Asian Journal Science and Engineering
Vol. 1, No. 2, December 2022
https://attractivejournal.com/index.php/ajse

Solar Charger Controller Efficiency Analysis of Type Pulse Width Modulation (PWM) and Maximum Power Point Tracking (MPPT)

Elka Faizal[1], Yuniarto Agus Winoko[2], Mohammad Sukri Mustapa[3], Muhammad Kozin[4]
[1,2]Politekhnik Negeri Malang, Indonesia
[3]Universiti Tun Hussein Onn Malaysia, Malaysia
[4]National Research and Innovation Agency (BRIN), Indonesia

elka.faizal@polinema.ac.id*

ARTICLE INFO
Article history:
Received December 13, 2022
Revised January 05, 2022
Accepted January 24, 2022

Abstract

Solar radiation at any time can be different due to various things such as blocking of sunlight due to clouds, the intensity of the sun from sunrise to sunset, cloudiness in the rainy season, and the presence of fog in certain areas which causes different levels of solar energy. radiation that causes the output power of solar cells to vary. and not optimal. For that we need a control device that can stabilize the energy output from solar cells called Solar Charge Controller (SCC). This research was conducted to determine the value of the output power, voltage, and current of SCC type Type Pulse Width (PWM) and Maximum Power Point Tracking (MPPT), then determine the value of efficiency, and compare which type of SCC is better to use. Sampling of solar voltage and current data in the field at 10.00 – 15.00, this is because at that time the sunlight reaches its maximum intensity. The results showed that the MPPT type SCC efficiency was higher than the PWM type SCC efficiency value, namely 84.623% the MPPT type SCC efficiency compared to 80.935% PWM type SCC efficiency.

Keywords: Solar Charge Controller, Pulse Width Modulation, Maximum Power Point Tracking

Published by CV. Creative Tugu Pena
ISSN 2963-6752
Website https://attractivejournal.com/index.php/ajse

INTRODUCTION

The Solar Power Plant (PLTS) is a modular power plant, making it easy to install. In addition, PLTS can also be applied for installation on a small scale for household use, so that the potential of existing natural resources is utilized properly. Of course, in addition to utilizing existing natural resources, the installation of small-scale solar power plants for households can minimize monthly electricity bills. Installation of small-scale PLTS for household needs is usually an Off Grid system, this system regulates the use of energy produced from PLTS only for personal use, not distributed to the PLN network. Off Grid PLTS systems are usually equipped with battery installation for backup systems, the purpose is for use at night or when the electricity from PLN goes out [1].

Several researchers have conducted research related to SCC, among others: [2] stated that SCC is used in PV mini-grid systems to protect and control the process of charging and discharging batteries. There are two types of SCC technology on the market, namely the PWM and MPPT types. This paper examines the comparison of the characteristics of the two types of SCC with the same technical specifications and the same environmental conditions.

[3] tested the voltage and current values of the MPPT type SCC on the market using the ATmega328 microcontroller. SCC has its own type and specifications, in this study used ACS712 current sensor, Arduino nano voltage sensor contained in the ATmega328 microcontroller IC, LCD (Liquid Crystal Display), and personal computer. The solar panel receives sunlight then the current and voltage will be read by the current sensor and voltage sensor. After testing the tool, the data obtained in the form of voltage and current. [4] explained that with the increasing demand for energy, energy conservation and the use of renewable resources have become an important need. Solar energy will become the main energy source in the near future, therefore, highly efficient and energy-efficient solar-powered equipment and applications will soon become a major requirement in future PV mini-grid installations. In this journal, the Maximum Power Point Tracking (MPPT) solar charge controller and Pulse Width Modulation (PWM) solar charge controller are analyzed and compared. The role of the SCC is to regulate the power that flows from the solar panels to the battery. This charge controller is designed in such a way that the solar battery can be recharged quickly and does not become overloaded, thus extending the battery life. [5] said that solar panels are a solution to fight the energy crisis and also environmental pollution, but the high installation costs and large land required to build large-scale PLTS are obstacles to the sustainability of this technology. So it is necessary to maximize the value of equipment efficiency in PLTS installations so that the maximum potential of a PLTS is achieved.

Solar cells or also often called photovoltaic cells are devices that are able to directly convert sunlight energy into electrical energy [6]. Solar cells play a very important role in maximizing the enormous potential of abundant solar energy. Solar cells can be analogous to devices with two terminals that can generate voltage when exposed to sunlight [7]. There are various kinds of PLTS components for small-scale installations, two of which are batteries and SCC. SCC is basically an electronic device to control the current and voltage that flows into the battery when it is in a charging state so that there is no overcharging of the battery which can reduce the life of the battery itself, besides that SCC also controls the battery discharge process so that the battery voltage and drain conditions do not exceed the limit given from the battery datasheet. In the market, you can find two types of SCC, namely SCC with pulse width modulation (PWM) type and SCC with maximum power point tracking (MPPT) type, these two types of SCC have different characteristics. The aim of this study was to compare the efficiency of the two types of SCC. With this comparison, it is hoped that a complete picture of the process and results of controlling the output will be known. And it can be presented in a systematic way which can later support the application of solar cell renewable sources with optimal efficiency and effectiveness.

Literature Review

Charger Controller Charger

The controller is an electronic device that is used to regulate the direct current that is charged to the battery and taken from the battery to the load. The charger controller regulates over charging (excess charging because the battery is full) and excess voltage from the solar panel / solar cell. Overvoltage and charging will reduce battery life[8].

The charger controller applies pulse width modulation (PWM) technology to regulate the function of charging the battery and releasing current from the battery to the load. According to [9] some of the detailed functions of the charger controller are as follows:

1. Regulating the current for charging the battery, avoiding over charging and over voltage
2. Regulating the current released / taken from the battery so that the battery is not full discharge and overloading
3. Monitor battery temperature. To buy a charger controller that must be considered are: a. Voltage12 Volt DC / 24 Volt DC b. Capability (in direct current) of the controller. For example 5 Ampere, 10 Ampere and so on c. Full charge and low voltage cut.

A good charger controller usually has the ability to detect battery capacity. When the battery is fully charged, the charging current from the solar cell stops automatically. The way of detection is through the battery voltage level monitor. The charger controller will charge the battery to a certain voltage level, then when the voltage level drops, the battery will be recharged. Charge controllers usually consist of: 1 input (2 terminals) connected to the output of a solar cell, 1 output (2 terminals) connected to a battery/accumulator and 1 output (2 terminals) connected to a load[10].

Solar Charge Controller Technology

There are two types of technology commonly used by solar charge controllers, namely PWM (Pulse Wide Modulation). As the name suggests, it uses the pulse width of the offelectrical ondan, thus creating a sine wave electrical form. The PWM (Pulse Width Modulation) charge controller is a charging controller that functions to charge the battery from a solar panel by using pulse modulation to control the continuity of charging. As the battery approaches a fully charged state, the PWM tool will slowly decrease the amount of power going into the battery in order to reduce stress on the battery. PWM chargers are widely available in the market, they are also cheaper, and they come in various sizes for a wide range of applications. The limitations of the PWM controller include the size of the charger voltage must match the battery bank voltage, and the capacity of the PWM device is usually limited to 60 amperes Maximun Power Point Tracker[11].

All PV solar panels are rated in Watts. This identifies the potential power that can be generated by the PV panel when exposed to sunlight. If we multiply the maximum voltage (Vmp) with the maximum current (Imp) listed on the PV panel label, then we can determine the panel capacity in Watts. MPPT stands for Maximum Power Point Tracking, which is an electronic device found in a battery charging regulator that can optimize the performance of solar arrays (PV panels) and battery banks. In other words, this tool is able to convert the high voltage DC output from the solar panel to the lower voltage required by the battery / battery bank. In this charging process, the MPPT mechanism also increases the DC current (amperage) that is charged to the battery/battery bank. Back again to the example calculation above. With MPPT, the battery charging regulator maintains a stable voltage of 29.7V, so that the power drawn from the solar module remains 240W and the battery charger controller then converts the 29.7V voltage to 12V to adjust to the battery voltage. Thus the current going into the battery becomes 20A (240W / 12V). So the current power obtained by the battery is 20A and no longer 8.1A as generated by a PWM type charging regulator. The difference between the two types of battery charging controllers is very clear. With an increased amperage of 11.9A (20A-8.1A), MPPT is much more efficient than PWM [12].

Variable voltage regulator IC LM 317 to regulate a stable output voltage of around 16 volts, Variable resistor VR controls the output voltage, when the solar panel generates current on D1 it is forward biased and the regulator IC will receive current input at that time. The output voltage depends on the VR setting and the output current is controlled by R1. This current passes through D2 and R3, when the output voltage is above 16 volts (as defined by VR), the ZD2 zener diode engages and provides a steady voltage of 15 volts for charging the 12 V battery charging depending on R1 and R3, around 250 s/ d 300 mil . Ampere current will be available for charging the 12 V battery. The green LED indicates the state of charge and when the battery reaches full voltage of approx. 13 volts, the zener diode ZD1 engages and T1 is in forward bias. This drains the output current from the IC regulator via T1 and 10 the charging process will stop. When the battery voltage drops below 12 volts, ZD1 turns off and battery charging starts again [13].

PWM Solar Charge Controller

The charge controller which is between the solar panel and the battery bank is with the function of preventing the solar panel from overcharging the battery. The algorithm, or control strategy, of the charge controller determines the efficiency of battery charging and solar panel utilization, which ultimately affects the system's ability to meet load demands, and battery life.

Pulse Width Modulation (PWM) Setting pulse width modulation or PWM is one of the "effective" techniques used in current control systems. Modulation width settings are used in a wide variety of fields, one of which is: speed control, power control, measurement and communication (measurement or instrumentation and telecommunication). Pulse width modulation (PWM) is achieved with the help of a square wave which is a duty cycle. The waveform can be varied to obtain a varying output voltage which is the average value of the waveform. PWM is basically turning on (ON) and turning off (OFF) a DC motor quickly. The key is to set how long the ON and OFF times. [14] PWM is a way of regulating the voltage by adjusting the on period (Ton) in a fixed period as shown in Figure II. 6 PWM time diagram The value of the duty cycle (D) is obtained if we compare the time at Ton (logic High) with the time at Toff (logic Low) [15].

PWM is the most effective way to achieve constant voltage battery charging by replacing solar system control power devices. When in PWM regulation, the current from the solar array decreases in response to battery condition and charging requirements. PWM solar chargers use technology like any other high quality modern battery charger. When the battery voltage reaches the setting set-point, the PWM algorithm slowly reduces the charging current to avoid heating and gassing of the battery, but charging continues to return the maximum amount of energy to the battery in the shortest time. The result is higher charging efficiency, fast recharging, and a normal battery at full capacity.

MPPT Solar Charge Controller

Maximum Power Point Tracker (MPPT) is used to condition the solar cell to be at its maximum power point. One of the algorithms used is Incremental Conductance (INC). MPPT itself consists of a DC-DC converter and a microcontroller. There are two types of MPPT, dynamic and static. Dynamic MPPT is an MPPT that uses a motor to position the surface of the solar panel so that it is perpendicular to the direction of sunlight, often referred to as a mechanical tracker. The mechanical tracker is expected to be able to maximize the output power of the solar panels, but the problem with this tool is that the mechanical tracker drive motor itself requires energy to move, so if the light sensor on this device is too sensitive, the motor will continue to move so that a lot of energy is wasted. Meanwhile, static MPPT has a different way from dynamic MPPT to maximize the output power of solar cells. The workings of static MPPT are by utilizing the current-voltage characteristic curve in which there is a maximum power point. In static MPPT, it has a DC – DC converter which functions as a conditioner for the output voltage of the solar panel. The presence of this DC – DC converter is expected to increase the working voltage of the solar panel so that the working voltage can be at the maximum power point.

Currently the use of DC electricity is needed, one of which is sunlight, which is a very effective renewable energy source. Alternative energy as a substitute for fuel for power generation. Maximum Power Point Tracker aims to maximize the power output of absorbed solar panels to make it more optimal. The tracking algorithm used is perturb and observe. An algorithm that looks for zero dP/dV as a sign of the peak of the Maximum Power Point (MPP) curve. To further maximize the system made by moving solar panels. The drive used is a DC motor gearbox. The results obtained from this system are tracking single axis solar panels that can be perpendicular to the direction of the sun and get greater voltage, current and power values using Maximum Power Point Tracker (MPPT) based on the perturb and observe method [16].The use of static control with the Maximum Power Point Tracker (MPPT) method, the Incremental Conductance algorithm works as a conditioner for solar panel operations. A buck converter is used to condition the operating voltage of the solar panels. A 6 V battery and a resistive load are used as the solar panel load. The solar panel used has a peak power of 50 watts [17]

Based on the use of the Human Machine Interface Supervisory Control and Acquisition Data (HMI SCADA) software which functions to receive or transmit data or information, controllers, networks, communication devices and several other supporting software. The HMI design and monitoring system is a simulation tool that functions to tell what activities are taking place in the laboratory room, so that the user can find out what activities are taking place in each laboratory room without having to check the rooms one by one. The function of this tool is to provide information on activities that occur on a display on an operating system and requires a design that is easy to see and read [18].

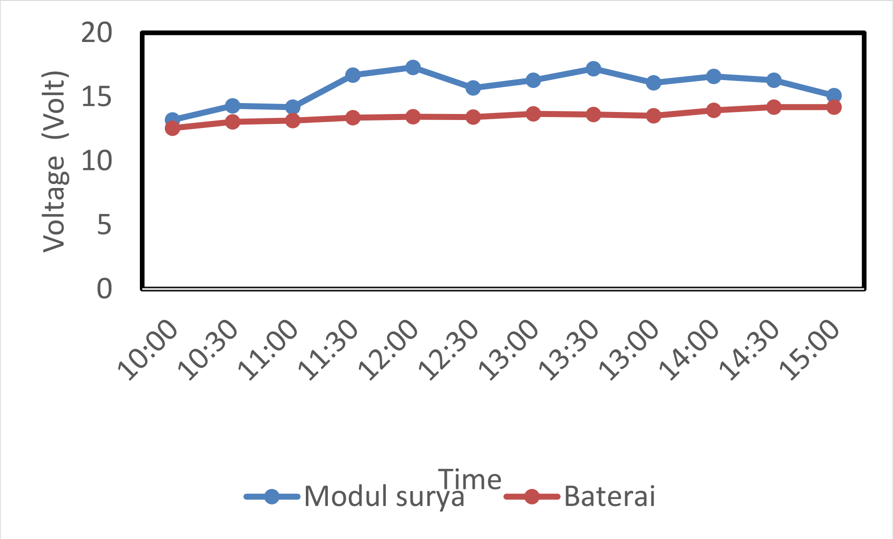
METHOD

In this study, we will compare how the performance of the PWM type SCC with the MPPT type SCC with the same equipment specifications and with the same environmental conditions will be compared. Using Solar Panel Solana Poly l00Wp with GH solar specifications with type PSP-50 W with specifications Maximum power Pmac 50 Watt, Voltage at Pmax Vmp 18 Volt, Current at Pmax lmp 2.78 Ampere, Open circuit voltage VOC 21.6 Volt, Short circuit voltage ISC 2.99 Ampere, Temperature module -40 to 85°C, ACT 18" Small Matrix Dc 36volt, Power Interer Hanaya 1000W DC to AC 220V, Solar Charge Controller PWM with battery specifications 12/24 Volt voltage, LED Current 50-3000 mA, Max LED Voltage 55 V, L/N 170505V112, MPPT Solar charge controller with specifications Max PV Charge 15 A 256 W/12 V, 510 W/24 V, Max LED Power 60 Watt, Output Voltage 17-55 V/12 V, 29-55 V/ 24 V, Output Current 150-3300 mA, and Dry Battery 60 AH, 12 Volt with specifications Nominal Voltage 12 V, Nominal Capacity 7 Ah, Standby Used 13.5 to 13.8 Volt Cycle Use14.4 s/ d 15.0 Volts, Initial Current 0.7 to 1.7 A.

RESULT AND DISCUSSION

Comparison of PV Voltage and Battery Connected to PWM

Figure 1 Charging Test Between PV Voltage and Battery



Based on figure 1, the solar module voltage is directly proportional to the irradiation value given by the sunny web box sensor. The higher the irradiation value, the higher the voltage value on the module. In the test there are several times of irradiation decrease, it can be seen in the graph that there is a decrease in voltage. Although the voltage on the module increases and decreases several times, the voltage on the battery remains stable due to the use of PWM type SCC.

Comparison of PV Voltage and Battery Connected to MPPT

Figure 2. Charging Test of the Relationship between PV Voltage and Battery Voltage

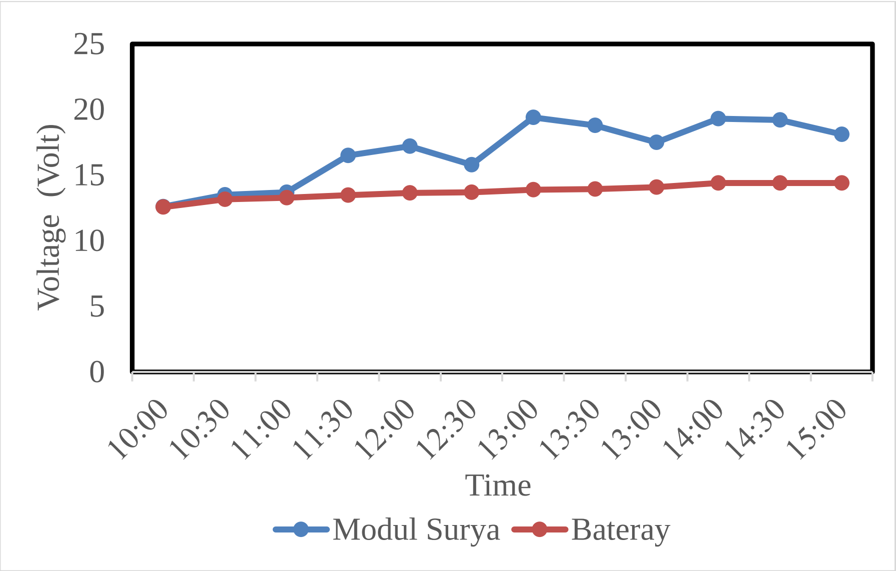


Figure 2 shows that the solar module voltage is directly proportional to the irradiation value given by the sunny web box sensor. The higher the irradiation value, the higher the voltage value on the module. In the test there are several times of irradiation decrease, it can be seen in the graph that there is a decrease in voltage. Although the voltage on the module increases and decreases several times, the voltage on the battery remains stable due to the use of MPPT type SCC. It can be seen that the graph of the solar module voltage on the MPPT type SCC is higher than the graph of the solar module voltage with the PWM type SCC.

Comparison of PV Voltage on SCC Type PWM and MPPT

Figure 3 Comparison of the Voltage on the Solar Module With SCC PVM And MPPT

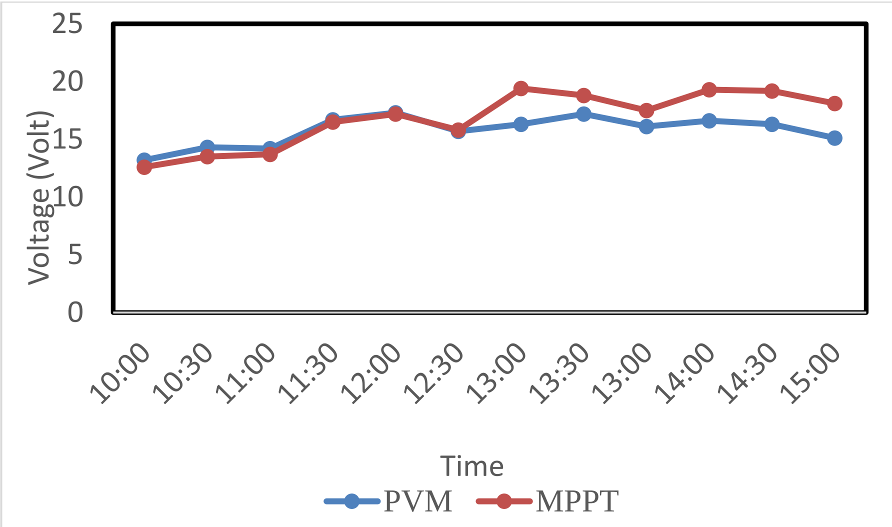


Figure 3 shows that the voltage generated by the solar module with MPPT type SCC has a higher voltage when compared to the solar module with PWM type SCC. This is because the MPPT type SCC works by maximizing the voltage on the module, while the PWM type SCC works by equating the module voltage with the battery voltage. The average PV voltage connected to the PWM type SCC is 15.69 Volts while the average PV voltage connected to the MPPT type SCC is 17,099 Volts.

Comparison of PV Currents in SCC Types of PWM and MPPT

Figure 4 Comparison of Currents in Solar Modules with Two Different SCC

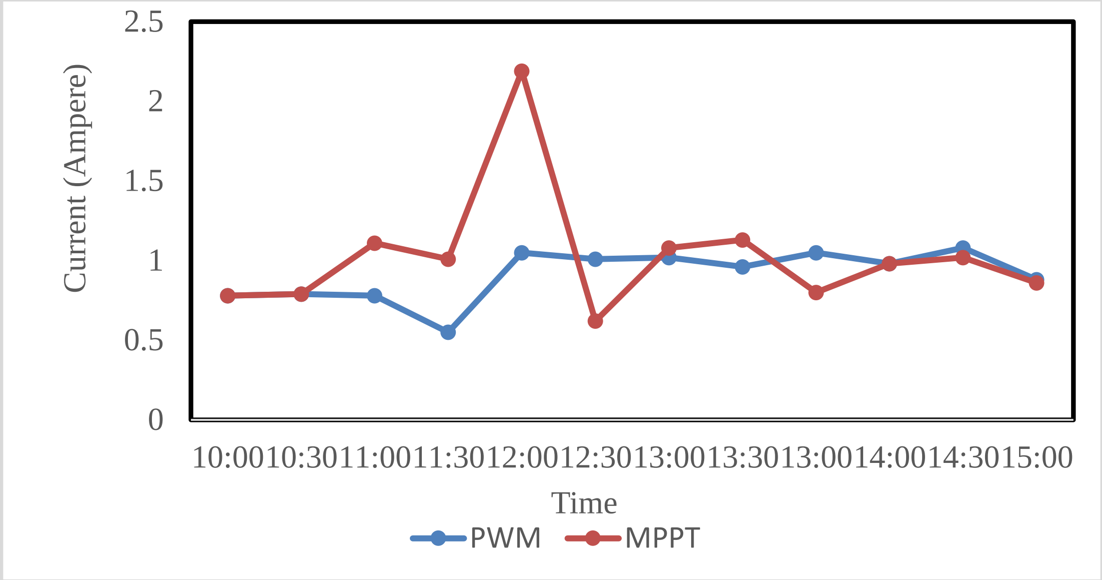
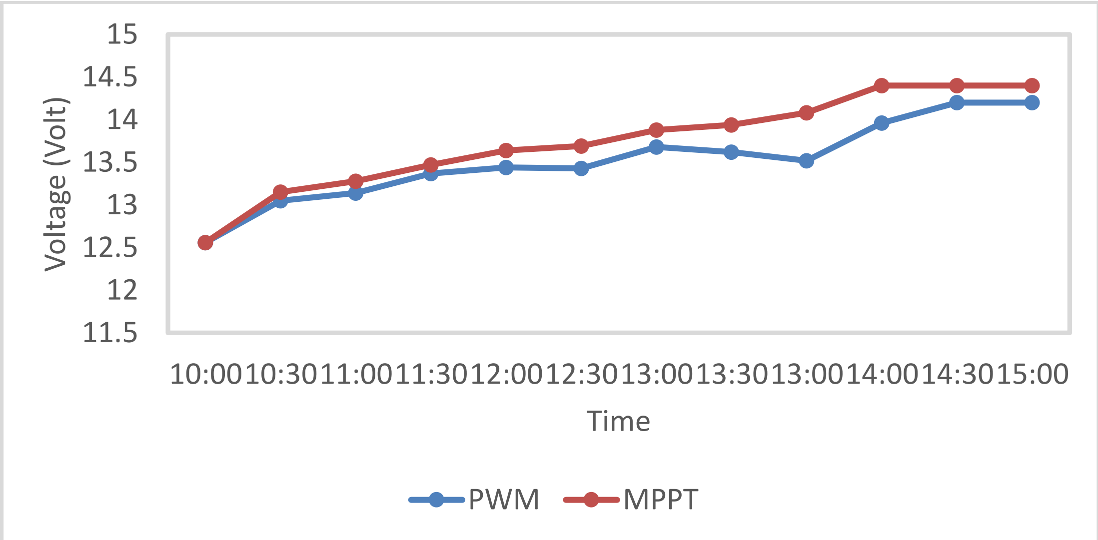


Figure 4 shows that the current generated by the solar module with MPPT type SCC has a higher current when compared to the solar module with PWM type SCC. The average PV current connected to the PWM type SCC is 0.9077 Ampere while the average PV current connected to the MPPT type SCC is 1.024615 Ampere.

Comparison of battery voltage at SCC Type PWM and MPPT

Figure 5 Comparison of the Voltage on the Battery with Two Different SCC



Based on the figure 5, it can be seen in the graph. The voltage on the battery using the MPPT type SCC is higher than the battery using the PWM type SCC. Based on the experimental results, it is known that the MPPT type SCC is more suitable for use in lithium-ion batteries, because lithium ion batteries have a smaller than lead acid batteries, so they require a longer time and higher voltage for charging.

The average battery voltage connected to the PWM type SCC is 13,566 Volts while the average battery voltage connected to the MPPT type SCC is 13,791 Volts.

Comparison of Battery Current in SCC Type PWM and MPPT

Figure 6 Comparison of Current in Batteries with Two Different SCC

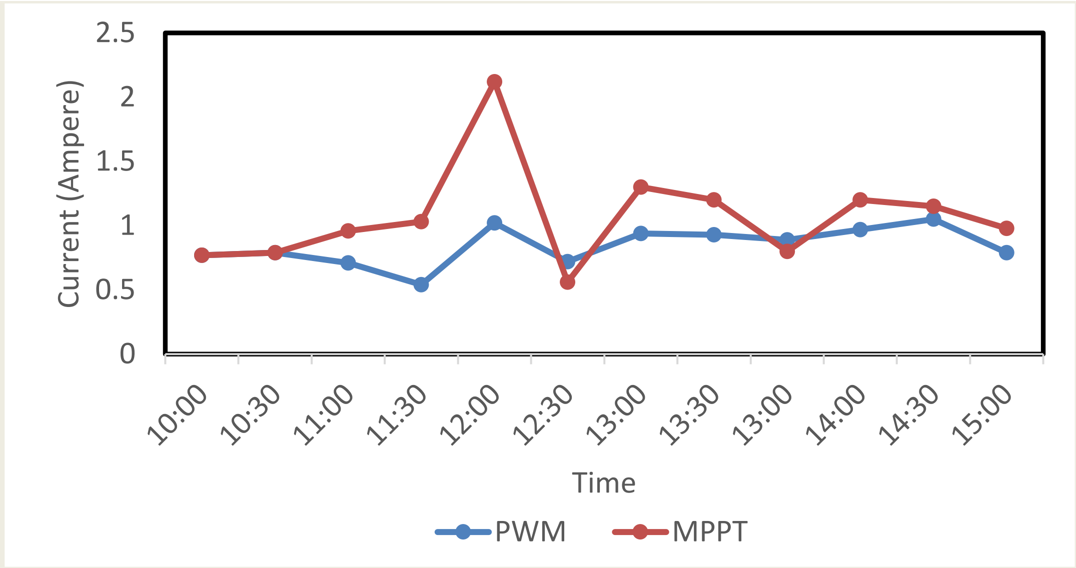


Figure 6 shows that at 11.30 to 12.00 there is a current surge in both types of SCC. However, the battery is currently in bulk mode, after which the current tends to stabilize. There is a slight change in current up and down due to changing irradiation conditions. At the end of the test time the current in the battery decreases, this is because the battery is full so it enters absorption mode. This mode is to maintain a constant charge to prevent overcharge. In addition, it can be seen in the graph, the final voltage of the battery using the MPPT type SCC is higher than the battery using the PWM type SCC. This means that the MPPT type SCC causes excessive stress during the charging process. The average battery current connected to the PWM type SCC is 0.839230 Ampere while the average battery current connected to the MPPT type SCC is 1.062307 Ampere.

Efficiency Comparison of PWM and MPP . SCC Types

Figure 7 Comparison of Efficiency at Two Different SCC

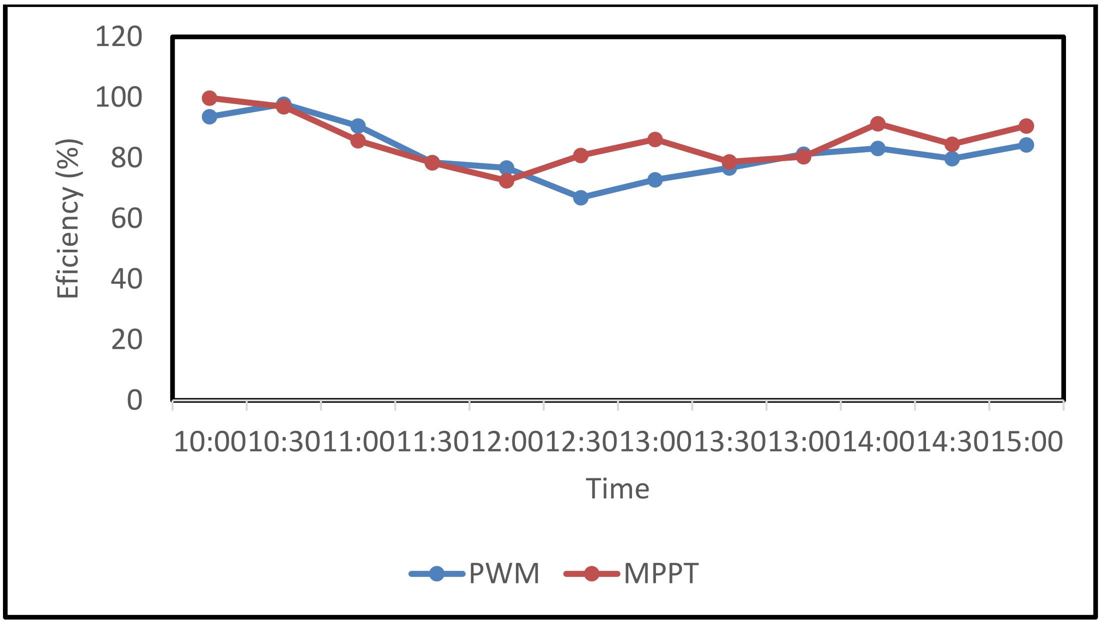


Figure 7 shows that the MPPT type SCC has a slightly higher efficiency value when compared to the PWM type SCC. However, this depends on many factors, including irradiation and temperature. In this study, the temperature used comes from the sunny box sensor, so the temperature obtained is the average temperature instead of the individual temperatures of the two solar modules used for testing so there is a possibility of error due to slightly different temperatures between the two solar modules which can cause differences in efficiency.

CONCLUSION

Based on the research that has been done, the following conclusions can be drawn that he efficiency of the MPPT type SCC is higher than the efficiency value of the PWM type SCC, which is 84.623% the MPPT type SCC efficiency compared to 80.935% the PWM type SCC efficiency. The characteristics of the MPPT and PWM types of SCC are different, including: the first MPPT type SCC can maximize the voltage and current from the solar panel to near its maximum power point value, when charging the current and voltage values flowing to the battery are greater than the PWM type SCC. And the second the PWM type SCC produces a voltage and current output whose value is slightly higher than the nominal voltage and current of the battery, but not close to the maximum power point of the solar panel. The irradiation value affects the output voltage and current from the solar panel connected to the MPPT and PWM type SCC. When the irradiation value is low, the current and voltage from the solar panel output also decreases in value. When the irradiation value increases, the current and voltage values of the solar panel output also increase.

ACKNOWLEDGMENTS

Thank you to state polytechnic of Malang who has assisted in financing this research, with research contract number: SP DIPA-023.18.2.677606/2022.

REFFERENCES

[1] M. N. M. Nasir, M. H. Jali, M. A. R. Rashid, M. F. Sulaima, Z. H. Bohari, and M. S. Yahaya, "Development of Hybrid Photovoltaic-Wind System for LED Street Lighting," *Appl. Mech. Mater.*, vol. 699, 2014, doi: 10.4028/www.scientific.net/amm.699.583.

[2] A. Al Nabulsi, A. El Nosh, A. Ahli, M. Sulaiman, and R. Dhaouadi, "Efficiency optimization of a 150W PV system using dual axis tracking and MPPT," 2010, doi: 10.1109/ENERGYCON.2010.5771713.

[3] F. Muhammad, M. Waleed Raza, S. Khan, and A. Ahmed, "Low Efficiency of the Photovoltaic Cells: Causes and Impacts," *Int. J. Sci. Eng. Res.*, vol. 8, no. 11, 2017.

[4] B. I. Madububa, J. C. Mbagwu, and D. O. Isiohia, "Design, Construction, and Testing of Maximum Power Point Tracking (MPPT) Charge Controller for Photovoltaic (PV) Power Generation," *J. Eng. Res. Reports*, 2020, doi: 10.9734/jerr/2020/v17i117180.

[5] M. Chaudhari, K. Babu, S. W. Khubalkar, and P. Daigavane, "Off-grid hybrid solar power conditioning unit for critical and non-critical loads," 2019, doi: 10.1109/ICCS45141.2019.9065782.

[6] I. S. Kim, "Robust state estimator design for a solar battery charging system," *Int. J. Electron.*, vol. 96, no. 3, 2009, doi: 10.1080/00207210802524278.

[7] S. Vavilapalli, U. Subramaniam, S. Padmanaban, and V. K. Ramachandaramurthy, "Design and real-time simulation of an AC voltage regulator based battery charger for large-scale PV-grid energy storage systems," *IEEE Access*, vol. 5, 2017, doi: 10.1109/ACCESS.2017.2768438.

[8] W. Pokakul and N. Ketjoy, "Performance Analyzing of Stand-Alone PV Hybrid Mini-Grid System with PV at DC and AC Coupling," *Appl. Mech. Mater.*, vol. 839, 2016, doi: 10.4028/www.scientific.net/amm.839.23.

[9] S. Iqbal *et al.*, "Aggregation of EVs for Primary Frequency Control of an Industrial Microgrid by Implementing Grid Regulation Charger Controller," *IEEE Access*, vol. 8, 2020, doi: 10.1109/ACCESS.2020.3013762.

[10] K. S. P. Oruganti, C. A. Vaithilingam, G. Rajendran, and A. Ramasamy, "Design and sizing of mobile solar photovoltaic power plant to support rapid charging for electric vehicles," *Energies*, vol. 12, no. 18, 2019, doi: 10.3390/en12183579.

[11] A. Jain and C. Nagarajan, "Efficient Control Algorithm for a Smart Solar Street Light," 2016, doi: 10.1109/NGMAST.2015.40.

[12] A. Rajaei, “A New Robust Analog Maximum Power Point Tracker for a PV Battery Charger,” *Iran. J. Sci. Technol. - Trans. Electr. Eng.*, vol. 42, no. 2, 2018, doi: 10.1007/s40998-017-0043-3.
[13] Y. Teekaraman and K. Ramya, “A vigorous simple most extreme force point tracker for pv battery charger,” *Environ. Syst. Res.*, vol. 5, no. 1, 2016, doi: 10.1186/s40068-016-0075-0.
[14] A. Thangavelu, S. Vairakannu, and D. Parvathyshankar, “Linear open circuit voltage-variable step-size-incremental conductance strategy-based hybrid MPPT controller for remote power applications,” *IET Power Electron.*, vol. 10, no. 11, 2017, doi: 10.1049/iet-pel.2016.0245.
[15] C. S. A. Gong and L. X. Chang, “A Wide-Range Charge Controller for Solar Sensor,” *J. Circuits, Syst. Comput.*, vol. 24, no. 7, 2015, doi: 10.1142/S021812661550108X.
[16] R. R. Varma and P. P. Bartakke, “IP for solar MPPT charger,” 2016, doi: 10.1109/ICCSP.2016.7754514.
[17] A. I. M. Ali, M. A. Sayed, and A. A. S. Mohamed, “Seven-level inverter with reduced switches for pv system supporting home-grid and ev charger,” *Energies*, vol. 14, no. 9, 2021, doi: 10.3390/en14092718.
[18] J. B. Woudstra, P. Van Duijsen, P. Van Willigenburg, and P. M. Witte, “DC educational development improving understanding of DC to DC / DC to AC conversion,” 2019.