Solar Charge Controller Using Maximum Power Point Tracking Technique

Marhaposan Situmorang1*, Kurnia Brahmana2, Takdir Tamba3

Department of Physics, Faculty of Mathematics and Natural Science, University of Sumatera Utara, Medan

Email Address marhaposan@usu.ac.id*

Abstract. Maximum Power Point Tracker (MPPT) has been constructed which consist of booster Direct Current to Direct Current (DC to DC) converter, triggered by Pulse Width Modulation (PWM) given by Arduino board ATMega 328 microcontroller and MOSFET as a switch. The maximum power resulted from Photovoltaic Generator (PVG) which was illuminated with halogen lamp was tracked using Perturb and Observe (P&O) algorithm which was written in ATMega 328. The execution of P & O algorithm was based on voltage and current measurements using voltage and ACS 712 current sensors and then the calculation of power value was used to decide the execution direction of P&O algorithm to track maximum power value. The measurement results of current, voltage and power before and after tracking was tabulated in Excell Table and plotted in graphical form using Parallax Data Acquisition (PLX-DAQ) software. The tracking output voltage was achieved higher than input voltage value and nearly constant, although input voltage values was slightly varying. The implementation of MPPT in battery charging process gives that charging time of 8 hours was needed without using MPPT and charging time of 3 hours and 20 minutes was needed after using MPPT.

1. Introduction

Renewable energy resources such as solar energy has been extensively investigated since the energy free of pollution and exist abundantly in almost all of earth sky. Photovoltaic Generator (PVG) convert sunlight directly into electricity and can be used in many applications. One of major problem of using PVG is related with the optimum load resistance that must be used in order to achieve maximum power and then maximum efficiency [1]. At optimum load resistance, the voltage and power exist in maximum condition and the point is called maximum power point (MPP). In practice it is very difficult to adjust the load resistance into the optimum load value since the load may change during converting process, consequently the voltage and then the power extracted from PVG will move from maximum value.

To overcome these difficulties an MPPT must be used to force the PVG output voltage module back into operating point at maximum voltage and at maximum power point. There are several MPPT techniques that has been proposed such as Perturb and Observe (P&O), Increment Conductance (IncCon) and Fuzzy Logic. Among them P&O technique is simple and easily implemented into hardware [2][3][4] and can be applied in irradiance changes [5][6]. Fuzzy logic techniques also proposed and was claimed to be faster than P&O technique [7][8][9][10] but most of them was evaluated and presented in simulation process, since it has a complexity in hardware
implementation [11][12]. Fares et al compare fuzzy logic algorithms with commonly used algorithms such as P&O and IncCon algorithms. It was decided that fuzzy logic are more stable and superior than P&O and IncCon. algorithm [13]. Recently, Mars N et al proposed synergetic MPPT controller to track maximum power under variation of temperature and irradiation. It was claimed that extraction of maximum power was achieved without chattering effect [14]. However, since implementation of fuzzy logic in circuit need a complexity in hardware design, most of fuzzy logic control publications mentioned before was implemented in simulation using Matlab-Simulink. Implementation in real circuit is therefore our goal using a commonly used P&O algorithm and than implemented in battery solar charging system.

In this paper we propose MPPT techniques using DC to DC boost converter which is triggered by PWM pulse from ATMega 328. The control algorithm that has been downloaded in ATMega 328 is written in P &O algorithm [15][16]. The execution P &O algorithm will track the maximum voltage value of the boost converter by applying a sets of duty cycle of a PWM signal into the MOSFET in the boost converter to result the tracked output voltage and then to result the maximum power output. The booster converter output voltage after tracking using MPPT is finally implemented into battery as a load and charging discharging processes will be evaluated.

2. Proposed Approach
2.1. Block Diagram.
Block diagram of battery solar charging system is shown in Figure 1.

![Figure 1. Block diagram of battery solar charging system.](image)

PVG of 85 Wp power was illuminated using halogen lamp with such a certain intensity measured by TES 132 solarimeter. The output voltage of PVG is connected into booster DC to DC converter and execution of P & O algorithm in ATMega 328, gives such a duty cycle to drive MOSFET and then the output voltage was perturb into direction of maximum power. With these steps the maximum power was determined and then extracted from PVG output into the load which in this case a battery to be charged. The maximum power with maximum voltage then will charge the battery. In order to start and stop charging, between DC to DC converter and battery is equipped with MOSFET switch.
to start charging process when the battery is empty and to stop charging process when the battery is in a full condition.

2.2 The Circuit Scheme of MPPT controller.
The circuit scheme of MPPT controller is shown in Figure 2 which consist of $V_s$ as a photovoltaic voltage source, inductor $L$, diode $D$, capacitor $C$, MOSFET as a fast switch ($S$) and load in this case as a chargeable battery. The switch $S$ of MOSFET in circuit of MPPT is connected with PWM which result duty cycle from P&O algorithm in ATMega 328.

![Figure 2. The circuit scheme of MPPT controller.](image)

2.3. Perturb and Observe Algorithm.
In order to activate switch $S$ into on and off conditions, a source code of algorithm P&O is written in ATMega 328 and obey the flow chart as shown in Figure 3. The principle of tracking is to decide the direction of perturbation after first measurement of voltage and current and then the calculation of power. If the calculation of power increase compare with initial condition then direction of perturbation is in correct direction and tracking is continue in the same direction until the calculation of power decrease. If the calculation of power decrease compare with initial condition then direction of perturbation is not correct and tracking direction must be done in reverse direction.

![Figure 3. Perturb and Observe Algorithm.](image)

2.4. Current, Voltage and Power measurement.
During charging process voltage and current flowing out of PVG and voltage and current flowing into battery are measured using voltage sensor and ACS 712 current sensor. Voltage, current and
power data stored in microcontroller is sent into personal computer. Using PLX-DAQ software installed in personal computer, voltage, current and power data out of PVG and voltage, current and power data out of MPPT used for charging process was tabulated in real time in excel table with such a time spacing which can be adjusted. The tabulation of data, can be used to plot graph of PVG output voltage and MPPT output voltage versus time and also voltage, current and power of battery during charging process until battery is full and also graph of discharging process until battery is empty. The graph of charging and discharging process will show the difference between time consumed of charging process using MPPT and without MPPT.

3. Results and Discussion

3.1. MPPT voltage tracking.
DC to DC converter was constructed with 6 mH inductor L and 10 µF capacitor C. Load consist of a ceramic resistor of 18 Ohm (20W) and battery is not included. The varying illumination of 400 W/m² to 600 W/m² was given into solar panel using dim switch. The PVG output voltage are also vary as shown in Figure 4. The PVG output voltage is then directed into MPPT controller to track output voltage of PVG. The output voltage of MPPT after tracking are shown in nearly constant value. The stable value of MPPT output voltage gives a such proof that maximum voltage tracking occurs in our MPPT controller.

![Figure 4. Output voltage PVG and MPPT under illumination variation.](image)

3.2. Battery charging directly from PVG without MPPT tracker.
In order to observe the role of MPPT tracker in charging process, an empty lead acid battery 10 Ah, 12V, was charged directly using PVG output voltage. The PVG was illuminated using halogen lamp with intensity of 600 W/m². Figure 5 shows time needed for charging process is about 8 hours. Figure 6 shows battery power charging and the available PVG output power. It seems that plenty of PVG output power are not absorbed by the battery.
Figure 5. Battery charging process using PVG output voltage.

Figure 6. Power absorbed in charging process inside battery.
Figure 7. Discharging process of battery after full charging.

Figure 7 shows the discharging process of the battery after full charging. The discharging is done using bulb as a load. It is needed about 3 hours and 10 minutes to discharge and make the battery into an empty condition.

3.3. Battery charging from PVG using MPPT tracker.

Charging process using an MPPT tracker shows the difference in terms of charging time and power absorbed by battery. The PVG was illuminated using halogen lamp with the same intensity (600 W/m^2) and an empty battery will be charged using MPPT output voltage. The MPPT output voltage of charging process is shown in Figure 8. Nearly in whole charging time, about 4 hours and 20 minutes the battery voltage value is very closed with tracker PVG output voltage value.

Figure 8. Battery charging process using MPPT.

It would indicate that nearly all power extracted from PVG using MPPT was absorbed by the battery. It is also shown in Figure 9 that nearly all power delivered from the PVG using MPPT tracker, was absorbed by battery. The charging time using MPPT is faster than charging time without using MPPT.
Figure 9. Power absorbed by the battery in charging process using MPPT.

This indication means that an MPPT tracker able to extract maximum power from PVG since the full condition of the battery is proved by the discharging process as shown in Figure 10 using bulb as a load which takes the same time as in Figure 7 about 3 hours and 10 minutes.

Figure 10. Discharging process of battery after full charging using MPPT.

3.4. Discussion.
Graphical presentation of charging process using MPPT and without using MPPT give us the proof that MPPT has been able successfully extract maximum output power from PVG. In battery charging process using MPPT, power absorbed by the battery are in the same quantity with the power extracted from PVG. It shows that charging using MPPT exist in a high efficiency compare with charging without using MPPT. Furthermore, charging time are found to be faster if using MPPT tracker in about half of charging time needed without using MPPT.

4. Conclusion
The MPPT has been found successful to extract maximum power from PVG system for arbitrary load resistance. Graphical representation of output voltage and power which is measured in real time using PLX-DAQ software exhibit the presence of tracking maximum voltage and power in output voltage of PVG system. Charging process of battery using MPPT shows that nearly all output power from PVG
is absorbed by battery and charging time is found two times faster using MPPT compare with charging process without using MPPT.

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