Design and Build a Charging Battery Solar Cell Using the Maximum Power Point Tracker (MPPT) System

Fauzan Hasibuan
e-mail: fauzanhasibuan78@gmail.com
Parlin Siagian
e-mail: parlinsiagian@dosen.pancabudi.ac.id
Haris Gunawan
e-mail: gharis785@gmail.com

ABSTRACT
Solar panels, or often referred to as photovoltaic (PV) panels, are devices that convert direct sunlight into electricity. The polycrystalline type of solar panel is the most commonly used type. The low efficiency of polycrystalline solar panels which is only 13-16% in converting solar energy into electrical energy, requires MPPT technology to increase efficiency, so it is necessary to conduct research to determine the increase in efficiency of the use of SCC MPPT and without the use of SCC MPPT on solar panels at the University of Development Panca Budi Medan City. This study aims to examine how long it takes to charge the battery and how much efficiency increase is produced after using MPPT, with environmental conditions such as solar irradiation, intensity, sunlight and temperature at the Panca Budi Development University, Medan City. The method carried out in this study is to measure and compare the power output produced by Polycrystalline solar panels for 3 (days) of research and interpreted. The results obtained are that SCC PWM shows better performance compared to SCC MPPT. During three days of testing with an average solar irradiation of 571W/m², an average sunlight intensity of 104,305 Lux and an average temperature of 43.85 degrees Celsius, the average SCC MPPT produced a power of 14.44 Watts, while the SCC PWM produced an average power of 21.99 Watts. The average difference in power output produced from the two solar panels is 7.55 Watts. This shows that SCC PWM is proven to be superior to SCC MPPT.

***Keywords**:* Solar Panel, Polycrystalline, MPPT, Solar Charge Controller Pulse Width Modulation.

Introduction

Indonesia is a country that is very benefited because of its astronomical location and geographical location, which makes the territory of Indonesia get the potential of renewable energy sources by very abundant amount. Solar energy is one of the energy that is abundant in availability, especially in the tropics. Solar energy has several advantages such as pollution-free, long life, easy maintenance, and no harm to the environment.

The utilization of the potential of renewable energy sources must continue to be developed considering the limited amount of supply in nature and the increasingly expensive price of fossil energy itself every year as a conventional energy source used by PLN (Juen, 2020). Indonesia as a tropical country has a land area of almost 2 million Km^2 and gets sunlight all the time with a duration of more than 6 hours a day (2,400 hours a year) with the average radiation intensity received reaching 4.8 kWh/^{m2} per day.

The need for electrical energy is increasing along with population growth and industrial needs. Research and development in the field of renewable energy sources will make a considerable contribution in meeting today's energy needs.

The main problem obtained from solar panels is their small efficiency value, compared to other power plants. Solar energy is converted into electrical energy with an efficiency of only 18%. The energy is reduced when the energy is used to electrical equipment due to the influence of the efficiency of voltage, batteries, cables, inverters to 10-15%. Triggers for low conversion include changes in sunlight intensity, operating temperature, and load current. In addition, solar panels have non-linear characteristics, this makes it difficult for us to get the maximum point of the solar panel. Solar cell modules (PLTS) are more effectively used in mountainous areas with lower air temperatures than in coastal areas with higher air temperatures. At the time of voltage testing generated by Solar panels are greatly influenced by the intensity of light received by solar panels. A maximum power finder system (Maximum Power Point Tracker) is needed on the solar panel to increase the efficiency value of the solar panel. MPPT is an electronic system that as a whole changes the electronic operating points of the solar cell module so that it can transmit the maximum available power.

From 1954 to 2018, all researchers focused on MPPT, which was the main target of the study. to follow up on the history of the development of maximum power point in PV systems as well as explore the advantages and disadvantages of many MPPT methods proposed in the literature. Its history includes offline and online MPPT techniques and their improvements as documented in the literature during the period 1954–2018.

The purpose of using MPPT is to ensure that at any environmental conditions (in particular radiation and solar temperature), maximum power can be extracted from the PV modules. This is achieved by matching the MPP to the appropriate converter operating voltage and current. MPPT works as follows. First, the current and voltage of the PV array are sensed by the current and voltage sensors, respectively. These values are incorporated into the MPPT block that calculates the MPP at a given sampling cycle. Once found, the MPPT block provides reference values for current (I*) and voltage (V*). This is the value that needs to be matched with the converter; In most cases, only one variable is selected (usually voltage). Then the measured power value is compared to the current MPP value. If there is a difference between the two, then the duty cycle (d) the converter is adjusted in an effort to reduce such discrepancies.

Control is carried out by the PI or hysteresis controller. In certain cases, the work cycle is determined directly, i.e. without a PI controller. Once the measured value is equal to the reference value, the maximum power of the array is extracted.

In the previous research on the MPPT system with the P&O method implemented on wind turbines to meet the needs of electrical energy in rural areas and remote areas, it was shown that the output power output of wind turbines integrated with MPPT, was able to obtain maximum electrical power than wind turbines that did not use MPPT, this research was conducted at the CITEE Yogyakarta National Seminar.

In the previous research on the design of a public street lighting system based on DC/DC Single Ended Primary Inductor Concerter converter that is integrated with MPPT and PMW systems, it was stated that the efficiency and output power value of solar panels are greater when compared to solar panels that are not integrated with MPPT. MPPT technology produces an efficiency of 45.80% while solar power plants that do not use MPPT only have an efficiency level of 30%.

Many studies have been conducted to address the factors that can reduce the efficiency of these cells. Therefore, it is necessary to search for the maximum power point of the solar panel system to reduce the decrease in power efficiency produced and optimize the power produced by photovoltaic.

Literature Review

Time and Place

This research was conducted for 3 (Three) days, starting from September 10 to September 12, 2024. This research was conducted at University of Pembangunan Panca Budi Medan City.

Tools and Materials

The tools and materials that will be used in this research can be seen in the picture below.

Table 1. Tools and materials

NO.	Tools and Materials	Information
1.	*Solar Cell 50Wp Polycrystalline* *MY SOLAR MODEL:MY50S-12 MODEL:IK-50*	2 Pieces
2.	*Solar Charge Controller Pulse Width Modulation*	1 Piece
3.	*Controller Maximum Power Point Tracker (MPPT)*	1 Piece
4.	12V 8Ah VRLA (*Valve Regulated Lead Acid*)	2 Pieces
5.	*Watt Meter 100A*	1 Piece
6.	*Digital Lux Meter Kuber AS803*	1 Piece
7.	*Solar Power Meter SM206-Solar*	1 Piece
8.	*Sanwa Digital Multimeter CD800a*	1 Piece
9.	RC-4 temperature and humidity analyzer	1 Piece
10.	Cable	To taste
11.	Cutting Pliers	1 Piece
12.	Screwdriver	1 Piece

Table 2. Specifications of Polycrystalline Solar Panels 1

KAWACHI GP-50P-36	
Cell Type	Polycrystalline Silicone Solar Cell
Peak Power (Pmax)	50 WP
Max. Power Volt (Vmp)	18-25
Max. Power Current (Imp)	2.75A
Open Circuit Volt (Voc)	21.6V
Short circuit current (Isc)	2.91A
Max. system Voltage	700V DC

Table 3. Spesifikasi Panel Surya Polycrystalline 2

MODEL IK-50	
Cell Type	Polycrystalline Silicone Solar Cell
Peak Power (Pmax)	50 WP
Max. Power Volt (Vmp)	18V
Max. Power Current (Imp)	2.78A
Open Circuit Volt (Voc)	20.7V
Short circuit current (Isc)	2.98A
Max. system Voltage	700V DC

Figure 2. Solar Cell 50 Wp Polycrystalline

Figure 1. SCC MPPT

Figure 4. Watt Meter

Figure 3. SCC PWM

Figure 6. Solar Power Meter

Figure 5. Battery 12v 8Ah

Figure 7. Digital Lux Meter

Figure 8. Network Using SCC MPPT

Figure 9. Network Using SCC PWM

Research Methodology

Experiment is the method used in the research on which this writing is based. This means that the data obtained in the field both through field observations are analyzed and interpreted to solve research problems.

Results

How long does it take to charge the battery without and by using MPPT

This test was carried out to find out how long it takes to charge the battery, using the Solar Charge Controller Maximum Power Point Tracker and Solar Charge Controller Pulse Width Modulation at the same temperature, sunlight intensity, solar irradiation and temperature on both solar panels. The test was carried out by measuring how long it takes to charge a battery with a capacity of 8 Ah, 12v and measuring how much voltage, current, and power are produced with different sunlight intensity, solar irradiation, temperature and humidity. Each solar panel is connected to a watt meter to measure the current, voltage, power produced, then the wattage meter is connected to the Solar Charge Controller Maximum Power Point Tracker/Solar Charge Controller Pulse Width Modulation and then connected to the battery. In addition to the power output produced, data on sunlight intensity, solar irradiation, temperature and humidity are also required.

a. **First Day**

MPPT							
Battery Charging Time	**Flow/hour Avg. (Ah)**	**Average Current (A)**	**Average Power (W)**	**Average Temperature (°C)**	**Average Humidity (%)**	**Average Sunlight Irradiation average W/^{m2}**	**Average Sunlight Intensity**
4 hours	0.23	0.46	8.55W	35.5	53.85	227	31905
PWM							
Battery Charging Time	**Flow/hour Avg. (Ah)**	**Average Current (A)**	**Average Power (W)**	**Average Temperature (°C)**	**Average Humidity (%)**	**Average Sunlight Irradiation average W/^{m2}**	**Average Sunlight Intensity**
4 hours	0.023	0.73	9.81	35.5	53.85	227	31905

Table 4. Average Data of the First Day

The table is the average data on battery charging on the second day of the study. With a sunlight intensity of 43,410–20,410 Lux and irradiation of 303.8–151.5 W/m^2. When charging the battery, the highest current reaches 0.44A with MPPT and 0.73A PWM.

Figure ***10.*** *Graph of Temperature and Humidity on Day One*

The weather on the first day of the study was cloudy with an average solar irradiation of 227 W/m^2 and a sunlight intensity of 31,905 lx from 10:00 WIB to 14:00 WIB. In table 4 we can see that the power output produced by MPPT and PWM has a power difference of 1.26W, with the same irradiation of sunlight, sunlight intensity, temperature and humidity.

b. Second Day

MPPT							
Battery Charging Time	**Flow/hour Avg. (Ah)**	**Average Current (A)**	**Average Power (W)**	**Average Temperature (°C)**	**Average Humidity (%)**	**Average Sunlight Irradiation W/m^2**	**Average Sunlight Intensity**
2 hours	0.049	0.94	15.89	51.35	57.05	975.5	182.100
PWM							
Battery Charging Time	**Flow/hour Avg. (Ah)**	**Average Current (A)**	**Average Power (W)**	**Average Temperature (°C)**	**Average Humidity (%)**	**Average Sunlight Irradiation average W/^{m2}**	**Average Sunlight Intensity**
2 hours	0.049	1.71	23.34	51.35	57.05	975.5	182.100

Table 5. Second Day Average Data

Table 5 is the average data on battery charging on the second day of the study. With a solar intensity of 180,300–120,400 Lux and irradiation of 1080.5–871.98 W/m^2. When charging the battery, the highest current reaches 0.97A with MPPT and 1.73A with PWM.

Figure 11. Temperature and Humidity Graph on Day Two

The weather on the second day of the study was brighter than the first day of the study with an average of 975.5 W/m^2 of sunlight irradiation and a sunlight intensity of 182,100 lx from 10:00 a.m. to 12:00 p.m. In table 5 we can see that the power output produced by MPPT and PWM has a power difference of 7.45W, with the same irradiation of sunlight, sunlight intensity, temperature and humidity.

c. Third Day

MPPT							
Battery Charging Time	**Flow/hour Avg. (Ah)**	**Average Current (A)**	**Average Power (W)**	**Average Temperature (°C)**	**Average Humidity (%)**	**Average Sunlight Irradiation average W/^{m2}**	**Average Sunlight Intensity**
3 hours	0.033	1.12	18.88	44.7	48.6	510.5	98.910
PWM							
Battery Charging Time	**Flow/hour Avg. (Ah)**	**Average Current (A)**	**Average Power (W)**	**Average Temperature (°C)**	**Average Humidity (%)**	**Average Sunlight Irradiation average W/^{m2}**	**Average Sunlight Intensity**
3 hours	0.155	2.19	30.12	44.7	48.6	510.5	98.910

Table 6. Third Day Average Data

Table 6 is the average data of battery charge on the third day of the study. With a sunlight intensity of 167.00–13,350 Lux and irradiation of 956.3-108.3 W/m^2. When charging the battery, the highest current reaches 1.16A with MPPT and 2.23A with PWM.

Figure 12. Temperature and Humidity Graph on Day Three

The weather on the third day of the study was quite sunny with an average of 510.5 W/m2 of sunlight irradiation and a sunlight intensity of 98,910 lx from 10:00 a.m. to 1:00 p.m., at 11:00 a.m. the sunlight lost light intensity at 40,740 Ix and light irradiation at 251.6 W/m2, at 12:00 p.m. sunlight lost light intensity at 30.120 and light irradiation at 114.7 W/m2 and a few minutes later the sun returned to brightness with intensity sunlight with a figure of 167,700 Ix and sunlight irradiation at 1020.1 W/m2. In table 6 we can see that the power output produced by MPPT and PWM has a power difference of 11.24W, with the same sunlight irradiation, sunlight intensity, temperature and humidity.

How much efficiency increase is produced after using MPPT

This test was carried out to find out how much increase was produced after using MPPT at the same temperature, sunlight intensity, solar irradiation and temperature. The test was carried out by interpreting the data that had been obtained from the two solar panels, measuring how much current, wattage and current/hour were generated during battery charging, with a capacity of 8 Ah 12V.

Day	Solar Radiation (W/m²) Average	Average Power Output		Average		
		SCC MPPT (W)	SCC PWM (W)	Temperature (°C)	Humidity (%)	Sunlight Intensity (Ix)
1	227	8.55	9.81	35.5	53.85	31905
2	975.5	15.89	23.34	51.35	57.05	182.100
3	510.5	18.88	30.12	44.7	48.6	98.910
Rata-rata selama 3 hari	571	14.44	21.09	43.85	53.16	104.305

Tabel 7. Averange Data

Table 7 is the average data of power output produced during 3 (three) days of research. The data shows that SCC PWM has a power output that is greater than the power output produced by SCC MPPT with a power output difference of 6.65W. To find out which is more efficient between MPPT and PWM, we need to calculate the battery charging efficiency using the data obtained. This can be done using the following formula:

Efficiency Calculation

MPPT

Efisiensi MPPT = $\frac{50W}{14.44W}$ = 3.46%

PWM

Efisiensi MPPT = $\frac{50W}{21.09W}$ = 2.37%

In this study, MPPT has a higher efficiency value than PWM with a difference of about 1.09%.

Conclusion

Based on the data produced during this study, it was found that MPPT data had an efficiency greater than 1.09% of PWM. In this study, MPPT has a higher efficiency value than PWM with a difference of about 1.09%. Higher MPPT efficiency does not automatically make the battery charge faster. Factors such as weather conditions, ambient temperature, and battery requirements are also very important in determining the charging speed of a battery. In this case, PWM has better battery charging with a voltage at full charge of 13.10V and MPPT of 13.03V, resulting in a battery voltage difference of 0.7V after being fully charged. The choice between MPPT and PWM should be based on the specific needs of the system and the operating conditions to be encountered.

References

[1] M kaliamoorthy, V Rajasekaran, and IGC Raj, "Single-phase fifteen-level grid-connected inverter for photovoltaic system with evolutionary programming based MPPT algorithm," *Solar Energy*, pp. 314–329, 2014.

[2] Wasistha, "Efisiensi Pembangkit Listrik Tenaga Surya Off Grid di Laboratorium Teknik Listrik Politeknik Negeri Jakarta".

[3] B. Azmi *et al.*, "REVIEW PERBANDINGAN TEKNIK MAXIMUM POWER POINT TRACKER (MPPT) UNTUK SISTEM PENGISIAN DAYA MENGGUNAKAN SEL SURYA (REVIEW COMPARISON MAXIMUM POWER POINT TRACKER (MPPT) TECHNIQUE FOR CHARGING SYSTEMS USING SOLAR CELLS)."

[4] J. H. R. Enslin, "MAXIMUM POWER POINT TRACKING: A COST SAVING NECESSITY IN SOLAR ENERGY SYSTEMS," 1992.

[5] Hamdani, H., Z. Tharo and S. Anisah, *PERBANDINGAN PERFORMANSI PEMBANGKIT LISTRIK TENAGA SURYA ANTARA DAERAH PEGUNUNGAN DENGAN DAERAH PESISIR*.

[6] P. Siagian, H. Alam, M. Fahreza, and R. J. Tampubolon, "Peningkatan Daya Panel Surya Dengan Konsentrator Cahaya dari Bahan Aluminium Foil," vol. IX, no. 2, 2024.

[7] A. Faizal, B. Setyaji, J. Teknik Elektro, F. Sains dan Teknologi, U. H. Sultan Syarif Kasim Riau Jl Soebrantas No, and S. Baru, "Desain Maximum Power Point Tracking (MPPT) pada Panel Surya MenggunakanMetode Sliding Mode Control," *Jurnal Sains, Teknologi dan Industri*, vol. 14, no. 1, pp. 22–31, 2016.

[8] A. M. Eltamaly and A. Y. Abdelaziz Editors, "Green Energy and Technology Modern Maximum Power Point Tracking Techniques for Photovoltaic Energy Systems." [Online]. Available: http://www.springer.com/series/8059

[9] Z. Salam, J. Ahmed, and B. S. Merugu, “The application of soft computing methods for MPPT of PV system: A technological and status review,” 2013, *Elsevier Ltd*. doi: 10.1016/j.apenergy.2013.02.008.

[10] A. Fitriah, F. Wijaya, and E. Fimansyah, “Implementasi Maximum Power Point Tracking (MPPT) Berbasis Perturb and Observe (P&O) pada Photovoltaic (PV) dengan Variasi Iradiasi,” *Seminar Nasional CITEE Yogyakarta*, pp. 120–124, 2019.

[11] K. Moradi, M. Ali Ebadian, and C. X. Lin, “A review of PV/T technologies: Effects of control parameters,” *Int J Heat Mass Transf*, vol. 64, pp. 483–500, 2013, doi: 10.1016/j.ijheatmasstransfer.2013.04.044.

[12] Anisah, S., & Tarigan, A. D. (2023). Perencanaan Pembangkit Listrik Tenaga Surya Atap On-Grid sebagai Sumber Energi Alternatif Ramah Lingkungan. INTECOMS: Journal of Information Technology and Computer Science, 6(1), 503-510.

[13] Rahmaniar., B Mesra., Junaidi Agus. (2023). Pemanfaatan Inovasi Teknologi EBT Panel Surya pada Mesin Serut Lidi untuk Pemberdayaan Masyarakat Desa Bandar Senembah. Jurnal SOLMA, 12(3): 1186-1194; 2023

[14] Rahmaniar., Khairul., Junaidi Agus., Sari Keumala Debby. (2023). Analysis of Shadow Effect on Solar PV Plant using Helioscope Simulation Technology in Palipi Village. JTEV (Jurnal Teknik Elektro dan Vokasional). Vol. 9 No. 1 (2023)

[15] Tharo, Z., & Hamdani, H. (2020). Analisis Biaya Atap Pembangkit Listrik Tenaga Surya Skala Rumah Tangga. Journal of Electrical and System Control Engineering, 3(2), 65-71.