Implementation of The MPPT Short Circuit Method in Determining the Number of Electrical Load That Can Be Supplied by Solar Panels

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Abstract. This paper discusses the applied research of MPPT implementation in determining the number of electrical loads that may be connected to the Solar Panel. This research is an implementation of the short circuit method in determining MPPT. MATLAB simulations for testing the short circuit method in MPPT are discussed in this paper, as well as MATLAB simulations for MPPT implementation in choosing the most appropriate number of electrical loads. The real test was carried out by implementing this algorithm using an Arduino microprocessor, a boost converter module, an inverter and 3 lamps of 100 Watt each, and a solar panel with a power of 400 Watt. The test results measuring the current during the short circuit process show the maximum power. This maximum power is obtained by setting the output voltage to 24 Vdc and measuring the solar panel's short circuit current. Implementation in determining the number of lights that can be connected to solar panels has also been tested in this study. The conclusion of this study is that the application of MPPT to determine the amount of power connected to solar panels is very important so that a solar panel can produce maximum power.

Keywords: Solar Panels, MPPT, Short Circuit.

1 Introduction

In this paper, a power tracking system is made using the short circuit method to determine the number of electrical load that solar panels can supply. The electrical power from the solar panels used is 400 Wp. This electrical power is used to supply 3 connected loads with each load of 100 Watts. An Maximum Power Point Tracking (MPPT) algorithm is needed to find out how much electrical power is being generated by solar panels [1][2]. Knowing the amount of electrical power generated by solar panels as a source of electrical energy for loads can determine the number of loads that can be connected to the solar panel power source. [3]. The simple MPPT algorithm is the short circuit method [4][5]. This method works by performing a short process for a certain period of time. From this process it will be known the maximum power that is being generated at that time [6][7]. In this study, information on electrical power

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generated by solar panels is used as data on the control system to determine the load that must be connected to the solar panel power source. With this technological system, the need for batteries as a place to store energy produced by solar panels is not needed. This paper discusses how a solar panel works which are explained from the equivalent circuit, maximum power point, short circuit mppt algorithm, mppt simulation in MATLAB, mppt implementation simulation with loads in MATLAB, implementation into a real system, and analysis of results.

2 Solar panel equivalent circuit

A solar panel can be described as an equivalent circuit. This equivalent circuit draws the working characteristics of a solar panel in generating voltage and current [8]. The equivalent circuit is shown in **Figure 1** below. This equivalent circuit consists of a current source where the output of this current source depends on the intensity of the irradiation, a diode in parallel with the current source, a parallel resistor in parallel with the current source, and a series resistor in series with the output terminal. [9]. The formula equation that can be used in this circuit is Kirchhoff's current law with a formula such as [10].

$$I_{PV} = I_{ph} - I_d - I_r \; . \quad (1)$$

Ipv is the current flowing into the load, Iph is the current generated by the solar panel, and Ir is the current flowing into the parallel resistance. From this equation, it can be seen that the electric current generated by the solar panel does not entirely flow to the load, but there are still two other paths to flow.

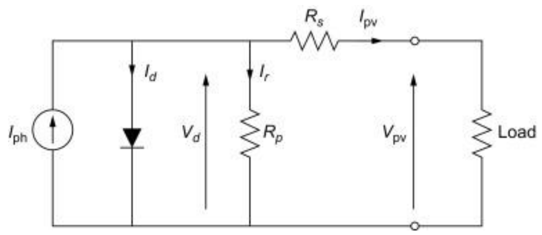

Fig. 1. The equivalent circuit of a solar panel [11].

Ipv is the amount of current flowing to the load, which is affected by the series resistance Rs. When the load is short-circuited, almost all of the current generated by the current source will flow to the short-circuited load. As a result, the current flowing into Rsh becomes small, so the voltage across Rsh becomes small. Because Rsh is parallel, this voltage becomes an indicator of the output voltage on the solar panel. When the load is shorted, a large current will flow, but unfortunately the voltage will be very small, so the solar panel's power will also be small. In the case of an open output terminal, all current will flow to Rsh so that the voltage Rsh becomes large. Because Rsh is in parallel, it will cause the diode to be active. When the diode is active, current will also flow to the diode and generate diode voltage. Because these diodes are parallel, the output voltage when the terminals are open is equal to the diode voltage.

When buying a solar panel, the panel will have a data sheet listed that shows the value of the Isc short circuit current and the value of the open VOC voltage. The complete equation is obtained by entering the Shockley diode equation into the above formula: [11].

$$I_{PV} = I_{ph} - I_d - I_p = I_{ph} - I_0 \left(e^{\frac{V_{PV} + R_S I_{PV}}{n_S V_t Q_d}} - 1 \right) - \frac{V_{PV} + R_S I_{PV}}{R_p} \quad (2)$$

3 Maximum power point

The maximum power point is the maximum power that can be generated by the solar panel when it gets a certain radiation intensity. The determination of the solar panel's maximum power does not depend on the intensity of radiation but on the voltage and current. So for every light intensity value, there will be a maximum power point value generated by the solar panel. In **Figure 2** below shows an example of determining the maximum power point of a radiation intensity value [6].

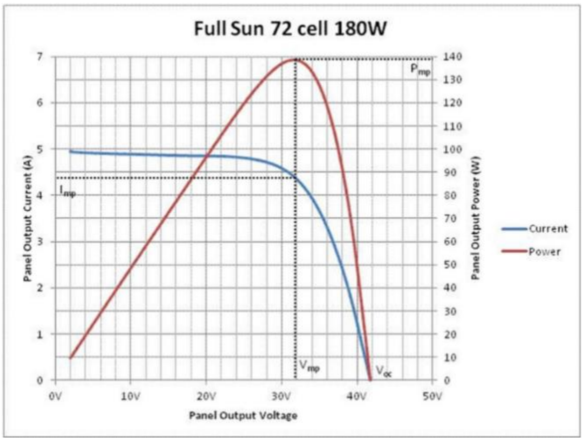

Fig. 2. Determination of the maximum power point based on the current and output voltage of a solar panel [6].

From the graph above, assuming that the solar panel gets full radiation, the output voltage from the panel will vary depending on the amount of electricity supplied. It can be explained that when the current coming out of the solar panel is about 5 A, the output voltage from the solar panel drops to 2 V so that the power generated is relatively small, namely 10 Watts. Furthermore, when the current is reduced to 4.7 A, the voltage will be 20 V, so the power becomes 94 Watts. Continue to decrease until the current becomes 4.4 A then the voltage becomes 30V. At this point, the electric power generated is in a maximum state, referred to as the point of maximum power current and maximum power voltage. A change in the current value can be determined by two things: the load is fixed, then the voltage changes, or the load changes.

4 Characteristics of radiation and temperature

From the graph, it can be read that the test to make a data-sheet is carried out by the solar panel manufacturer. This data sheet is used as a basis for making the MPPT algorithm by applied researchers. The main point to note is the short circuit current Isc. Isc is a parameter generated by the solar panel. These parameters are easily obtained by taking measurements. Changes in irradiation cause the value of this parameter to change. As shown in the graph in Figure 3, at the same temperature at 25 degrees, with an irradiation of 400 W/m2, the current obtained is 3.3 A. When the irradiation is increased to a maximum of 1200 W/m2, the current value obtained is 9.8 A. This parameter will be an indicator to determine the electrical power being generated by the solar panel. To get the value of the electrical power generated by the solar panel, the resulting current is multiplied by the output voltage [6].

The voltage will affect the output power of the solar panel. When a short circuit current is observed, there will produce a very small voltage output so that when observing, this parameter occurs at a small power. To get the maximum power generated, the solar panels must be operated at Impp currents. Current Impp = 0.9 x Isc. The next operation is to keep this solar panel operating at Impp current. For example, based on the graph, when irradiating 400 W/m2, the resulting Isc current is 3.3 A in the measurement process. For the solar panel to produce maximum power, the load must be adjusted so that the current coming out of the solar panel is = 0.9 x 3.3 A = 2.97A.

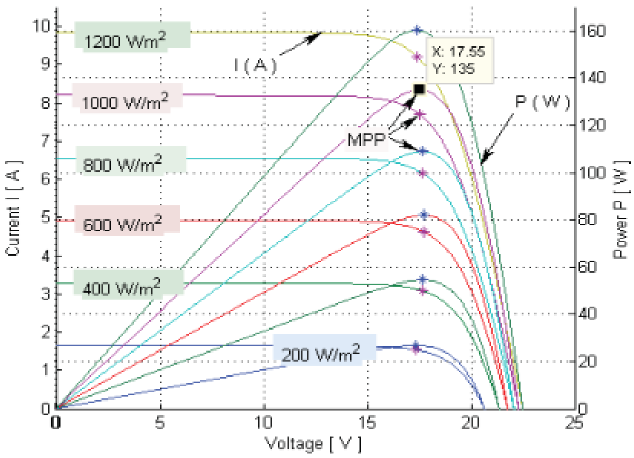

Fig. 3. Determination of the maximum power point of several current values of a solar panel [6].

Figure 3 above shows that when the temperature remained at 25 degrees, with the irradiation changing between 400 W/m2 and 1200 W/m2, the current experienced a significant change while the voltage remained almost constant. The maximum power when irradiating 200W/m2 is 25 Watts which is given at a current of 1.5A and a voltage of 17.5 V. In terms of power generation, whether sourced from a generator or solar panels, the capacity or size of a generator is measured based on the amount of power it generates. Maximum power will be generated by keeping the output at a certain voltage and current. The amount of output voltage can be set at a certain value. While the installed load and the output voltage determine the outgoing current. Keep the output voltage at 24 Volts according to the MPP datasheet. To obtain MPP, the current must also be adjusted to match the MPP. The magnitude of this current corresponds to the irradiation.

5 Implementation of short circuit MPPT algorithm

Figure 3 above shows the point of occurrence of the maximum peak power (Pmpp) where this condition is reached when the current flowing to the load is Impp and the voltage drop across the load is Vmpp. Impp and Vmpp are datasheets provided by the fabrication of a solar panel. In real measurement, the output value that can be measured on a solar panel is Isc or short circuit current. This short circuit current is obtained when connecting to the two terminals of the solar panel.

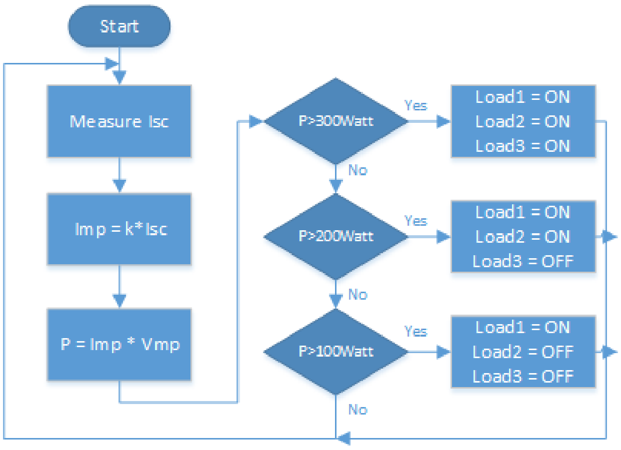

Fig. 4. Flowchart of the implementation of the short-circuit MPPT algorithm.

From **Figure 4** above, it can be explained that the short circuit current will be measured from the solar panel. The way to measure this short-circuit current is to short-circuit the output terminal of the solar panel. In this state, the current flowing to the load will be stopped.

6 MPPT implementation simulation in MATLAB

The implementation of the MPPT algorithm applied to determine the number of load that the solar panel can supply has been simulated in MATLAB, as shown in **Figure 5** below. There are additional three loads using resistors and switches as opening and closing. Added a control function to control the switch. The simulation block of the above circuit can be explained as follows. Each load operates at 100 Watts of power. Power is a unit of electrical load, while the operational voltage for this load is set to 24 Vdc. So this load requires a current of 4 A.

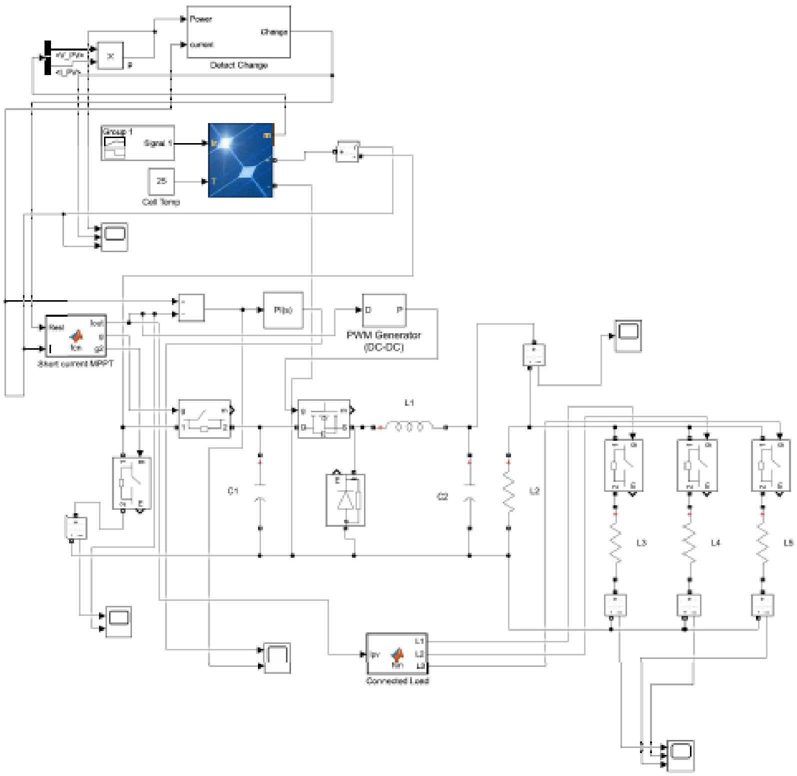

Fig. 5. Circuit simulation in MATLAB for implementing MPPT Short Circuit algorithm

Simulations for this power can be implemented at different voltages, such as 220 Vac, because voltage and current are variable to reach the power value. By using the function block in matlab, the short circuit MPPT algorithm is processed. This function block then outputs the output of the process where this output will be used as input by the load control block. To produce a constant voltage of 24 Vdc required by the load, there is a boost converter circuit in the simulation.

7 The implemented system

Implementation in the real form of this research is to power 3 lamps with an ac voltage of 220 Vac as seen in **Figure 6**. By using a 100 Watt lamp, the simulations carried out in MATLAB can be directly applied to the system. This system uses an inverter to convert the 24 V voltage generated from the converter module. Because the quantity that plays a role here is power, then the voltage conversion from 24 Vdc to 220 Vac will adjust automatically to the amount of current. With a solar panel power of 400 Watts, the current for a 24 Volt voltage is 400 Watt / 24 Volt = 16.7 A. While the current for a 220 Volt voltage is 400 Watt / 220 Volt = 1.8 A.

Fig. 6. A device made for the implementation of the MPPT Short Circuit algorithm

In the system made to implement this MPPT algorithm, it uses a boost converter so that the output from the solar panel remains at a voltage of 24 Vdc. With a boost converter, the output voltage of the solar panel will stay the same, so it is easier to calculate the power being generated by the solar panel because two variables will change, namely current and voltage. The Arduino microprocessor is used as the main control in the process of calculating the maximum power and controlling the switch for the lamp. An inverter is also used to convert 24 Volt dc voltage to 220 Volt AC voltage.

8 Result and analysis

Because the research uses an inverter to use household lamp loads and is real according to the general electrical load conditions in the household, the voltage used by the lamp is 220 Vac. Because this solar panel has a maximum power of 400 Watts, the maximum current using a voltage of 220 Vac is 1.8A. Because the lamps used are 100 Watts each, each lamp uses a current of 0.45 A. This system is running correctly in the test of this system, as shown in Table 1.

Table 1. The data on the implementation of the MPPT Short Circuit algorithm on three 100 Watt lamps.

Isc	Load 1	Load 2	Load 3
0.45	ON	OFF	OFF
0.50	ON	ON	OFF
0.95	ON	ON	OFF
1.3	ON	ON	OFF
1.4	ON	ON	OFF
1.6	ON	ON	ON

From testing the implementation system of the MPPT algorithm that has been made, an analysis can be carried out. This system is able to determine the number of lights that solar panels can supply. When the current generated is 0.45 A, the system will only connect one lamp to the solar panel power source. When the solar panel produces 0.5 A, the number of lamps connected to the solar panel source is two. Determining the number of connected loads can make solar panels have maximum electrical energy.

9 Conclusion

From the research that has been done, it can be concluded that the MPPT algorithm with the short circuit method can be implemented in real terms. Solar panels can produce maximum power according to the radiation intensity if they get the appropriate load. If the load is too small, the current generated is small, resulting in the power generated. If the load is too large, it will cause the output voltage to decrease, affecting the power generated. So the MPPT algorithm is needed to determine the maximum power that is being generated by the solar panel. And the load connected to the solar panel must also be adjustable. In this study, the three lamps used could represent the load adjusted to the maximum power being generated by the solar panels.

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