overcome this problem. MPPT or Maximum Power Point Tracking is a tracking method so that the output power of solar panels is maximized under conditions of varying temperature and environmental irradiation. [D. S. Morales, 2010]. Efforts to increase point tracking to achieve maximum power points with algorithms are easier than increasing the efficiency of panels and inverters that depend on existing technology.

Basically, MPPT's accuracy in finding the maximum power point value is the most important aspect. The initial development of MPPT used traditional techniques, namely Perturb and Observe (P&O) and Incremental Conductance. However, these methods still have not overcome the output curve with multi peaks caused by partial shadow conditions in the PV array [K. H. Chao et al., 2015]. The right algorithm for the MPPT problem under partial shadow conditions is a metaheuristic algorithm that can obtain global peaks by utilizing randomization so that the algorithm does not get stuck at local peaks and allows global searches [D. F. Teshome et al., 2017]. Some commonly known metaheuristic algorithms include Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), and Firefly Algorithm (FA).

In this final project, the design and manufacture of a PV output power optimization system is carried out using a direct current boost converter with the Firefly algorithm. Firefly algorithm was chosen because the computational load is lower than PSO [S. D. Nugraha et al., 2016]. The output voltage value will be greater than the input voltage because it is increased by the boost converter, then connected to the load [M. H. Rashid].

1.2 Literature review

Photovoltaic (PV) cell is a semiconductor device that conducts electricity. PV cells have a function to convert solar energy to produce DC electrical energy. The PV cell will continue to produce electrical energy as long as the semiconductor material is exposed to light and if it is not exposed to light, the PV cell will stop producing electrical energy [Ditjen EBTKE, 2016].

The combined PV cells will form a solar panel, while the combined solar panels will form an array of solar cells [Y. Baghzouz, 2013]

The PV cells that are joined into a PV block are called PV modules. A PV unit cell is capable of generating a voltage of 0.5-0.8 volts. This voltage value is very small for commercial use, so that the PV cell can produce a voltage large enough to charge at least a 12 volt battery, the PV cell is connected into a module [S. Nema and R. Nema, 2010].

A combination of several PV modules arranged in series and/or parallel is a PV array. The I-V curve of a PV array with a larger scale than a single module is illustrated as shown in Figure 2.4 [Solmetric, 2011].

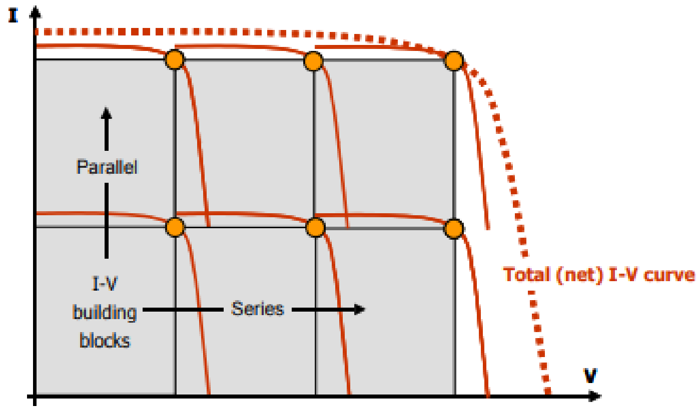

Figure 1.PV array curve composed of series-parallel arrangement

1.3 Research design steps

The system design in this study consists of 5 parts, namely 2 100 WP PV modules connected in series, the design of the boost converter power circuit, the design of the control circuit, the design of the MOSFET driver circuit and the design of the MPPT algorithm. Figure 3 is a block diagram of the system design.

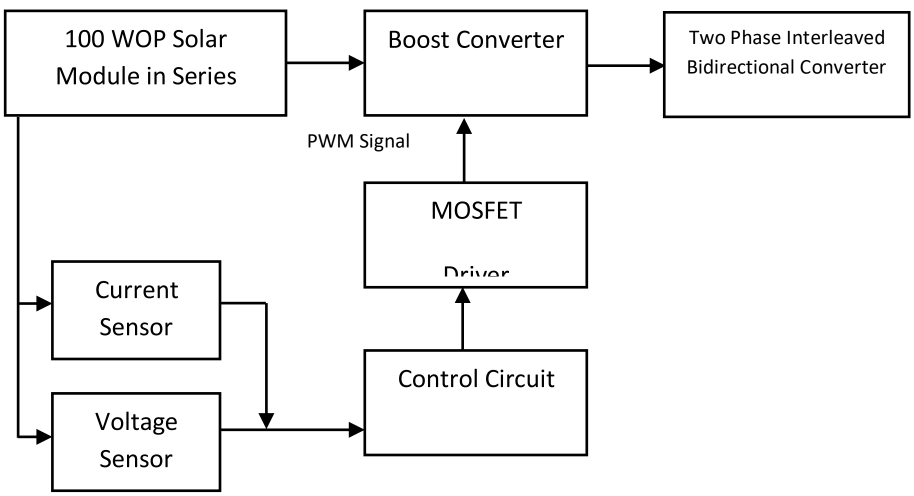

Figure 2. Hardware design block diagram

2. Method

2.1 Power Circuit Design

A direct current converter with a boost type converter topology is used as a power circuit in this study. The boost converter functions as a voltage booster so that the output voltage value is greater than the input voltage with the same polarity between the input and output voltages. The boost converter has the specifications shown in Table 2.

Table 1. Boost Converter Circuit Specifications

Specification	Value
Input Voltage	0 – 43,7 V
Output Voltage	60 V
Maximum Current	5,5 A
Duty Cycle(D)	10% - 70%
Switching Frequency(FS)	20 kHz

The boost converter circuit consists of five components, namely MUR1560 diode [9], Metal Oxide Semiconductor Field Effect Transistor or MOSFET IRFP460 [10], inductor, capacitor, and resistive load. The boost converter is realized using the following components which can be seen in Table 3.

Table 2. Boost Converter Components

Component	Type/Value
MOSFET	IRFP460
Diode	MUR1560
Inductor	450µH
Kapacitor	330µF/250V
Resistor	47 Ω, 56 Ω, dan 100 Ω

2.2 Control Circuit Design

The design of the control circuit for this research includes three parts, namely the design of the PWM generator circuit using Arduino Nano, the design of the current sensor and the design of the voltage sensor.

This research uses Arduino Nano controller circuit. The function of the Arduino Nano as a data receiver from the voltage and current that is read from the boost converter and by the microcontroller is processed to execute the MPPT algorithm. The operating frequency selected for programming Arduino Nano is 20kHz. The PWM output pin on the Arduino Nano is pin 3. [Arduino Nano Specifications Datasheet].

This design uses ACS712-20A current sensor. The reason for choosing the ACS712-20A current sensor to be used in this research is because the maximum current value that passes through the sensor can reach 20 A. The maximum output current of the solar panel is 11.33 A, so the selection of the ACS712-20A current sensor is correct. The sensitivity of the current sensor is enhanced by a signal amplifier built into the ACS712-20A current sensor. [DT-Sense Current Sensor ACS712 Datasheet]. Gain and offset to adjust is done via two potentiometers. The offset and gain potentiometer settings are set so that the output voltage produced by the sensor is 5 V above 12 A. This value adjustment is due to the maximum output current limit where the maximum value of the solar panel is 11.33A. When the current is 0 A the sensor is configured to produce an output voltage of 1 V. Adjustment of the potentiometer is made to achieve a sensitivity value of 1 V/A.

2.3 Driver Circuit Design

TLP250 is used as a MOSFET driver circuit for this research design. The reason for using the MOSFET driver circuit is due to its isolation function, so that the power circuit ground with a separate control circuit [TOSHIBA, 2002]. Not only that, the TLP250 is also able to amplify the PWM signal generated by the control circuit from a voltage of 5 V to a PWM signal with a voltage of 15 V, so that changes in the condition of the IRFP460 MOSFET which requires a VGS voltage of ± 20 V can be triggered.

2.4 MPPT Algorithm Design

This study uses the Firefly algorithm as the MPPT algorithm for tracking the maximum power point of the solar panel in partial shading conditions. The Firefly algorithm is a tracking method used to obtain the maximum power point of the solar panel which in this study is in a partial shadow condition inspired by the behavior of fireflies in attracting the opposite sex. Fireflies are assumed to be asexual so that individuals will be attracted to other individuals in the population [I. Robandi]. In this study, the number of duty cycles distributed represents the number of firefly populations to find the maximum power point. Factors that show attraction between fireflies are used as beta factors [I. Robandi].

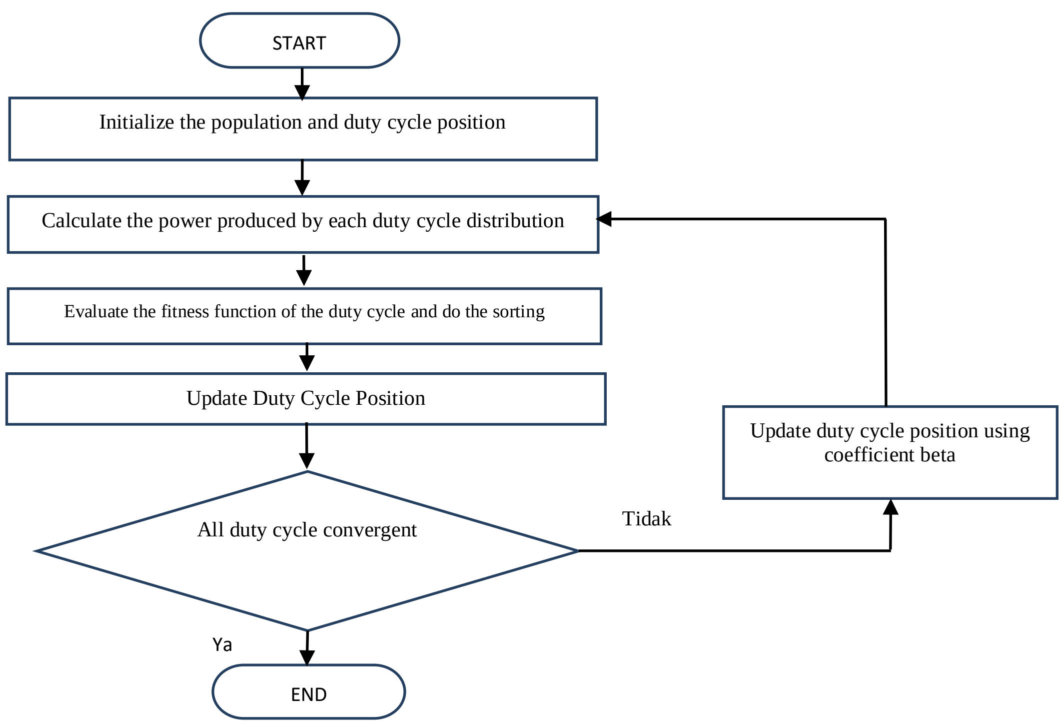

Figure 3. Firefly Method Flow Diagram

3. Results

3.1 Solar Panel Module Testing

The solar panels were tested to analyze their characteristic curves under partial shading conditions. The solar panel output is connected to a rheostat which is set to change the current and voltage values of the solar panel output. Characteristic curves can be formed due to changes in the current value and output voltage of the solar panel. The characteristics of the solar panels were tested at 950 W/m^2 of irradiation on 100 WP solar modules that were not covered by shadows and 95.3 W/m^2 of 100 WP solar modules that were covered with shadows at a temperature of 35ºC. The power value is obtained from the product of the current and voltage values produced by the solar panel.

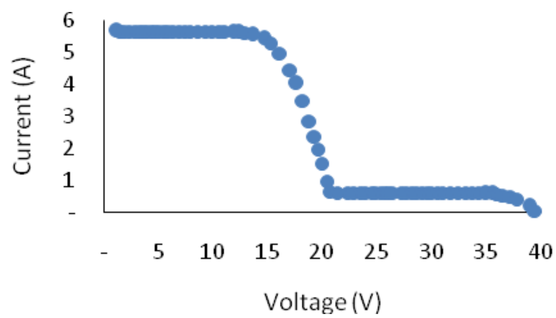

Figure 4. Current-voltage curve

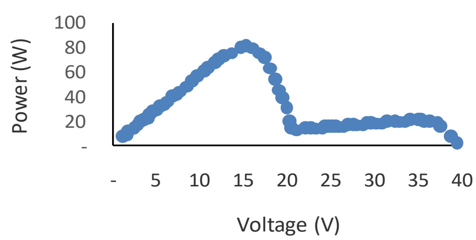

Figure 4. Power-voltage curve

Figures 6 and 7 are characteristic curves of solar panels. The maximum power is at a point of 80.77 W with a voltage of 15.24 V and a current of 5.30 A when the partial shading irradiation condition is 950 W/m2 on a 100 WP solar module that is not covered by shadows and 95.3 W/m2 on a solar module. 100 WP sun that is not covered in shadow with a temperature of 35ºC.

3.2 Power Circuit Test

The performance of the boost converter is measured in a power circuit test to determine the efficiency and gain of the boost converter. In this test, measurements of voltage and current values were carried out. The value of the load and duty cycle that is varied aims to see the value of the voltage and current both on the input and output sides that change in the boost converter circuit.

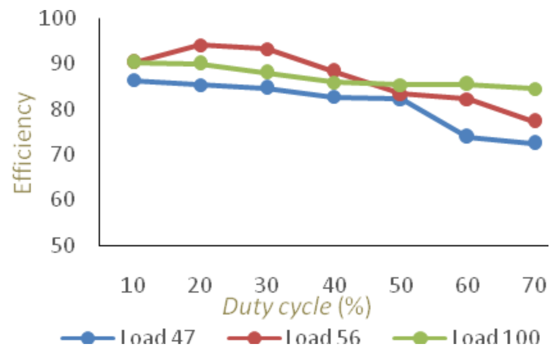

Figure 5. Efficiency of boost converter with duty cycle variation

Based on Figure 8, the average value of boost converter efficiency with a load of 47Ω , 56Ω , and 100Ω respectively is 81.06%, 86.94%, and 87.01%. Power dissipation or wasted power from the components that make up the boost converter circuit in an operating state makes the boost converter efficiency value not 100%. The decrease in efficiency value is also due to the larger duty cycle value. A large duty cycle value will result in a longer MOSFET switching duration in the active state. When the MOSFET switch is active, the inductor will experience charging due to the input voltage from the boost converter to the inductor. If the value of the duty cycle is also greater, the duration of charging the inductor will also increase. Therefore, the decrease in the boost converter efficiency value can be caused by a decrease in the voltage on the output side of the boost converter circuit because the inductor is constantly being charged until it reaches its saturation point.

3.3 MPPT Test

The MPPT algorithm testing has the aim of realizing that the algorithm is successful in tracking the power point in the solar panel's maximum operating area. The MPPT algorithm test was carried out with three conditions. The first condition is when the 200 WP panel is not covered in shadow so that the third gets the same solar irradiation, namely 950 W/m^2 and a temperature of 35ºC, the second condition when the panel is covered in shadows by 25% of the total panel surface area, and the third condition when the panel is covered by 50% shadow. of the total panel surface area. The irradiation on the panel covered with shadow is 95.3 W/m^2 at 35ºC, while the irradiation for the panel that is not covered in shadow is 950 W/m^2 at 35ºC. In testing the MPPT algorithm, the load used is a resistor with a value of 56 Ω and 100Ω.

The first MPPT test was carried out at 950 W/m^2 of irradiation and 35ºC with the condition that both panels were not covered in shadows. This test uses 2 different load values, namely 56Ω and 100Ω.

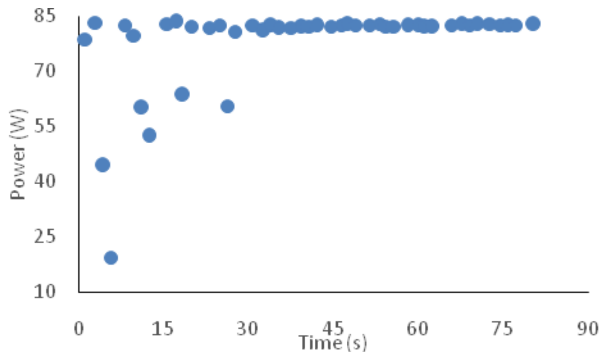

Figure 6. MPPT graph with 56Ω load

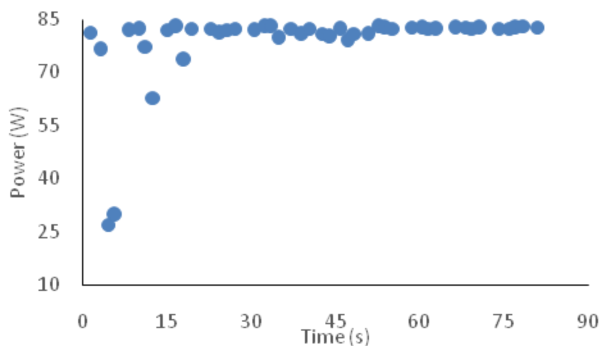

Figure7. MPPT graph with 100 Ω load

The second condition MPPT test was carried out at 25%. The total surface of the 200 WP panel is covered in shadow with the irradiation hitting the panel surface is 95.3 W/m^2 and the irradiation is 950 W/m^2 at a temperature of 35°C. This test uses 2 variations of the load value, namely 56 Ω and 100 Ω.

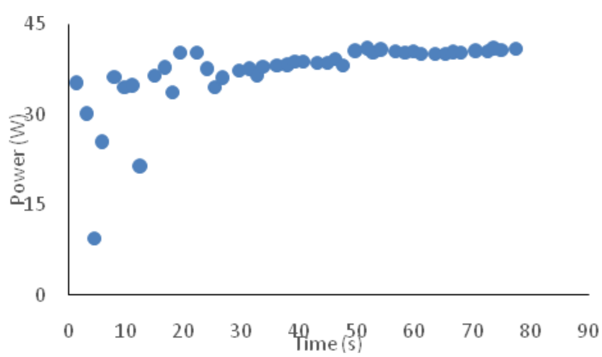

Figure 8. MPPT graph of panel surface covered with 25% shadow with load 56Ω

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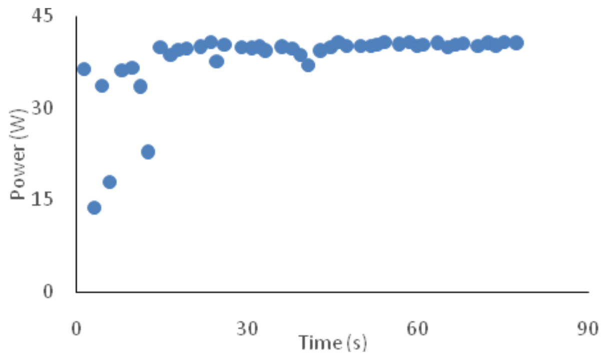

Figure 9. MPPT graph of panel surface covered with 25% shadow with load 100Ω

The third condition MPPT test was carried out in the condition that 50% of the total surface of the 200 WP panel was covered in shadow. The irradiation that hits the surface of the 100 WP panel is 95.3 W/m^2 and 950 W/m^2 at a temperature of 35°C. This test uses 2 variations of the load value, namely 56Ω and 100Ω.

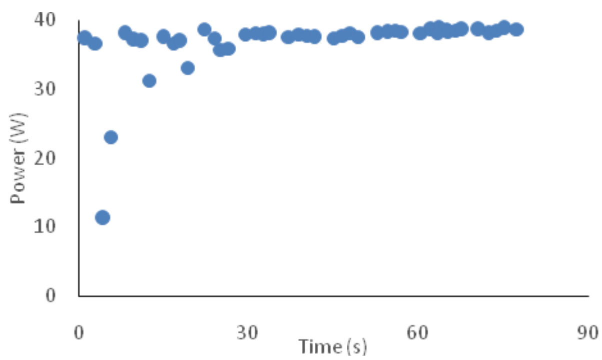

Figure 10. MPPT graph of panel surface covered with 50% shadow with load 56Ω

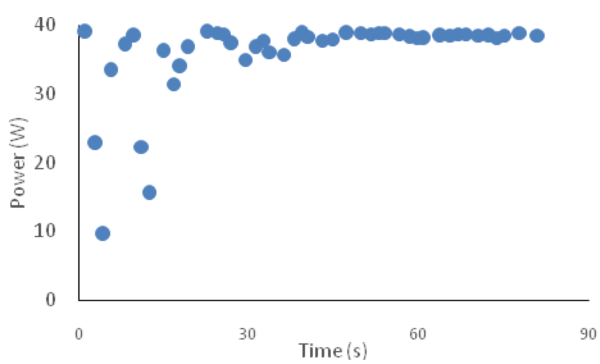

Figure 11. MPPT graph of panel surface covered with 50% shadow with load 100 Ω

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4. Discussion

The conclusion that can be drawn from the results of the testing and analysis of this research is that the solar panel maximum power point tracking system with the firefly algorithm has been realized. In the first test maximum power point where the 200 WP solar panel surface gets the same irradiation, namely 950 W/m2 with a load variation of 56 and 100 , the maximum MPPT output power is 82.85 W and 82.99 W, respectively. the second maximum power point test where the panel surface is covered with a shadow by 25% with a load variation of 56 and 100 , the maximum MPPT output power is 40.98 W and 40.82 W respectively. In the third condition maximum power point test where the surface 50% shaded panel with a load variation of 56 and 100, the maximum MPPT output power is 38.81 W and 38.95 W respectively. Partial shading conditions affect the maximum power point gain. The more the panel surface is covered, the maximum output power of the panel will decrease.

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References

Ditjen EBTKE, "Statistik EBTKE 2016," p. 68, 2016.

A. Luque and S. Hegedus, *Handbook of Photovoltaic Science and Engineering*, vol. 129. 1964.

M. Miyatake, M. Veerachary, F. Toriumi, N. Fujii, and H. Ko, "Maximum power point tracking of multiple photovoltaic arrays: A PSO approach," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 47, no. 1, pp. 367–380, 2011, doi: 10.1109/TAES.2011.5705681.

D. S. Morales, "Maximum Power Point Tracking Algorithms for Photovoltaic Applications," 2010.

K. H. Chao, Y. S. Lin, and U. D. Lai, "Improved particle swarm optimization for maximum power point tracking in photovoltaic module arrays," *Appl. Energy*, vol. 158, pp. 609–618, 2015, doi: 10.1016/j.apenergy.2015.08.047.

D. F. Teshome, C. H. Lee, Y. W. Lin, and K. L. Lian, "A modified firefly algorithm for photovoltaic maximum power point tracking control under partial shading," *IEEE J. Emerg. Sel. Top. Power Electron.*, vol. 5, no. 2, pp. 661–671, 2017, doi: 10.1109/JESTPE.2016.2581858.

S. D. Nugraha, E. Wahjono, E. Sunarno, D. O. Anggriawan, E. Prasetyono, and A. Tjahjono, "Maximum power point tracking of photovoltaic module for battery charging based on modified firefly algorithm," *Proc. - 2016 Int. Electron. Symp. IES 2016*, pp. 238–243, 2017, doi: 10.1109/ELECSYM.2016.7861009.

M. H. Rashid, *POWER ELECTRONICS Academic Press Series in Engineering*.

Y. Baghzouz, "Photovoltaic Devices III," 2013.

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ISSN: 2456-3676

S. Nema and R. Nema, “Matlab / simulink based study of photovoltaic cells / modules / array and their experimental verification,” *Int. J. Energy Environ.*, no. June 2014, 2010.

Solmetric, “Guide To Interpreting I-V Curve Measurements of PV Arrays,” *Appl. Note PVA-600-1*, p. 23, 2011.

Intersil, “Mur1540, mur1560, rurp1540, rurp1560,” *Current*, no. October, 2008.

“MOSFET IRF460 Datasheet,” no. 2291, pp. 359–365, 1999.

“Arduino Nano Specifications Datasheet,” pp. 38–45.

“DT-Sense Current Sensor ACS712 Datasheet, Innovative Electronics,” pp. 1–15.

TOSHIBA, “TLP 250,” vol. 250, pp. 1–6, 2002.

I. Robandi, “ARTIFICIAL INTELLIGENCE: Mengupas Rekayasa Kecerdasan Tiruan.”