MPPT Design for Optimizing the Output Power of Solar Power Plants Using Matlab Simulink

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ABSTRACT

The depletion of fossil energy reserves leads to the need for energy that can replace it, one of which is solar energy. In order for the maximum photovoltaic power produced, MPPT is needed. The MPPT system overcomes the problem of photovoltaics that cannot expend maximum power due to the influence of irradiation and temperature by tracking the maximum power point of solar panels using a DC-DC boost converter. This final project aims to design and simulate MPPT for PLTS Off-Grid using Matlab Simulink software. The test was conducted based on irradiation data and daily temperature in Semarang City, Central Java. Test results showed that when irradiation conditions are 204 W / m and temperatures of 29 ° C solar panels without the use of MPPT produce power of 200.2 W while solar panels using MPPT produce power of 207.4 W. When irradiation conditions are 895 W / m and temperatures of 24 ° C solar panels without the use of MPPT produce power of 342.3 W while solar panels using MPPT produce power of 948.8 W. So by using MPPT solar panels can produce more maximum power.

Keyword : - *Photovoltaic, PLTS, MPPT, Matlab Simulink*

1. INTRODUCTION

Currently, one of the efforts being developed is the use of solar energy as a fuel for power generation. Indonesia has big capital to develop Solar Power Generation technology. Indonesia's geographical location which is located on the equator provides high benefits of sunlight every year. Indonesia has an average solar radiation value of 4.50 KWh/m2/day to 4.80 KWh/m2/day [3]. Therefore, the use of solar energy is the best alternative energy solution to gradually replace fossil energy. Since solar energy is a renewable energy that is easy to obtain and easy to use, solar energy also has a low level of pollution compared to fossil energy, thereby minimizing negative impacts on the surrounding environment [4].

Solar Power Plant (PLTS) is a power plant that uses solar energy as fuel to generate electricity. An important component in PLTS that functions to convert solar radiation into electrical energy is called Photovoltaic (PV). In Photovoltaic, there are several advantages, among others, it does not produce noise and does not emit emissions so it is very safe and environmentally friendly compared to conventional generators. However, the irradiation factor and the temperature of the module greatly determine the amount of electrical energy produced by the PV system. Changes in these two factors cause the PV system output power is not always optimal. Therefore, we need a solution so that the PV system can operate optimally for every lighting condition and every temperature change in the module. The solution is to use Maximum Power Point Tracker (MPPT).

MPPT is a method used so that PV always works optimally at the maximum power point. The maximum power point is the point at which the power generated by the solar panel reaches its maximum power. It is hoped that with the MPPT, the PV system can work to produce maximum output power at different lighting conditions and temperatures [5].

This study aims to design and simulate MPPT for PLTS and PLN with a Hybrid system with the aim of maximizing and optimizing the PV output power using Simulink Matlab 2017b software.

2. RESEARCH METHOD

2.1 Simulation Design Method

The PLTS system in this study uses the MPPT (Maximum Power Point Tracker) Incremental Conductance method with a boost converter which is designed and simulated to maximize the output power of the solar panels. This system works by forcing the solar panels to work at the maximum power point by tracking the MPP point using a converter controlled by the MPPT. This research consists of several main blocks, solar panel blocks, namely boost converter blocks, MPPT blocks, and load blocks. The simulation block diagram designed in this study is shown in Figure 3.1.

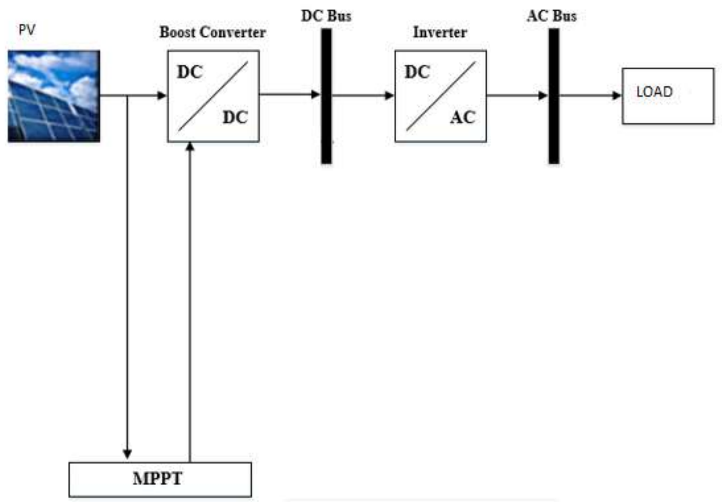

Fig-1 Simulation Design Block Diagram

2.2 Data Retrieval

The data needed in this research work are the parameters that affect the performance of solar panels in generating electricity, namely radiation intensity and temperature. The data can be taken from NASA's Prediction of World Energy Resources High Resolution Climatological Resources Daily Time Series for SSE-Renewable Energy to determine the value of these parameters in Semarang City throughout 2020. The following data has been summarized.

Table-1 Data on Solar Radiation Intensity in Semarang City in 2020

MONTH	Solar Radiation Intensity (kWh/m^2/hari)
January	4.22
February	4.53
March	5.43
April	5.52
May	5.50
June	5.27
July	5.73

August	6.41
September	6.80
October	6.40
November	5.33
December	4.61
Average	**5.48**

Table-2 Semarang City Temperature Data in 2020

MONTH	Average Temperature (^oC)
January	27,2
February	26,9
March	27,5
April	27,9
May	28,0
June	27,6
July	27,4
August	28,0
September	29,0
October	29,2
November	28,7
December	27,9
Average	**27,9**

Furthermore, data collection is carried out in the form of the use of the load installed on the household. The use of electrical energy in households tends to fluctuate. Therefore, in this study the estimation of the daily load on the Semarang household was carried out by means of manual and periodic observations in order to determine the estimated daily load used every day. Based on Table 3, it is known that the total load installed is 1233 W. Meanwhile, the average overall load in 1 day can reach 3348 Wh.

Table-3 Estimated Daily Energy Needs

No	Item	Amount	Power (Watt)	TOTAL (W)	Duration (hour)	Energy (wh)
1	Porchlight	1 Unit	12	12	12	144
2	Street light	1 Unit	12	12	12	144
3	Living room light	1 Unit	15	15	5	75
4	Bedroom light	4 Unit	10	40	5	200
5	Kitchen light	1 Unit	15	15	5	75
6	Bathroom light	3 Unit	7	21	2	42
7	Warehouse light	1 Unit	7	7	2	14
8	Dining room light	1 Unit	15	15	5	75
9	Living room light	1 Unit	14	14	5	70
10	Stair light	1 Unit	12	12	12	144
11	Backroom light	1 Unit	10	10	12	120
12	Workspace light	1 Unit	15	15	5	75
13	Iron	1 Unit	350	350	1	350
14	Router	1 Unit	30	30	24	720
15	Washing machine	1 Unit	350	350	1	350
16	Laptop	2 Unit	65	130	2	260
17	LCD TV 24" (bedroom)	1 Unit	60	60	4	240
18	Water pump	1 Unit	125	125	2	250
	Total load (W)			1233	Total (wh)	3348

2.3 MATLAB Simulation

MATLAB is a software used for numerical computation and data visualization. MATLAB already uses a high-level language to make it easier for users to use this application. In general, Matlab can solve problems related to mathematics and computing, the use of algorithms, data acquisition, modeling and prototyping, scientific graphics and engineering fields. Currently, almost 1 million more people are using MATLAB, from students, academics, universities, researchers, to industry. MATLAB stands for matrix laboratory, which was originally intended to assist in managing data related to matrix. Matlab was created by Cleve Moler in 1970 with the intention of providing easy access to LINPACK and EISPACK. MATLAB features itself very much and is very helpful in performing calculations and simulations. One of the most well-known features of MATLAB is Simulink. Simulink is a feature of MATLAB which can be accessed when you have purchased the MATLAB application. Simulink serves to provide services in the form of simulation and modeling of a prototype in real time. In Simulink there are lots of libraries that can be used to simulate a system

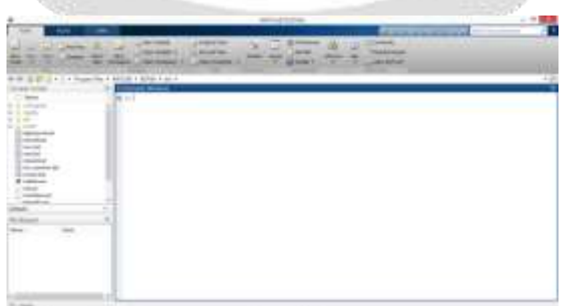

Fig-2 Initial view of Matlab Software

Fig-3 Simulink Initial View

2.4 Maximum Power Point Tracker

Maximum Power Point Tracker (MPPT) method to track the maximum power point of solar panels and force the solar panels to keep working at that point. Due to the influence of radiation and temperature that is always changing, the output power of solar panels is always not at its maximum power point. The MPPT system allows the solar panel to supply the load at the maximum power point in all irradiation and temperature conditions by reading each output point on the P – V characteristic curve of the solar panel and controlling the current through the voltage using a converter so that the system voltage always works at its maximum point. . . MPPT is not a mechanical system that can make solar panels track the movement of the sun, but an electronic system that makes solar panels always produce maximum power [4]. In this research work using MPPT with the method of Incremental Conductance.

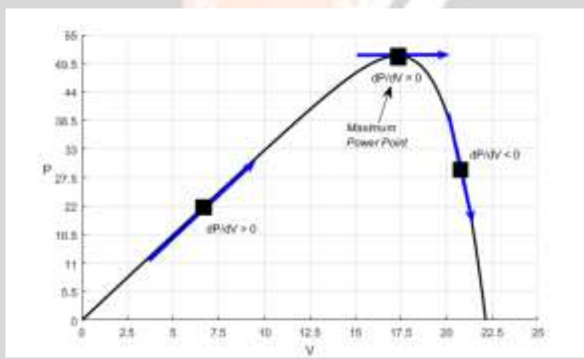

Fig-4 Characteristics of the P-V curve

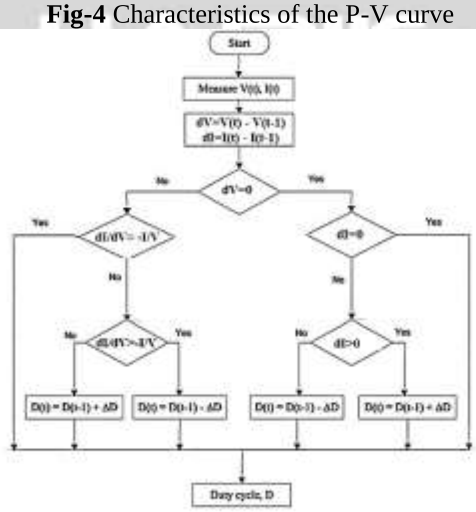

Fig-5 Flowchart of the Incremental Conductance method

MPPT can improve the output of solar panels by using an algorithm to find the maximum power point (MPP) and maintain the working point of the solar panels. The Incremental Conductance Algorithm can be used as an MPPT control algorithm. This algorithm can be described as in Figure 5, the maximum power point can be tracked by comparing the calculated instantaneous (I/V) with the incremental conductance (ΔI/V) as shown in the above equation. Once the maximum power point is reached, the solar panel output is maintained at this point, unless a change in I indicates a change in environmental conditions and the maximum power point (MPP). This algorithm reduces or increases the duty cycle to track the solar panel's maximum power point.

3. RESULT AND ANALYSIS

3.1 Test results of PV circuit implementation

Testing the implementation of the PV circuit aims to determine the performance of solar panels to determine the power output of the solar panels. This test was carried out for 8 hours (08.00-16.00) and then analyzed the value of the voltage, current and output power of the solar panel.

Table-4 PV System Implementation Test Results

No	Time	Irradiation	Temperature	Solar Panel		
		w/m2	(°C)	Voltage	Current	Power
				Volt	Ampere	Watt
1	08.00	310	25	52,9	12,40	326
2	09.00	543	29	58,8	23,10	573
3	10:00	815	30	56,5	32,90	869
4	11:00	872	31	55,5	35,80	926
5	12:00	895	32	55,9	34,30	949
6	13:00	833	32	60,9	31,00	881
7	14:00	482	31	57,0	17,70	503
8	15:00	211	30	40,8	08.70	213
9	16:00	204	29	50,8	07,80	206

Based on Table 4., initially at 08.00 the new PV system was able to produce 326 Watts of power with an irradiation of 275 W/m2/. Then the PV system produces the largest power of 949 at 12:00 where the irradiation at that hour is 895 W/m2. After 12:00 the PV system will experience a decrease in power until 16:00 due to the condition of the sun which has started to dim. The smallest power that the PV system can produce occurs at 16:00 which is 206 Watt, where the irradiation condition at that time was 204 W/m2.

3.2 PV circuit simulation test results without using MPPT

PV circuit testing without using MPPT aims to determine the performance of solar panels in generating power without using the MPPT algorithm. This test is carried out by using different irradiation and temperature values and then analyzing the voltage, current and output power values of the solar panels. The picture is a series of PV testing without using the MPPT algorithm.

The test is carried out by providing variations in irradiation and temperature based on the results of testing the implementation of solar panels for 8 hours. This test was conducted to determine the effect of irradiation and temperature on the PV circuit without using the MPPT algorithm.

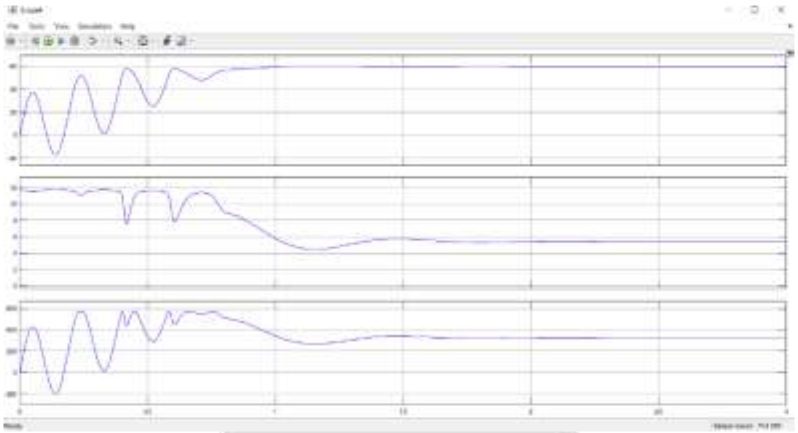

Fig-6 Test graph without MPPT with Irradiation 543 W/m2 and 29° C temperature

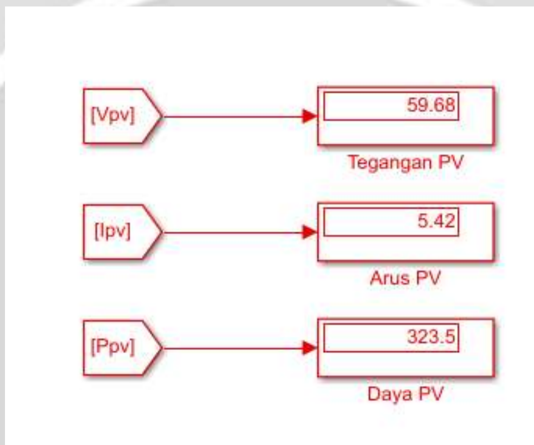

Fig-7 Test display without MPPT with 543 W/m2 irradiation and 29° C temperature

Table-5 PV System Simulation Test Results

No.	Irradiation (W/m2)	Temperature (°C)	V PV (V)	I PV (A)	Power (W)
1.	310	25	56,33	5,126	291,9
2.	543	29	59,68	5,420	323,5
3.	815	30	61,22	5,584	341,9
4.	872	31	61,25	5,605	343,3
5.	895	32	61,11	5,601	342,3
6.	833	32	60,84	5,555	338,0
7.	482	31	58,59	5,322	311,8
8.	211	30	48,07	4,375	210,3
9.	204	29	46,97	4,263	200,2

3.3 PV circuit simulation test results using MPPT

Introduction related your research work. PV circuit testing using MPPT aims to determine the performance of the panel in generating power designed using the MPPT algorithm. The test is carried out by varying the value of irradiation and temperature and then analyzing the value of the voltage and current of the solar panel. The picture below is a series of PV testing using the MPPT algorithm...

The test is carried out by providing variations in irradiation and temperature based on the results of testing the implementation of solar panels for 8 hours. This test was conducted to determine the effect of irradiation and temperature on the PV circuit with using the MPPT algorithm.

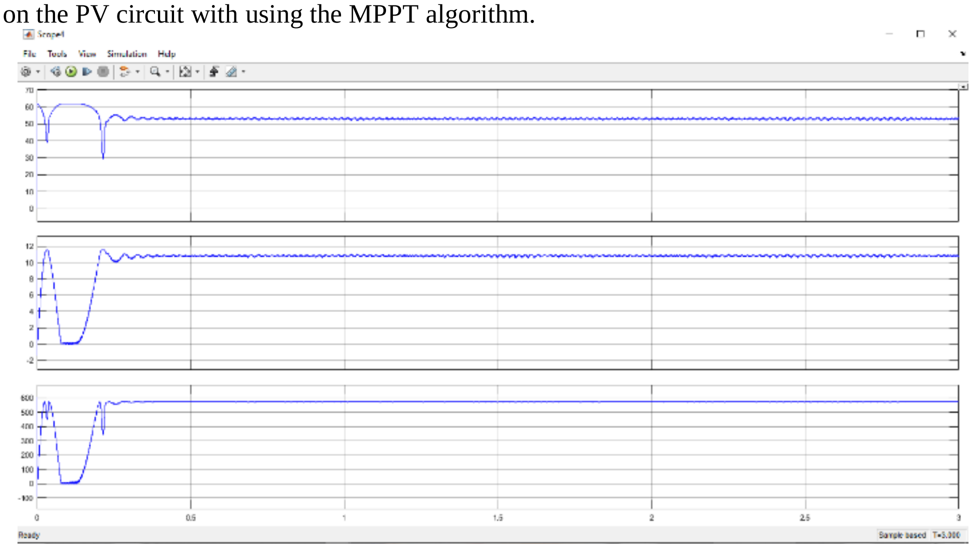

Fig-8 Test graph with MPPT with Irradiation 543 W/m2 and temperature 29° C

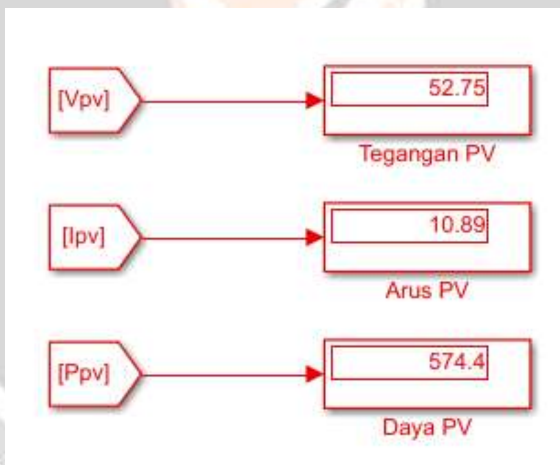

Fig-9 Test display with MPPT with 543 W/m2 irradiation and 29° C temperature

Table-6 PV System Simulation Test Results using MPPT

No.	Irradiation (W/m2)	Temperature (°C)	V PV (V)	I PV (A)	Power (W)
1.	310	25	52,40	6,232	326,6
2.	543	29	52,75	10,89	574,4

3.	815	30	53,23	16,23	868,9
4.	872	31	53,12	17,47	927,7
5.	895	32	52,75	17,99	948,8
6.	833	32	52,89	16,67	881,6
7.	482	31	51,55	9,763	503,2
8.	211	30	50,15	4,264	213,9
9.	204	29	50,4	4,116	207,4

Based on Table 6, the results of testing the PV system without using MPPT with the lowest irradiation variation of 204 W/m2 PV produces a power of 207.4 W, while the highest irradiation variation is 895 W/m2 PV produces a power of 948.8 W. the lowest temperature of 25° PV can produce 326.6 W of power, while the highest temperature of 32° PV produces 948.8 W of power. In the PV system without using MPPT, the lowest power is 207.4 W of 204 W irradiation. W/m2 and a temperature of 29° C, while the highest power obtained is 946.4 W when irradiated at 895 W/m2 and a temperature of 32° C.

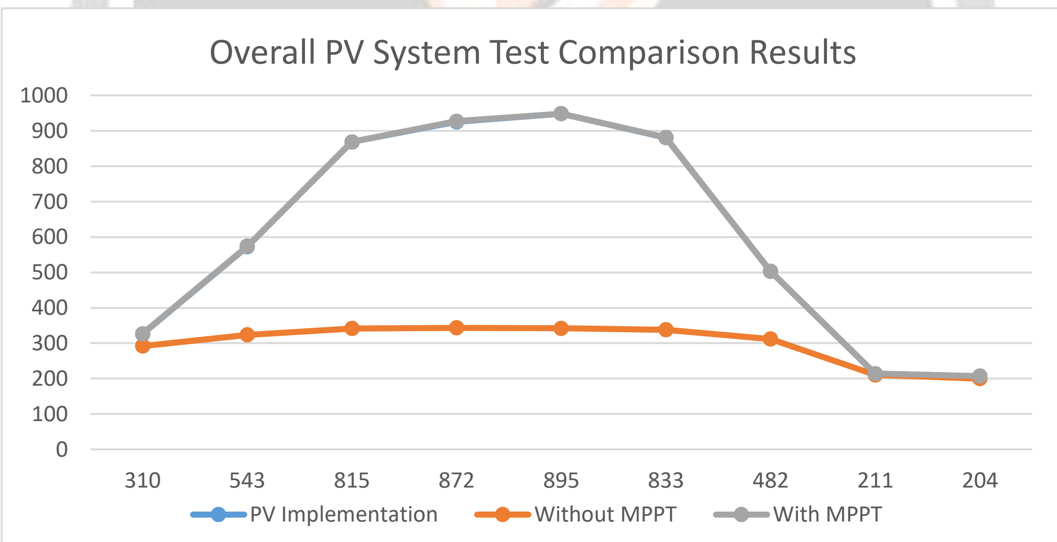

Fig-10 Comparative Result Curve of Overall PV System Testing

Based on Table 6 and Figure 8, it can be seen that PV with MPPT produces more maximum power than PV without MPPT. For PV using MPPT, it has an increase in power of 3.6 W to 606.5 W from PV power without using MPPT. This shows that MPPT has worked well by forcing the solar panels to produce maximum power.

Based on the comparison results above, the results of the PV simulation without MPPT have a power difference ratio that is quite far compared to the results of the PV implementation test, which is 11.4% to 63.2% of the PV implementation power, while the results of the PV simulation using MPPT have a very different ratio. small with the results of the PV implementation test that is 0.01% to 0.27% of the PV implementation power. This shows that the MPPT simulation results have worked well and are in accordance with the test results.

4. CONCLUSIONS

Based on the results of MPPT Simulation and Modeling for PV systems using Matlab Simulink, it can be concluded that the experimental results without using MPPT at the lowest irradiation of 350 W/m2 with a temperature of 27.2°C the solar panel produces 189 W of power while the experimental results using MPPT with the same irradiation and temperature solar panels produce a power of 215.7 W, so that by using the MPPT algorithm the power generated is maximized.
The experimental results without using MPPT at the highest irradiation is 879 W/m2 with a temperature of 28.0°C the solar panel produces a power of 349 W while the experimental results using MPPT with irradiation and the same temperature the solar panel produces a power of 946.4 W, so by using the MPPT algorithm the resulting power is maximized.
PV systems using MPPT are able to increase solar panel power from 26.7 W to a maximum of 597. 4 W compared to PV systems without using MPPT, this power increase is because MPPT can track changes in MPP points by increasing and decreasing the duty cycle, where systems without MPPT cannot do this.
The PV simulation results without MPPT have a power difference ratio that is quite far compared to the results of the PV implementation test, which is 11.4% to 63.2% of the PV implementation power, while the PV simulation results using MPPT have a very small difference ratio with the implementation test results. PV is 0.01% to 0.27% of the PV implementation power.

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