# Comparative Analysis of Arduino-microcontroller based on PWM and MPPT Solar Charge Controller for Stand-alone Solar PV System in Charging Stations of Electric Vehicles

Manuscript received January 4, 2025; revised April 14, 2025

Chan Myae Aung
*Department of Mechanical Engineering*
*Yangon Technological University*
Yangon, Myanmar
mgchanmyaeaung.ytu@gmail.com

Ei Mon
*Department of Microcontroller*
*Yangon Technological University*
Yangon, Myanmar
maeimon.ytu@gmail.com

Than Than Htike
*Department of Mechanical Engineering*
*Yangon Technological University*
Yangon, Myanmar
mathanthanhtike.ytu@gmail.com

Hla Myo Tun
*Pro-Rector for Research and Engineering Higher Education*
*Yangon Technological University*
Yangon, Myanmar
hmt.ytu@gmail.com

***Abstract*—This study especially focuses on Arduino-microcontroller based pulse width modulation (PWM) and maximum power point tracking (MPPT) solar charge controller design using buck topology for stand-alone solar photovoltaic (PV) application where the PV output voltage is larger than the load/battery voltage. It consists of the design calculation for solar charge controller, design simulation techniques, construction of the hardware circuit design and modified perturb and observe (P&O) MPPT algorithm by utilizing the variable duty cycle step size. In the PWM solar charge controller design approaches, the fixed duty cycle, D=89% is specified and in the MPPT approaches, the variable duty cycle step size is applied. The design approaches with simulation techniques are also performed by professional circuit IDE (Proteus). After completing the design approaches with simulation techniques, the construction of hardware circuit for both PWM and MPPT is also conducted in the research laboratory of Yangon Technological University (YTU). In this study, the real-time measurement (RTM) technique for practical measurements and their results are offered and compared with the results on simulation techniques. The practical operation, monitoring and recording of data are also executed by using Arduino microcontroller (ATmega328P) with Arduino Data Logger Shield. The comparison results on RTM practical approaches for both PWM and MPPT solar charge controllers are given and their performance specifications are also evaluated. Both of two approaches can safely be used to charge the 12V rechargeable battery in reality. However, RTM practical results confirm that the designed MPPT controller could be improved 9% efficiency than PWM technique. Therefore, the designed MPPT solar charge controller is more efficient than PWM technique and suitable for real world applications in 12V, 100Wp stand-alone PV system.**

***Keywords*—Arduino-Microcontroller, Real-Time Measurement, Arduino Data Logger Shield, Pulse Width Modulation, MPPT**

## I. INTRODUCTION

Renewable energy sources are rapidly grabbing in place of conventional energy sources. Among the renewable energy sources [1], stand-alone solar PV systems are the most widely used and very popular renewable energy sources that are used in areas that are not easily accessible or have no access to a grid connected electricity system. However, energy extraction methods from stand-alone solar PV systems remain relatively less efficient and need to further improve quickly to a greener and more environmentally friendly energy future. Since most renewable energy resources produce only DC voltage, DC-DC power electronic converter circuits such as solar charge controllers are widely used to convert a DC voltage level to another DC voltage level. In many solar PV applications, buck, boost, buck-boost, CUK, SEPIC and ZETA converter topologies are commonly used to achieve the regulated DC power depending upon the corresponding application. In this study, Arduino-microcontroller-based solar charge controller using buck topology is comparatively analyzed on both PWM and MPPT techniques to apply in the stand-alone solar PV system [2].

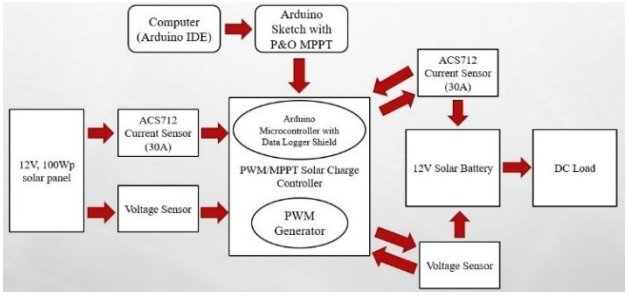



**Fig.1.** Stand-alone PV System with Arduino-microcontroller-based PWM/MPPT Solar Charge Controller

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.555

In this study, the design with simulation approaches and hardware construction of both Arduino-microcontroller based PWM and MPPT solar charge controllers for stand-alone PV systems are presented. For the simulation approaches and practical measurement techniques, 100 Wp solar PV module is utilized as the sources and 12V, 70Ah rechargeable lead acid battery as the load. The design calculations are conducted to confirm the stability of the selected PV module and battery rating. After completing the design calculation, modeling and simulation are conducted with Proteus Circuit software. Finally, the hardware design construction is completed with the utilization of calculated component values. The results are recorded and logged by using Arduino Data Logger Shield, described with the graphs and then the performances of designed PWM and MPPT controllers are evaluated.

The main contribution of this study is to implement the Arduino-microcontroller based PWM and MPPT solar charge controller for stand-alone solar PV System with discrete components and the performance comparison of the developed circuit design. The previous research at YTU was completed based on the separate contribution especially on the MPPT solar charge controller and different switching condition. The integrated system is based on that previous experience to reach the high-performance design. The novelty of this study could be observed by using the optimal switching algorithm with high frequency switching devices in real world applications.

The paper is organized as follows. Section 2 presents the operation of arduino-microcontroller-based PWM and MPPT solar charge controller. Section 3 offers the main components of arduino-microcontroller- based PWM and MPPT solar charge controller for stand-alone PV system. Section 4 mentions the mathematical design calculation of arduiono-microcontroller based PWM and MPPT solar charge controller. Section 5 expresses the research methodology. Section 6 presents the hardware design construction of arduino-microcontroller based PWM solar charge controller. Section 7 gives the hardware design construction of arduino-microcontroller based MPPT solar charge controller. Section 8 concludes the study in this paper.



**Fig. 2**. 100Wp solar panel.



**Fig. 3.** 12V, 70Ah battery.

## II. Operation of Arduino-Microcontroller-Based PWM and MPPT Solar Charge Controller

The Arduino-microcontroller-based PWM and MPPT solar charge controller mostly consists of the storage elements (i.e. inductor and capacitor), the power electronic switches (transistor switch such as BJT or MOSFET or IGBT and diode switch), the switch driver and the Arduino microcontroller. As shown in Figure. 4, the inductor is connected to the capacitor in such a way that form of LC low pass filter to reduce output ripple voltage in the whole system. The inductor is used to store energy in ON state condition and to discharge the stored energy to load in OFF state condition. The capacitor works as a smoothing filter for unwanted signals from the circuit. The potentiometer is used for adjustment of the range from 0% to 100% duty cycle. Transistor switches such as MOSFET (IRF3710) are used to control the specific duty cycle of pulse width modulation (PWM) signal that generated from the Arduino microcontroller and the flow of energy between input and output.

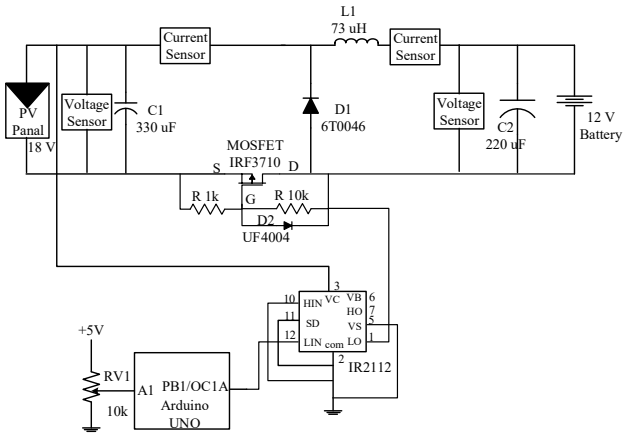



**Fig. 4.** Complete circuit diagram for Arduino-microcontroller based PWM/MPPT solar charge controller.

When the switch is ON, the diode will become reversed-bias, and it can provide energy to the inductor and load [3]. When the switch is OFF, the diode will become forward-bias and the stored energy by inductor current flow through it and the energy could be transferred to the load. The diode switch is used for continuous conduction even in open-circuit (OFF) condition. The MOSFET gate driver (IR2110) is used to trigger the MOSFET for switching purposes. The Arduino microcontroller is mainly used to implement perturb and observe (P&O) MPPT algorithm, and to generate PWM signal

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.555

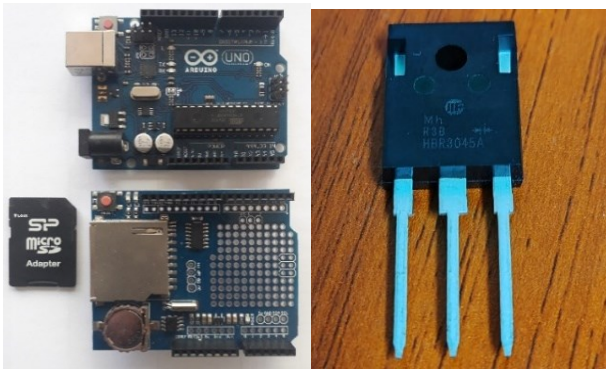
with desired switching frequency (31.375kHz). The voltage and current sensors are used to sense and measure input/output voltage and current. The main purpose of the designed PWM and MPPT solar charge controllers is to reduce power losses and improve the efficiency of the stand-alone PV system in reality. Another objective is to convert a higher input DC voltage level into lower battery chargeable output DC voltage level, and it can handle safely charge to the rechargeable battery [4].

## III. Main Components of Arduino-Microcontroller-Based PWM and MPPT Solar Charge Controller for Stand-Alone PV System

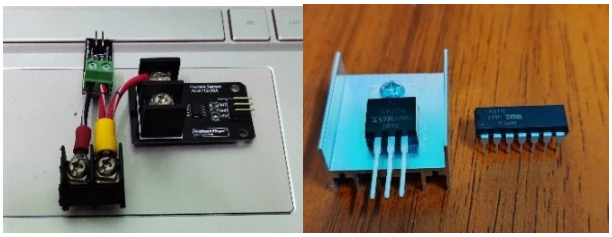
For the construction of hardware design, the components of Figure 4 have to be collected and systematic utilization. The main components in the hardware circuit are as follow.

- *Arduino Microcontroller (Atmega328P) and Arduino Data Logger Shield:* This microcontroller with shield is used to implement P&O MPPT algorithm, to generate the PWM signal to the Gate terminal of the MOSFET and to apply the real-time measurement (RTM) data logging of input/output voltage, current, power and efficiency.
- *Voltage and Current Sensor:* Four sensors are used to sense and measure the input/output voltage and current of the designed MPPT solar charge controller.
- *IRF3710 MOSFET and Schottky Diode:* These switches are used for observing the required switching control between input and output.
- *IR2110 MOSFET driver:* It is a circuit that used to drive the gate of power MOSFETs in high-speed switching applications.

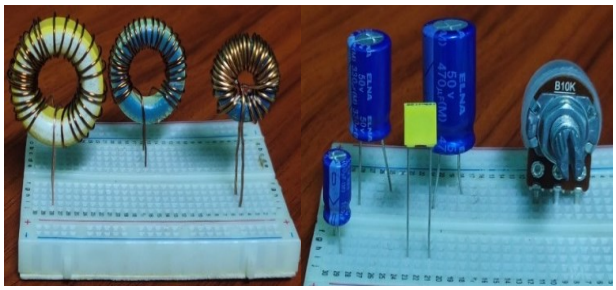
The main components used for Arduino-microcontroller based PWM and MPPT solar charge controller are shown in Fig. 5.



(a) (b)



(c) (d)



(e) (f)

**Fig. 5**. Circuit components used in MPPT solar charge controller: (a) Arduino microcontroller ATmega328P with data logger shield, (b) Schottky diode, (c) Voltage sensor and current Sensor, (d) IRF3710 MOSFET and IR2110 MOSFET driver, (e) Self-made Inductors and (f) Capacitors and potentiometer.

## IV. Mathematical Design Calculation of Arduino-Microcontroller Based PWM and MPPT Solar Charge Controller

In order to obtain the correct rating of circuit components, the following mathematical equations are utilized for Arduino-microcontroller-based PWM and MPPT solar charge controller design. Equation (1) is to calculate the desired output voltage depending upon the maximum input voltage. The converter efficiency (η) is added to the duty cycle (D) calculation with the approach for more realistic duty cycle value. Equation (2) is to calculate the maximum output current necessary in that design. Equation (3) is a good estimation for the right inductor ripple current. Equation (4) is to calculate the right power transistor switch current. Equation (5) with the desired switching frequency (fs) is a good estimation for the right inductor selection. The lower values of the inductance (L), the smaller the inductor size. Equation (6) with the peak-to-peak ripple voltage is to calculate the minimum input capacitance. Equation (7) with output ripple voltage is to calculate the minimum output capacitance [5-7].

$$D = \frac{V_{out(Desired)}}{V_{in(max)} \times \eta} \quad (1)$$

$$I_{out(max)} = \frac{P_{max}}{V_{out(Desired)}} \quad (2)$$

$$\Delta I_L = (0.2 \text{ to } 0.4) \times I_{out(max)} \quad (3)$$

$$I_{SW(max)} = \frac{\Delta I_L}{2} + I_{out(max)} \quad (4)$$

$$L = \frac{[V_{in(max)} - V_{out}] \times D}{f_s \times \Delta I_L} \quad (5)$$

$$C_{in(min)} = \frac{I_{out} \times D \times (1-D)}{f_s \times \Delta V_{pp}} \quad (6)$$

$$C_{in(max)} = \frac{\Delta I_L}{8 \times f_s \times \Delta V_{out}} \quad (7)$$

## V. Methodology

Arduino-microcontroller-based PWM and MPPT solar charge controller by using buck topology is designed to step down from the solar panel input DC voltage to battery chargeable output DC voltage range (11V to 14.5V). The selected desired switching frequency, fs is 31.375 kHz with the realistic values of converter efficiency (90%), the ripple voltage for input capacitance (75mV) and the ripple voltage for output capacitance (20mV). The calculated values are duty cycle (89%), inductor ripple current (1.39A), inductance

(73uH), input capacitance (291uF) and output capacitance (277uF). Arduino-microcontroller-based PWM and MPPT solar charge controller simulation models are completed by using Proteus 8 Professional Software with the estimated and calculated values according to Equation (1) to (7). The PWM output signal from Arduino microcontroller with desired switching frequency, fs (31.375 kHz) is measured by virtual instrument (oscilloscope) and voltage, current and power values are measured by virtual instruments (voltmeter, ammeter and wattmeter). Low pass filter is added to the circuit to yield purely DC output voltage and metal-oxide semiconductor field effect transistor (MOSFET) [8] as power transistor switch is used for higher switching speed.

For the hardware construction, the selection process for necessary components is performed depending upon the maximum transistor switch current and maximum solar input voltage because components such as MOSFET, inductor, capacitor, diode and resistor can withstand according to their specification. The constructed hardware design is tested, analyzed and measured by using measuring instruments such as digital oscilloscope, laboratory DC power supply, RLC meter, four digital multimeter and battery tester. In MPPT controller, Modified Perturb and observe (P&O) MPPT algorithm with variable duty cycle step size is utilized into the constructed hardware model for quickly tracking the maximum power at every instant. In PWM, Arduino sketches are used for only fixed duty cycle, D=89% from design calculation is integrated to constructed hardware model. The real-time measurement (RTM) practical results with 12V, 100Wp solar panel and 12V, 70Ah rechargeable battery confirm that the designed Arduino-microcontroller-based PWM and MPPT solar charge controller circuits could produce the expected outcomes [9].

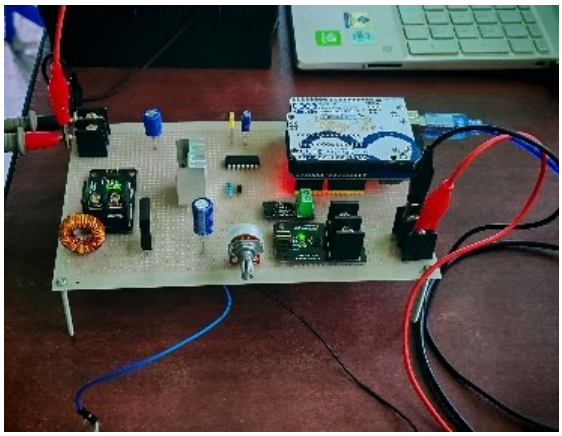
The Pulse Width Modulation (PWM) and the Maximum Power Point Tracker (MPPT) charge controllers are the two main types of charge controllers. Between the solar panel and the battery, the PWM charge controller functions as a switch [10]. In Samal et al. [11] model they had implemented MPPT based SCC along with one Wi-Fi module for monitoring the battery voltage, current, PWM pulses and battery status on smartphones. Applying a PWM-based MPPT method to an LLC converter could cause the loss of its soft switching characteristics [12]. The PWM-based Solar Hybrid Charge Controller (SHCC) that automatically switches the power source between the solar power or grid, based on the availability of solar power was reported in Sachin et al. [13].

Huang et al. [14] proposed a multi-objective optimization design methodology for coupled inductors in multiphase Buck converter. Efficiency, transient performance and size are the three dominant factors for design consideration. The detailed discussion on buck converter could be understood.

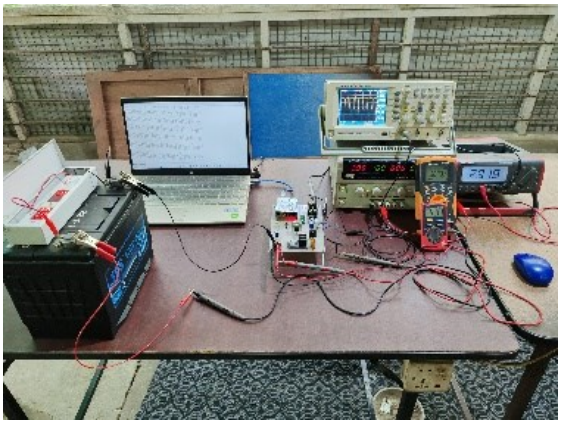
For the experimental procedures in real time consideration for EV Charging Stations [15-20], the developed system was allocated in the test place of YTU campus for the specific period of measurement duration. The measurement data was collected in a log file and the numerical analysis on the measured data was analyzed for the confirmation of the experimental setup in the outdoor test place. The performance evaluation on the measurement data for that implemented system was accomplished, and the detailed discussions are mentioned in the following sections.

## VI. Hardware Design Construction of Arduino-Microcontroller Based PWM Solar Charge Controller

The PWM control for solar charge controller is effective compared to MPPT control. In hardware design construction, Arduino microcontroller ATmega328P with Arduino Data Logger Shield is used as a control unit which generates pulse width modulation (PWM) signal with desired switching frequency (31.375kHz), control approach for the duty cycle, and for real-time measurement (RTM) practical data logging.



(a)

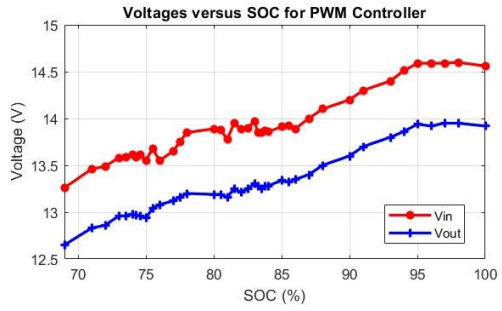


(b)

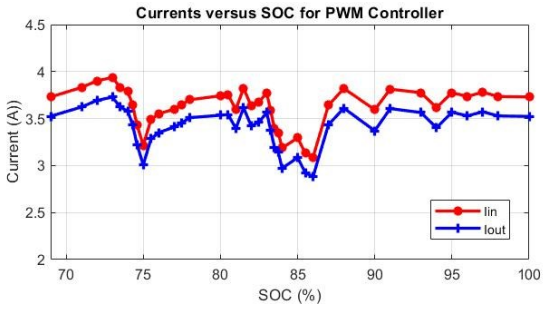
**Fig. 8.** (a) Hardware construction of Arduino-microcontroller based PWM solar charge controller and (b) Practical test

This PWM controller is used safely to charge a 12V, 70Ah rechargeable lead acid battery. In practical measurement, techniques on measurement and calculation for the input/output voltage, current and power, both sensors and digital multimeters are specifically utilized. The output of PWM controller is directly connected to the battery. The duty cycle is kept constant at 0.89% for optimum condition. Battery charging operation is carried out from 57% to full charging 100% of battery State of Charge (SoC). The time taken for battery charging is about 10 Hours and 35 Minutes to battery full charging. Fig. 8 shows the hardware [21] construction of Arduino-microcontroller-based PWM solar charge controller and practical setup.

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.555




(a)




(b)

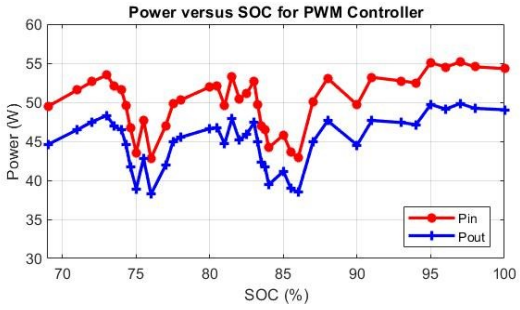
**Fig. 9.** (a) and (b) are for the RTM practical results for input and output voltage and current variation of Arduino-microcontroller-based PWM solar charge controller

In real-time measurement (RTM) practical test, the input/output voltages and currents are measured and then the power and efficiency of PWM controller is evaluated at different battery SoC conditions. In Fig. 9(a), the output voltages of the controller are smaller than input voltages and ranging between 12.65 V and 13.95 V. This range is in battery chargeable voltage range (11V~14.5V). The output voltages of the controller obtained from RTM practical results are suitable for the charging of the battery.

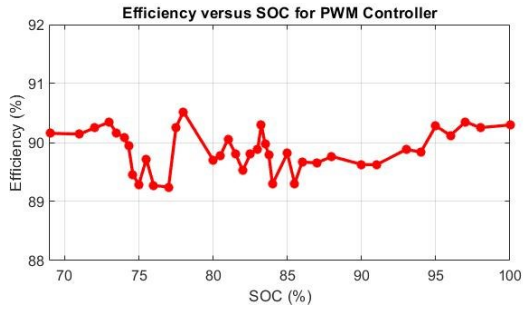
In Fig. 9(b), the output currents of PWM controllers are slightly smaller than the input currents. This can cause power losses and reduce system efficiency. The output currents range is between 2.881A and 3.728A.

In Fig. 10(a) and 10(b), the output powers range is between 35W and 50W. The maximum output power is 49.83W and minimum is 38.22W. The average efficiency of PWM controllers is at nearly 90%.

In this designed PWM circuit, the open-loop PWM control is used by setting the duty cycle with about 89 % constant. As a result, the output current of the controller is slightly smaller than the input. This causes lower efficiency of PWM controllers. In section 7, confirming the closed loop control using maximum power point tracking (MPPT), the duty cycle would be automatically adjusted by the Arduino microcontroller and efficiency of the controller will be improved [6].




(a)

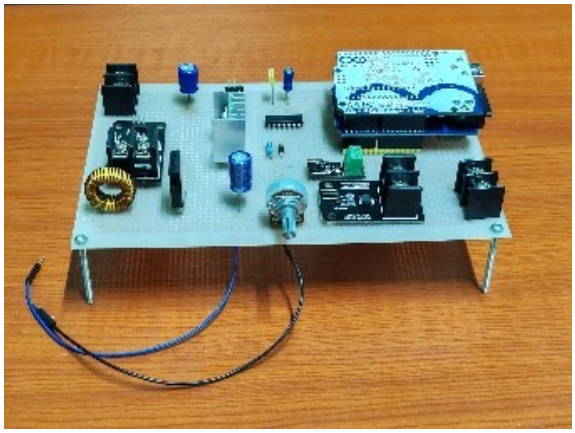



(b)

**Fig. 10.** (a) and (b) for the RTM Practical results for input and output power and efficiency variation of Arduino-microcontroller based PWM solar charge controller.

## VII. Hardware Design Construction of Arduino-Microcontroller-Based MPPT Solar Charge Controller

The MPPT control could be used for solar charge controller which is more efficient by comparing with the PWM controller. MPPT method could recover 30% of power losses and improve the efficiency of the overall system. In hardware design construction, Arduino microcontroller ATmega328P with Arduino Data Logger Shield is used as a control unit which implements modified perturb and observe (P&O) MPPT algorithm by variable duty cycle step size, generates pulse width modulation (PWM) signal with desired switching frequency (31.375kHz), and for real-time measurement (RTM) practical data logging. Figure. 10. shows the hardware construction of Arduino-microcontroller-based MPPT solar charge controller and practical setup.



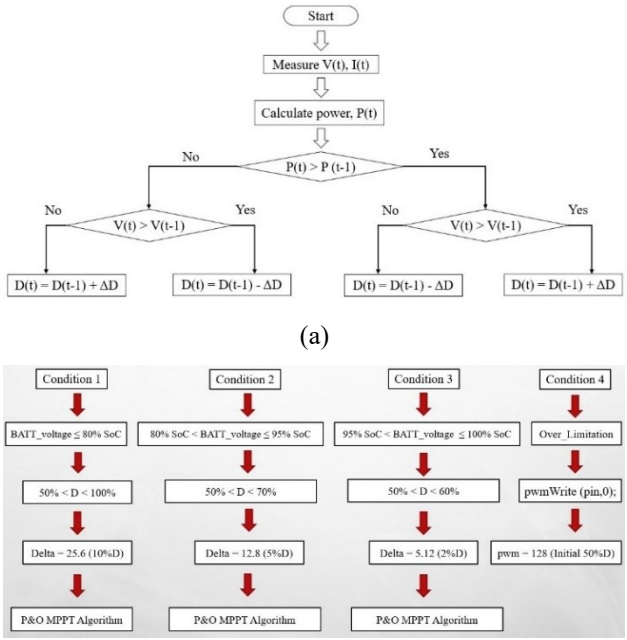
(a)



(b)

**Fig. 11.** (a) Hardware construction of Arduino-microcontroller-based MPPT solar charge controller and (b) Practical setup.

This MPPT controller is used efficiently to charge a 12V, 70Ah rechargeable lead acid battery. In practical test, by approaching the measurement and calculation of the input/output voltage, current and power, both sensors and digital multimeters are used. The output of MPPT controller is directly connected to the battery. The duty cycle is automatically adjusted by Arduino microcontroller. The duty cycle could be auto-adjustment by modified P&O MPPT which is carried out depending on battery SoC condition. Battery charging operation is carried out from 56% to full charging 100% of battery SoC. The time taken for battery charging is about 9 Hours and 15 Minutes to battery full charging. Figure. 11 shows modified perturb and observe (P&) MPPT algorithm [7].

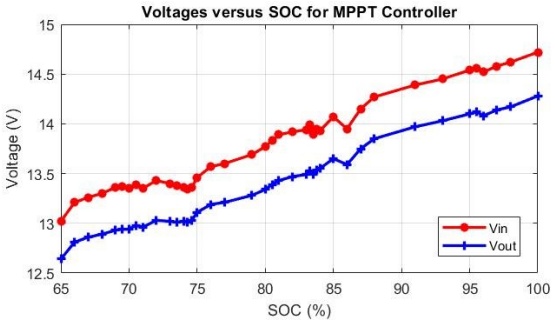



(a)

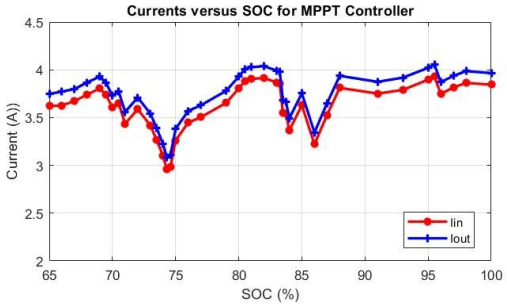
(b)

**Fig. 12.** Modified P&O MPPT algorithm: (a) Block diagram of Perturb and Observe (P&O) MPPT algorithm and (b) Variable duty cycle step size depending on battery SoC condition.

In real-time measurement (RTM) practical test, the input/output voltages and currents are measured and then the power and efficiency of PWM controller is evaluated at different battery SoC conditions. In Figure 13(a), the output voltages of the controller are smaller than input voltages and ranging between 12.64 V and 14.28 V. This range is in battery chargeable voltage range (11V~14.5V). The output voltages of the controller obtained from RTM practical results are suitable for the charging of the battery.



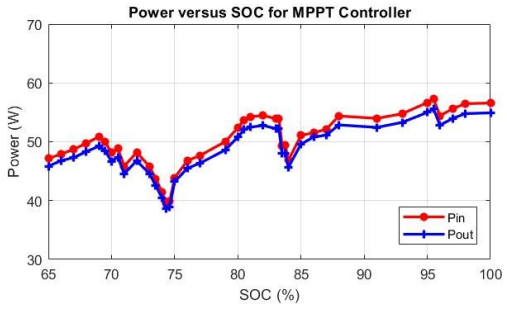

(a)



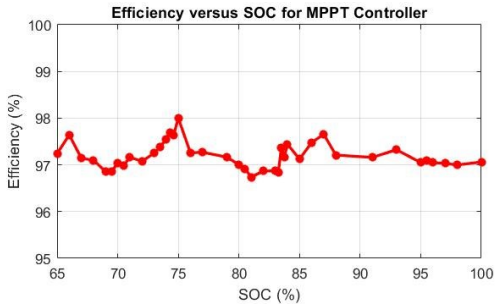

(b)

**Fig. 13.** (a) and (b) for the RTM practical results for input and output voltage and current variation of Arduino-microcontroller-based MPPT solar charge controller.

In Figure 13(b), the output currents of MPPT controller are slightly higher than the input currents. This recovers power losses due to boost current and improves the system efficiency. The maximum power loss is only 1.7W. The output currents range is between 3.109A and 3.918A.




(a)




(b)

**Fig. 14.** (a) and (b). RTM practical results for input and output power and efficiency variation.

In Figure 14(a) and 12(b), the output powers range is between 35W and 56W. The maximum output power is 55.58W and minimum is 38.5W. The average efficiency of MPPT controllers is at nearly 97%.

In this designed MPPT circuit, the closed-loop MPPT control technique is used by setting the variable duty cycle step size depending on the battery SoC condition. As a result, the output current of the controller is slightly higher than the input. That technique could recover the power losses and acquire higher efficiency than PWM controller.

The efficiency of the developed system achieved over 96% of the measurement results on MPPT is more efficient than PWM with different solar irradiance levels during the measured period in experimental studies at YTU campus. That is the confirmation of the performance evaluation on the

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i02.555

implemented design of solar charge controller for real world applications.

## VIII. CONCLUSION

In the application of stand-alone solar PV system, solar charge controllers are critical important to prevent the battery damage and lifespan reduction. It can be step-down the higher PV output voltage to the safely chargeable load/battery terminal voltage. In this research work, Arduino-microcontroller-based solar charge controller which had been designed by both PWM control and MPPT control is presented. In the comparative analysis, RTM practical results of both PWM and MPPT solar charge controllers are observed and their performance have been effectively evaluated. According to the results, both techniques can safely be charging for the 12V rechargeable battery effectively. However, the efficiency of the designed MPPT solar charge controller is higher than PWM due to output boost current compared of input current. This boost current recovers power losses of the PV system and improves the system efficiency. The efficiency of PWM is poor than MPPT due to output decreased current compared of input current. This decreased current increases power losses and reduces the system efficiency. RTM practical results demonstrate that the designed MPPT controller improve 9% efficiency than PWM. Therefore, the MPPT controller is more efficient than PWM and it could be used in stand-alone PV system for real world applications. The advanced research methodologies with deep learning and machine learning algorithm with AI approaches could be enhanced the high-level accuracy for the developed design.

## ACKNOWLEDGMENT

The authors thank many colleagues from the Electric Vehicle Engineering Research Group under the Department of Mechanical Engineering of the Yangon Technological University for completing this research work. The research work is fully supported by the Government Research Grants under the 2024-2025 Budget Year of the Republic of the Union of Myanmar.

## REFERENCES

[1] H. M. Tin Swe, E. Ei Khin, K. T. Soe, L. L. Y. Win, H. M. Tun, and D. Pradhan, "Analysis of third-generation solar cell design with physics of semiconductor," J. Novel Eng. Sci. Technol., vol. 3, no. 2, pp. 31–37, 2024, doi: 10.56741/jnest.v3i02.525.

[2] N. H. Baharudin et al., "Performance analysis of DC-DC buck converter for renewable energy application," IOP Conf. Ser.: J. Phys.: Conf. Ser., vol. 1019, p. 012020, 2018.

[3] S. A. Lopa et al., "Design and simulation of DC-DC converters," Int. Res. J. Eng. Technol. (IRJET), vol. 3, no. 1, Jan. 2016.

[4] M. Youssef et al., "Design of DC-DC converter bench controlled by an Arduino microcontroller," Int. J. Eng. Res. Technol. (IJERT), vol. 9, no. 7, Jul. 2020.

[5] B. Hauke, "Basic calculation of a buck converter's power stage," Application Report, Texas Instruments, SLVA477B, Dec. 2011, revised 2015.

[6] A. Dutta et al., "Design of an Arduino based maximum power point tracking (MPPT) solar charge controller," Dept. Elect. Electron. Eng., BRAC Univ., Dhaka, 2016.

[7] A. E. Garcia, "Maximum power point tracking algorithms for solar photovoltaic systems," Dept. Elect. Electron. Eng., BRAC Univ., Dhaka, 2016.

[8] H. M. Tun, R. E. Wulansari, D. Pradhan, and Z. M. Naing, "Design, fabrication and measurement of metal-semiconductor field effect transistor based on zinc oxide material," J. Eng. Res. Lect., vol. 2, no. 3, pp. 104–111, 2023, doi: 10.58712/jerel.v2i3.103.

[9] H. M. Tun and S. T. Z. M. Naing, "Light emitting diode modelling based on double heterojunction structure with hybrid II-VI compound semiconductor materials: Computational approaches," Solid State Technol., vol. 63, no. 6, pp. 12464–12493, 2020. [Online]. Available: https://solidstatetechnology.us/index.php/JSST/article/view/6261

[10] M. Deepika et al., "MPPT-based charge controller for battery fast charging," in Proc. 9th Int. Conf. Adv. Comput. Commun. Syst. (ICACCS), Coimbatore, India, 2023, pp. 449–453, doi: 10.1109/ICACCS57279.2023.10112852.

[11] S. Samal, R. K. Soni, S. Nayak, P. K. Barik, R. Dash, and G. Dei, "A smart solar charge controller based on IoT technology with hardware implementation," in Proc. Int. Conf. Intell. Controller Comput. Smart Power (ICICCSP), Hyderabad, India, 2022, pp. 1–6, doi: 10.1109/ICICCSP53532.2022.9862445.

[12] M. N. Alzyod, M. A. Abido, and K. M. Kotb, "MPPT-based optimal frequency control of LLC resonant converter in PV-powered EV charging stations," in Proc. IECON 2024 - 50th Annu. Conf. IEEE Ind. Electron. Soc., Chicago, IL, USA, 2024, pp. 1–6, doi: 10.1109/IECON55916.2024.10905399.

[13] K. Sachin, V. P. Yadav, A. N. Mukesh, P. K. Sharma, and L. Solanki, "Design and development of PWM based solar hybrid charge controller," in Proc. IEEE Int. Conf. Electron., Comput. Commun. Technol. (CONECCT), Bangalore, India, 2021, pp. 1–6, doi: 10.1109/CONECCT52877.2021.9622645.

[14] X. Huang, J. Yang, J. Wu, P. Ren, and W. Chen, "Optimal design of coupled inductors for multiphase buck converter," in Proc. IEEE Int. Power Electron. Appl. Conf. Expo. (PEAC), Guangzhou, China, 2022, pp. 734–738, doi: 10.1109/PEAC56338.2022.9959239.

[15] H. W. W. Nyo, H. M. Tun, L. L. Y. Win, T. Win, E. E. Khin, M. M. Aye, and D. Pradhan, "Analysis of high-performance step-down DC to DC converter design based on zero voltage switching with pulse width modulation technique for electric vehicles," J. Novel Eng. Sci. Technol., vol. 4, no. 1, pp. 25–32, 2025, doi: 10.56741/jnest.v4i01.775.

[16] M. M. K. Ko, E. Mon, T. T. Htike, and H. M. Tun, "Design and implementation of an IoT-based solar power measurement system for charging stations of electric vehicles," J. Novel Eng. Sci. Technol., vol. 4, no. 2, pp. 44–50, 2025, doi: 10.56741/jnest.v4i02.806.

[17] T. N. Hsu, T. Win, L. L. Y. Win, K. T. Soe, H. M. Tun, and D. Pradhan, "Comparative analysis of state of charge estimation methods for lithium-ion batteries in a 4S3P configuration," Scientia. Technol. Sci. Soc., vol. 2, no. 2, pp. 27–35, 2025, doi: 10.59324/stss.2025.2(2).02.

[18] M. M. Aung, S. Win, H. A. Thar, and H. M. Tun, "Implementation of efficient electric vehicle fast charging system using dual active bridge converter," Andalas. Int. J. Appl. Sci. Eng. Technol., vol. 4, no. 3, pp. 278–287, 2024.

[19] H. W. W. Nyo et al., "Design of half-wave rectifier with inductive load for high speed converter design in charging station of electric vehicles," Middle East Res. J. Eng. Technol., vol. 5, no. 1, pp. 10–17, 2025.

[20] A. K. Htay, H. M. Tun, L. L. Y. Win, E. E. Khin, and D. Pradhan, "Analysis of step up or boost converter design for charging station of electric vehicles," in Proc. IEMTRONICS 2024, P. G. Bradford, S. A. Gadsden, S. K. Koul, and K. P. Ghatak, Eds., Lect. Notes Electr. Eng., vol. 1229, Singapore: Springer, 2025, doi: 10.1007/978-981-97-4780-1_15.

[21] H. M. Tun and M. S. Nwe, "Fabrication of high performance high electron mobility transistor design based on III-V compound semiconductor," in Proc. 11th Int. Conf. Robot., Vision, Signal Process. Power Appl., N. M. Mahyuddin, N. R. Mat Noor, and H. A. Mat Sakim, Eds., Lect. Notes Electr. Eng., vol. 829, Singapore: Springer, 2022, doi: 10.1007/978-981-16-8129-5_59.