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Solar panel optimization using maximum power point tracking based on Artificial Bee Colony algorithm

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HIGHLIGHTS

- Solar panel improvement using Maximum power point is proposed
- Artificial Bee Colony algorithm is prosed to solve the problem

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ABSTRACT

Solar panels are a renewable energy generator widely used by the wider community. However, solar panels have a disadvantage in operation, namely very low efficiency. One way to improve the performance of solar panels is to find the MPP (Maximum Power Point) on the V-P curve of the solar panel. This study aims to find the maximum point of the solar panel so that the output power is maximized. This research has succeeded in making a model of a solar panel-based MPPT system using the Artificial Bee Colony method using a DC-DC converter of the choke type. The model is made using Solarland 200 WP solar panels. The difference in output power based on the test results obtained the results of the power efficiency generated by solar panels using MPPT on changes in irradiation with an average fixed temperature of 99.06%. At temperature changes with constant irradiation, the average is 99.12%.

1. Introduction

Photovoltaic (PV) modules are a very high source of electrical energy. However, its capacity to convert solar energy into electric power could be better, with conversion efficiencies generally ranging from 12 to 25%. This energy efficiency range is usually not achieved in practice due to variations in solar radiation, solar cell temperature, and electrical load [1]. Solar cells have variable output characteristics that are affected by solar irradiation, temperature, and load impedance. The maximum power of solar cells is obtained at a certain operating point, called the Maximum Power Point (MPP) [2]. The lower the solar radiation received by PV, the lower the energy produced. The MPP point will be under sunlight, so we need a method to track that point. This method is called Maximum Power Point Tracking (MPPT) [3]. The photovoltaic (PV) system must work at the maximum power point, a continuous variant that depends mainly on solar irradiance and temperature. Variations in temperature and irradiation alter the maximum power point and lower the efficiency of the PV array. Therefore, the operating point must be tracked using the Maximum Power Point Tracking (MPPT) algorithm [4].

One of the recently proposed heuristic algorithms is the Artificial Bee Colony (ABC) algorithm, which is based on the artificial intelligence of honeybee behavior [5]. Artificial Bee Colony (ABC) is a relatively new member of the intelligence swarm [6]. Artificial Bee Colony (ABC) is an optimization algorithm that looks at how honeybees work in searching for food, from finding the best quality food sources to exploiting them until they run out. Furthermore, they started looking for other best food sources after the first food sources were exhausted and exploited again. The process will be done repeatedly.

From the variety of data in the field from solar irradiation and temperature, photovoltaic (PV) output could be more optimal, takes a long time, and cost a lot to produce electrical energy. Behind it all, there is sunlight that never runs out. Therefore, searching for the maximum power point in photovoltaic (PV) to produce optimal power is needed. With this problem, it is hoped that a solution can be found to overcome it.

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In this research, Maximum Power Point Tracking (MPPT) modeling with Artificial Bee Colony algorithm and CUK type dc-dc converter is carried out between the solar panel and the load so that the maximum power point will be obtained on the solar panel.

2. Material and method

Testing of solar panels using MPPT and without MPPT by connecting to a resistive load (R). The irradiation and temperature parameters used vary. The data used are in Table 1 and Table 2. The input data vary to determine the effect of irradiation or temperature on solar panels. The results of this test are the value of the voltage and power generated by the solar panel. The following is a series of tests without MPPT described in Figure 1. Tests using MPPT were conducted to compare the test results with solar panels without MPPT. In addition, it compares how much maximum MPPT is when compared to no MPPT. The following is a solar panel connected to the MPPT described in Figure 2 Solar Panel Circuit Using MPPT.

3. Results and discussions

3.1. Fixed temperature irradiation change test

The solar panel optimization test using the MPPT Artificial Bee Colony converter is carried out using the first and second data as input values from the solar panels and the load side using changes in resistance values consisting of 9, 12, and 15. This test aims to compare the output value of solar panels that use MPPT with those that do not use MPPT. The different resistance load variations aim to determine the power characteristics of the solar panels for each load value. Variation of input data aims to determine the characteristics of solar panels on changes in irradiation with a fixed temperature, then changes in temperature with constant irradiation. Each test uses a load variation, and the optimization results can be seen by comparing the power generated by solar panels using Maximum Power Point Tracking and without Maximum Power Point Tracking. For example, the following test uses the first data, namely with changes in irradiation and constant temperature, and uses a load resistance of 9, 12, and 15. It can be seen in Table 1, test results of irradiation changes and fixed temperatures.

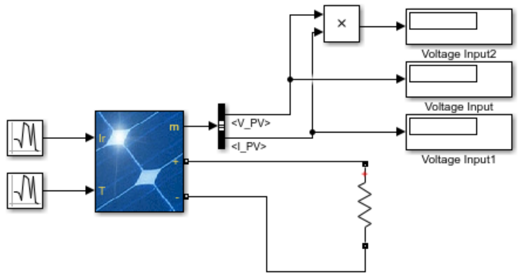

Figure 1. Series of solar panels without MPPT

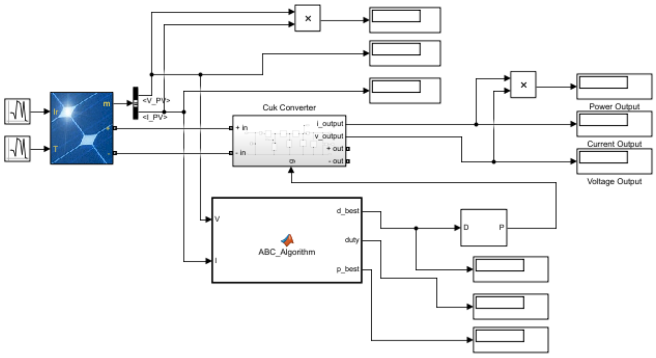

Figure 2. Solar panel circuit using MPPT

Table 1.
Test results of irradiation changes and fixed temperature

Expmt 1. Fix Temp. 25 °C		No MPPT			MPPT		
		Voltage (V)	Current (Amp)	Power (Watt)	Voltage (V)	Current (Amp)	Power (Watt)
9 Ω	800	37,98	4,22	160,3	37,12	4,12	153,1
	900	39,49	4,38	173,3	39,36	4,37	172
	1000	40,38	4,48	181,2	41,75	4,63	193,7
12 Ω	800	40,85	3,40	139,1	43,61	3,63	158,4
	900	41,52	3,48	143,6	46,25	3,85	178,2
	1000	42,01	3,5	147	48,79	4,06	198,4
15 Ω	800	41,95	2,79	117,3	46,03	3,06	141,3
	900	42,43	2,82	120	51,05	3,40	173,7
	1000	42,81	2,85	122,2	52,30	3,48	182,3

Based on Table 1, the optimization carried out compares the solar panels' output power value from those using Maximum Power Point Tracking and those without Maximum Power Point Tracking. In testing the changes in irradiation with a constant temperature and with a load of 9, 12, and 15, the results are very different when compared to the circuit without Maximum Power Point Tracking and the one using Maximum Power Point Tracking. It is due to an additional circuit in the form of a converter and the Artificial Bee Colony Algorithm that helps optimize the solar panel output. Although the load of 9 differs greatly from that without using Maximum Power Point Tracking or can be called greater than those using Maximum Power Point Tracking, this is because the resistive load setting on the converter is at a minimum value of 12.

For more details, it can be seen in the graphs for each experiment of 9, 12, and 15 at 800, 900, and 1000 irradiation and a constant temperature of 25. Figure 3 shows the experimental changes in irradiation and temperature fixed load 9.

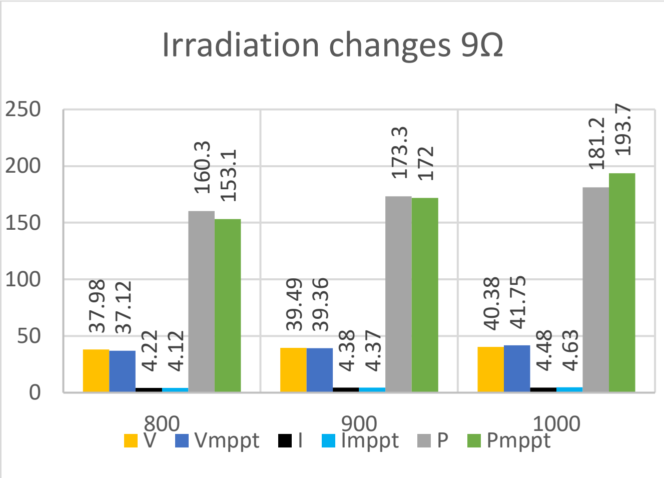

Figure 3. Temperature fixed load 9

In this experiment, circuits using Maximum PowerPoint Tracking or those without using Maximum PowerPoint Tracking appear to increase with changes in irradiation of 1000 W/m². Furthermore, from each circuit, both using Maximum Power Point Tracking and those not using Maximum Power Point Tracking, there is an increase in voltage (V) at 1000 W/m² irradiation changes and a slight change in Current (I). Thus, this circuit is under the solar cell law if the irradiation affects the voltage (V) and a little on the current (I). In the graph above, without using Maximum PowerPoint Tracking, the results are greater than those using Maximum PowerPoint Tracking. It can be seen that at 800 W/m^2, the circuit that uses Maximum Power Point Tracking has a power of 153.1 W, while that without using Maximum Power Point Tracking is 160.3 W, and at 900 W/m^2 the circuit uses Maximum Power Point Tracking. has a power of 172 W.

In contrast, those without using Maximum PowerPoint Tracking are 173.3 W. At 1000 W/m², the circuit using Maximum Power Point Tracking has a power of 193.7 W, while those without using Maximum Power Point Tracking are 181.2 W. This is because the converter circuit has a minimum resistive load setting of 12. Therefore, the Maximum Power Point Tracking circuit is unreliable when dealing small loads. However, when the irradiation is 1000 W/m², the circuit that uses Maximum Power Point Tracking has superior power compared to the circuit that does not use Maximum Power Point Tracking. Furthermore, the experiment on changes in irradiation and constant temperature with a load of 12 will be described in Figure 4—experiments on changes in irradiation and fixed temperature with 12 loads.

In this experiment, circuits using Maximum PowerPoint Tracking or those without using Maximum PowerPoint Tracking appear to increase with changes in irradiation of 1000 W/m². Furthermore, from each circuit, both using Maximum Power Point Tracking and those not using Maximum Power Point Tracking, there is an increase in voltage (V) at 1000 W/m² irradiation changes and a slight change in Current (I). Thus, this circuit is under the solar cell law if the irradiation affects the voltage (V) and a little on the current (I). However, in this experiment, the circuit that uses Maximum Power Point Tracking has greater results than the circuit that does not use Maximum Power Point Tracking.

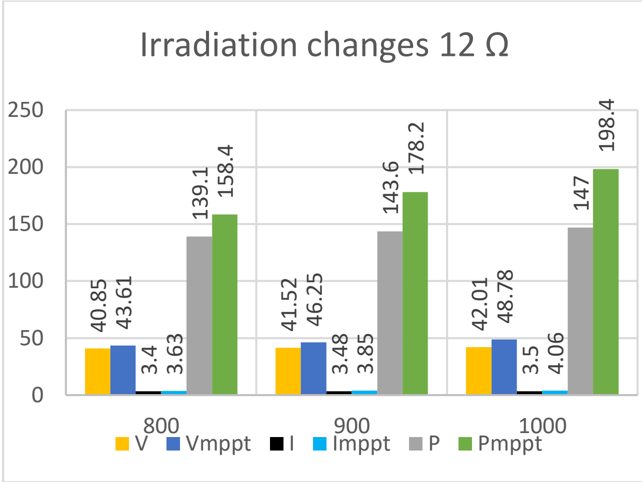

Figure 4. Experiments on changes in irradiation and fixed temperature with load 12

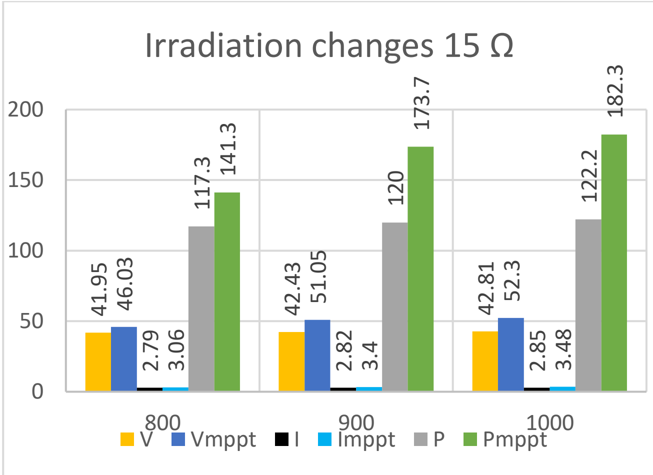

Figure 5. Experimental changes in irradiation and temperature fixed load 15

The graph shows that 800 W/m² has a power of 158.4 W in a circuit using Maximum Power Point Tracking and 139.1 W in a circuit without Maximum Power Point Tracking, and 900 W/m² it gets a value of 178. 2 W in a circuit that uses Maximum Power Point Tracking and 143.6 W in a circuit without Maximum Power Point Tracking, then at 1000 W/m², it has a power value of 198.4 W in a circuit that uses Maximum Power Point Tracking and 147 on a circuit without using Maximum Power Point Tracking. It can be seen that the circuit without using Maximum Power Point Tracking is unreliable in overcoming the load increase. Furthermore, the next experiment will be explained in Figure 5.

Similar to the previous experiment, this experiment shows that all circuits, both using Maximum Power Point Tracking or those without using Maximum Power Point Tracking, appear to increase with a change in irradiation of 1000 W/m². Furthermore, from each circuit, both using Maximum Power Point Tracking and those not using Maximum Power Point Tracking, there is an increase in voltage (V) at 1000 W/m^2 irradiation changes and a slight change in Current (I). Thus this circuit is under the solar cell law if the irradiation affects the voltage (V) and a little on the current (I). In the graph using Maximum PowerPoint Tracking, the results are greater than those without using Maximum PowerPoint Tracking, the same as the experiment using 12. At 800 W/m², there is a power output of 117.3 W in a circuit that does not use Maximum PowerPoint Tracking and 141.3 W in a circuit that uses Maximum PowerPoint Tracking.

Moreover, at 900 W/m², get a power output of 120 W in a circuit that does not use Maximum Power Point Tracking and 173.7 W in a circuit that uses Maximum Power Point Tracking. Then at 1000 W/m², get a power value of 122.2 W in a circuit not using Maximum Power Point Tracking and 182.3 in a circuit using Maximum Power Point Tracking. In the explanation above, it can be seen that the circuit that uses Maximum PowerPoint Tracking is more significant than that which does not use Maximum PowerPoint Tracking. Therefore, a circuit not using Maximum PowerPoint Tracking is unreliable in increasing resistive loads.

3.2. Constant irradiation temperature change test

The next solar panel optimization test uses the second data as the input value from the solar panel, namely changes in temperature and constant irradiation of 1000 W/m². In this experiment, the temperature changes using temperature data of 20, 30, and 35. Furthermore, from the load side, using a change in resistance value consisting of 9, 12, and 15. This test aims to compare the output value of solar panels that use MPPT with those that do not use MPPT. The different resistance load variations aim to determine the power characteristics of the solar panels for each load value.

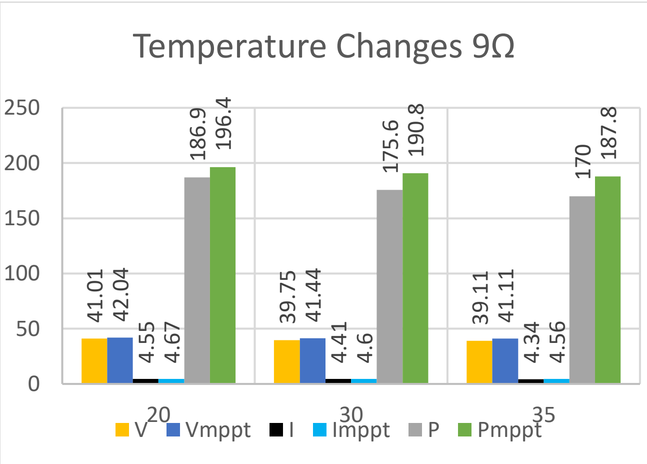

Figure 6. Experimental changes in irradiation and temperature fixed load 9

The optimization results can be seen from the comparison of the power generated by solar panels using Maximum Power Point Tracking and without Maximum Power Point Tracking. We can see in Table 2 the test results of irradiation changes and fixed temperatures. Based on Table 2, the optimization compares the solar panels' output power value from those using Maximum Power Point Tracking and those without Maximum Power Point Tracking. In testing the temperature changes with constant irradiation and loads of 9, 12, and 15, the results are very different compared to the circuit without Maximum PowerPoint Tracking and the one using Maximum Power Point Tracking. It is due to an additional circuit in the form of a converter and the Artificial Bee Colony Algorithm that helps optimize the solar panel output. Although the load of 9 is different from that without using Maximum Power Point Tracking, or it can be called greater than that using Maximum Power Point Tracking, this is because the resistive load setting on the converter is at a minimum value of 12. For more details, it can be seen in the graphs for each experiment of 9, 12, and 15 at a temperature of 20 and temperature of 20, 30, and 35, and the irradiation is still 1000 W/m². It can be seen in Figure 6, experimental changes in irradiation and temperature fixed load 9.

In this experiment, it can be seen that all circuits using Maximum PowerPoint Tracking or those without using Maximum PowerPoint Tracking appear to increase with a temperature change of 35. Moreover, from each circuit, both using Maximum PowerPoint Tracking and those not using Maximum PowerPoint Tracking, there is an increase in current (I) at 35 irradiation changes and a slight change in the voltage (V). Thus this circuit is under the solar cell law if the irradiation affects the voltage (V) and a little on the current (I). In graphs that use Maximum PowerPoint Tracking, the results are greater than those without using Maximum PowerPoint Tracking. For example, at a temperature of 20, the circuit that uses Maximum PowerPoint Tracking has a power of 196.4 W. In comparison, those that do not use Maximum PowerPoint Tracking have a power of 186.9 W.

Furthermore, at a temperature of 30 in, a circuit that uses Maximum Power Point Tracking gets a value of 190.8 W on power, and circuits that are not equipped with Maximum Power Point Tracking get a value of 175.6 W. For 35 circuits using Maximum Power Point Tracking, the power values are 187.8 W and 170 W on circuits that do not use Maximum Power Point Tracking.

Table 2
Test results of irradiation changes and fixed temperatures

2nd Experiment		Without MPPT			MPPT		
		Voltage (V)	Current (Amp)	Power (Watt)	Voltage (V)	Current (Amp)	Power (Watt)
9 Ω	20	41,01	4,55	186,9	42,04	4,67	196,4
	30	39,75	4,41	175,6	41,44	4,60	190,8
	35	39,11	4,34	170	41,11	4,56	187,8
12 Ω	20	42,7	3,55	151,9	49,18	4,09	201,6
	30	41,31	3,44	142,2	48,13	4,02	194,4
	35	40,62	3,38	137,5	47,74	3,97	190
15 Ω	20	43,53	2,90	126,2	53,10	3,54	187,9
	30	42,10	2,80	51,48	51,48	3,43	176,7
	35	41,38	2,75	114,2	50,67	3,37	171,1

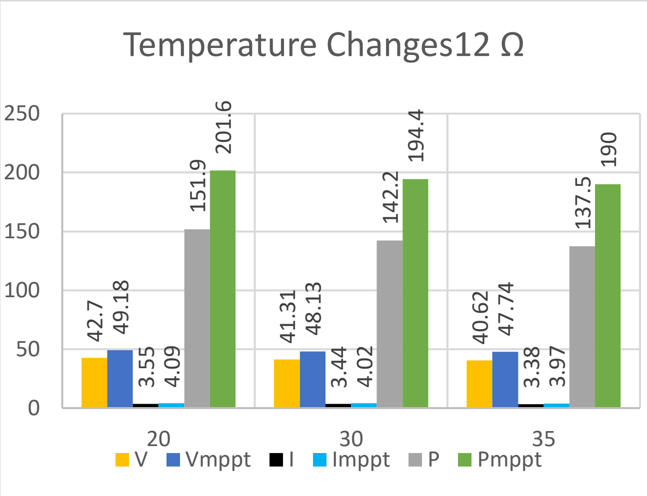

Figure 7. Experiments on changes in temperature and fixed irradiation with 12 load

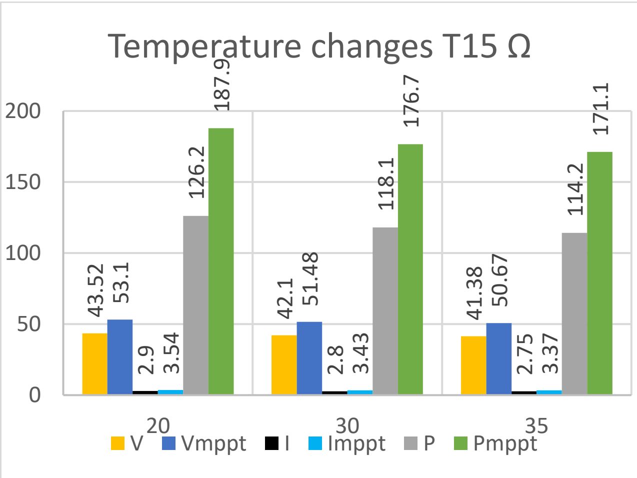

Figure 8. Experiment of temperature change and fixed irradiation load 15

Furthermore, the experiment on changes in irradiation and constant temperature with a load of 12 will be described in Figure 7—experiments on changes in temperature and fixed irradiation with 12 loads. In this experiment, it can be seen that all circuits using Maximum PowerPoint Tracking or those without using Maximum PowerPoint Tracking appear to increase with a temperature change of 35. Furthermore, from each circuit, both using Maximum PowerPoint Tracking and those not using Maximum PowerPoint Tracking, there is an increase in current (I) at 35 irradiation changes and a slight change in the voltage (V). Thus this circuit is under the solar cell law if the irradiation affects the voltage (V) and a little on the current (I).

However, in this experiment, the circuit that uses Maximum Power Point Tracking has greater results than the circuit that does not use Maximum Power Point Tracking. It can be seen that the graph with 20 has a power of 201.6 W on a circuit that uses Maximum Power Point Tracking and 151.9 W on a circuit that does not use Maximum Power Point Tracking. At 30, it gets a value of 194.4 W in a circuit that uses Maximum PowerPoint Tracking. Power Point Tracking and 142.2 W in a circuit without Maximum Power Point Tracking, then at 35, it has a power value of 187.8 W in a circuit using Maximum Power Point Tracking and 137.5 W in a circuit without using Maximum Power Point Tracking. Therefore, it can be seen that the circuit without using Maximum Power Point Tracking is unreliable in overcoming the load increase. Furthermore, the next experiment will be explained in Figure 8, experiment of temperature change and fixed irradiation load 15.

In this experiment, it can be seen that all circuits using Maximum PowerPoint Tracking or those without using Maximum PowerPoint Tracking appear to increase with a temperature change of 35. Moreover, from each circuit, both using Maximum PowerPoint Tracking and those not using Maximum PowerPoint Tracking, there is an increase in current (I) at 35 irradiation changes and a slight change in the voltage (V). Thus, this circuit is under the solar cell law if the irradiation affects the voltage (V) and a little on the current (I). In graphs that use Maximum PowerPoint Tracking, the results are greater than those without using Maximum PowerPoint Tracking. In the graph using Maximum PowerPoint Tracking, the results are greater than those without using Maximum PowerPoint Tracking, the same as the experiment using 12. At 20, there is a power output of 126.2 W in a circuit that does not use Maximum PowerPoint Tracking and 187.9 W in a circuit that uses Maximum PowerPoint Tracking.

Furthermore, at 30, we get a power result of 118.1 W in a circuit that does not use Maximum Power Point Tracking and 176.7 W in a circuit that uses Maximum Power Point Tracking. Then at 35, get a power value of 114.2 W in a circuit not using Maximum Power Point Tracking and 171.1 in a circuit using Maximum Power Point Tracking. In the explanation above, it can be seen that the circuit that uses Maximum PowerPoint Tracking is more significant than that which does not use Maximum PowerPoint Tracking. Therefore, a circuit not using Maximum PowerPoint Tracking is unreliable in increasing resistive loads. However, it has been seen in the experiment that the Maximum PowerPoint Tracking circuit can produce the optimum power value for each power.

3.3. Load change test

Subsequent tests were carried out to determine the output characteristics of the solar panels at each load change. Therefore, the data is taken only as a sample from the input data at 1000 W/m² irradiation and 25 temperatures in the Maximum PowerPoint Tracking circuit.

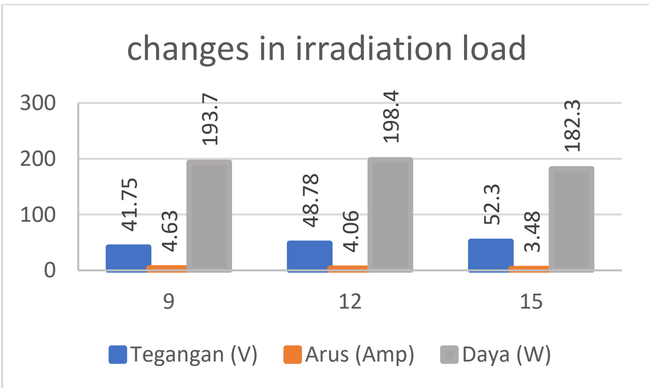

Figure 9. Changes in load at 1000 W/m² irradiation and 25 temperatures

Table 3.
Percentage of MPPT and without MPPT changes in irradiation

Irradiation (W/m²)	Power (W)		Pmax PV (W)	Efficiency	
	MPPT	Without MPPT		MPPT	Without MPPT
800	158,4	139,1	160	99	86,9
900	178,2	143,6	180	99	79,7
1000	198,4	147	200	99,2	73,5
Average				99.06	80,03

Table 4.
Percentage of MPPT and without MPPT changes in temperature

Irradiation (W/m²)	Power (W)		Pmax PV (W)	Efficiency	
	MPPT	Without MPPT		MPPT	Without MPPT
20	201,6	151,9	203	99,3	74,82
30	194,4	142,2	196	99,13	72,55
35	190	137,5	192	98,95	71,61
Average				99,12	72,99

It is done to determine whether the load changes affect the solar panel output. The results can be seen in Figure 9—changes in load at 1000 W/m² irradiation and 25 degree of temperature. Based on the graph above, it can be seen that the change in Load on changes in irradiation and at a constant temperature result in an increase in power at a load of 12 and a decrease at a load of 15. As can also be seen in the results from the picture above, the voltage increases significantly at 9, 12, and 15 load increases, and the current drops significantly at 9, 12, and 15 load increases. Therefore, it can be concluded from this experiment that increasing the Load can increase the voltage and decrease the current at each increase in Load.

3.4. Testing percentage

Furthermore, the percentage of the test at each input data will be displayed at fixed irradiation and different temperatures and at fixed temperatures and different irradiations at 12 standard load conditions. These results are in a series that uses Maximum Power Point Tracking and does not use Maximum Power Point Tracking. The results can be seen in Table 3 Percentage of MPPT and Without MPPT Changes in Irradiation.

From Table 3, it can be seen the efficiency of the test results in each irradiation and the average efficiency. It can be seen that the efficiency of the circuit using Maximum Power Point Tracking is higher than that of the circuit without Maximum Power Point Tracking. The efficiency of the Maximum Power Point Tracking series is seen in the 99% range. At the same time, the efficiency in the circuit without MPPT can be seen from 73.5% to 79.7% to 86.9%. Furthermore, the average efficiency in the Maximum Power Point Tracking series is in the range of 99.06%, while without MPPT is in the range of 80.03%. The percentage in the next test, namely the input data temperature changes and irradiation, can still be seen in Table 4, percentage of MPPT and without MPPT changes in temperature.

From the table above, it can be seen the efficiency of the test results at each temperature and the average efficiency. It can be seen that the efficiency of the circuit using Maximum Power Point Tracking is higher than that of the circuit without Maximum Power Point Tracking. The efficiency in the Maximum Power Point Tracking series has a value of 99.3, 99.13, and 98.9. In comparison, the efficiency in the circuit without MPPT is seen at 74.82, 72.55, and 71.61. Moreover, the average efficiency in the Maximum Power Point Tracking series is in the range of 99.12%, while without MPPT is in the range of 72.99%.

4. Conclusions

Optimization of solar panels using Maximum Power Point Tracking based on Artificial Bee Colony based on the test results showing an increase in the output power of solar panels compared to solar panels without Maximum Power Point Tracking. MPPT Artificial Bee Colony using a choke converter, can maximize the maximum power of solar panels by tracking the maximum point of solar panel power at every temperature change and irradiation change.

The difference in output power based on the test results showed that the difference in power generated between solar panels using Maximum Power Point Tracking and without Maximum Power Point Tracking using 9Ω, 12Ω and 15Ω resistance on changes in irradiation with an average fixed temperature of 35.1 W. However, at changes in temperature with constant irradiation, the average is 51.46 W.

Declaration statement

Hartono: **Conceptualization, Methodology, Supervision**. Yusraini Muharni: **Writing - Review & Editing**, Wahid Diana Tasdik: **Data**, **methodology, writing,** Alief Maulana: **Review, supervision**, Irma Saraswati: **conceptualization , supervision**

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