Solar Charge Controllers using MPPT and PWM: A Review

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Abstract: ***With the increasing demand of power and energy, energy conservation and use of renewable resources have become a crucial necessity. Solar energy will become the ultimate and prime source of energy in near future. Therefore, highly efficient and low energy consuming solar-powered equipment and applications will soon be a major requirement. In this paper, solar charge controller using Maximum Power Point Tracking (MPPT) and Pulse Width Modulation (PWM) have been analyzed and compared, which is needed in all solar powered systems that utilize batteries. Its role is to regulate the power going from the solar panel to the batteries. Most of the modern charge controllers include PWM and MPPT. These charge controllers are designed such that the solar battery gets recharged quickly and does not get over discharged, thereby ensuring the prolonged lifespan of the battery.***

Keywords: Solar energy, MPPT, PWM, Charge controller.

1. Introduction

Today's world is facing an energy shortage due to the increase in consumption of energy day by day. This led to a decrease in natural resources like oil and natural gas that are not eco-friendly. To meet this increasing demand of power, renewable energy sources are an urgent need. Hence, solar energy, which is pollution free and easily available natural resource, can be used for power generation.

The solar charge controller's primary function is to maintain the amount of charge coming from the solar PV module that flows into the battery bank in order to avoid the batteries being overcharge. It performs three basic functions:

(i) It limits and regulates the voltage from the solar panel to avoid overcharging the battery.
(ii) While dc loads are used, the controller does not allow the battery to get discharge.
(iii) Allows different dc loads to be used [1].

Modern charge controllers are pulse width modulation (PWM) and maximum power point tracking (MPPT) controllers which are mostly used now-a-days. Both technologies are widely used in the off grid solar industries and are both great options for efficiently charging the battery. MPPT charge controller major role is to extract the maximum power from the PV module. The MPPT checks the output of the PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery to get maximum current into the battery. It is also a DC to DC converter which takes DC input from the PV module then changing it to AC and converting it back to DC voltage and current of different values to match the PV module of the battery [2].PWM comes into play when battery bank is full. It is use to control high current and voltage [3].

2. PWM Charge Controller

Pulse width modulation (PWM) main purpose is to switch the solar system controller power devices by applying a constant voltage battery charging. Modern charge controllers used PWM to allow lower amount of power applied to the batteries when the batteries are almost fully charged. PWM allows the battery to be fully charged with less stress on the battery prolonging the battery life.

PWM controller works on the concept that when solar cell produces voltage, this voltage is then indicated by voltage indicator. After this measurement, voltage controller controls the voltage and thus by using this voltage solar panels batteries are charged [3].

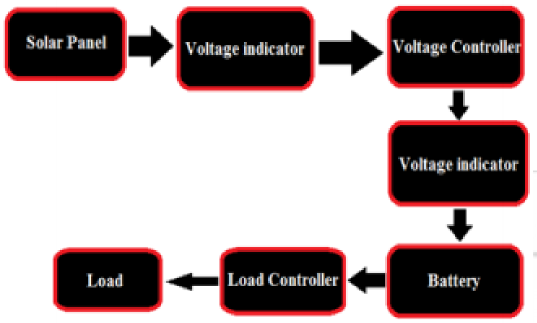

Figure 1: Flowchart of Pulse Width Modulation (PWM) charge controller [3]

PWM charge controllers use technologies similar to other modern high quality battery chargers. Some of the unique benefits of PWM pulsing [5] are:

- Ability to recognize lost battery capacity and to desulfate a battery.
- Dramatically increase the charge acceptance of the battery.
- Maximum high average battery capacities.
- Equalize drifting battery cells.
- Reduce battery heating and gassing.
- Automatically adjust for battery ageing.
- Self-regulate for voltage drops and temperature effects in solar systems.

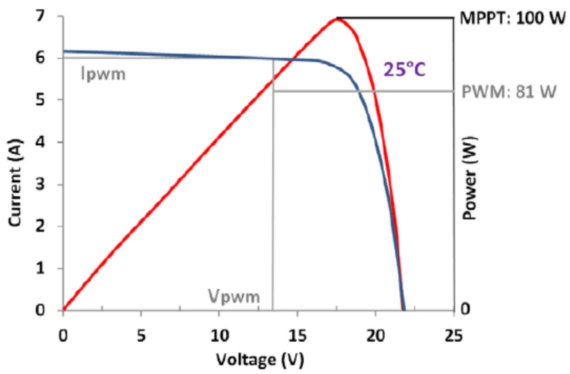

Figure 2: Current Vs Voltage curve for PWM [5]

A PWM controller is not a DC-DC transformer. It is a switch, which connects the solar panel to the battery. When the switch is close, the panel and the battery will be at nearly the same voltage. The voltage will increase with increasing state of charge of the battery [3].

3. MPPT Charge Controller

To increase the efficiency of a solar panel, use of MPPT, which is a power electronic device, comes into play. By using MPPT, the system will start operating at Maximum Power Point (MPP) and produces its maximum power output by detecting the maximum radiation on sun that falls into the PV module. Thus, it produces overall system cost [6].

Under certain conditions, MPPT charge controllers are used for extracting maximum available power from PV module so that the voltage at PV module can produce maximum power that is called 'maximum power point'. Maximum power changes with solar radiation, ambient temperature and solar cell temperature. Maximum power point tracking (MPPT) technique is used to improve efficiency of solar panel [6].

Fig. 1 shows I-V characteristics of a non-linear output efficiency of a solar cell as solar cells have a complex relationship between temperature and total resistance. Thus, the purpose of MPPT system is to sample the output PV cell and apply proper resistance to obtain maximum power for any environmental conditions. MPP is the product of MPP voltage (V_{mpp}) and MPP current (I_{mpp}) [7].

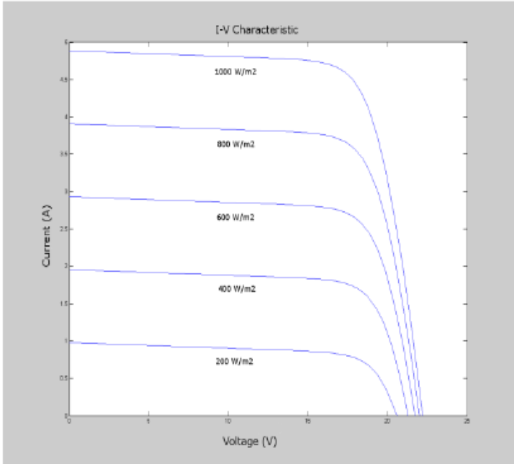

Figure 3(a): I-V characteristics of PV panel [7]

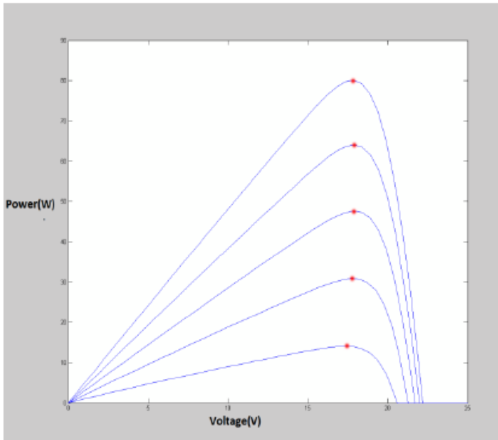

Figure 3(b): P-V characteristics corresponding to I-V characteristics (red dot shows maximum power point (MPP) [7]

The MPPT solar charge controller acts like a DC-DC transformer, which transforms power from a higher voltage to a lower voltage level. If the output voltage is lower than the input voltage, then the output current will be higher than its input current so product P=V*I remains constant. This equation implies that fluctuations in power also mean changing of voltage and current values [12].

There are three factors are to be considered when extracting maximum amount of power from a PV panel:

(i) **Irradiance:** Changes PV panel current operating point
(ii) **Temperature:** Changes PV panel voltage operating point.

(iii) **Load:** Used as a reference for the current and voltage [12].

4. Comparison Between PWM And MPPT Solar Charge Controllers

PWM helps to get the batteries charged up, extends the life of the battery, and more of the power generated by the solar panels is stored. Since the batteries store more energy on average, a smaller battery (or less battery in a battery bank) can be used reducing overall system costs [13].

MPPT solar charge controllers allow users to use PV module with a higher voltage output than operating voltage battery system. Since MPPT units are generally larger in physical size so they are more costly as compared to PWM controllers[2].

Table 1: Advantages of PWM and MPPT

PWM	MPPT
▪ PWM controllers are built on a time tested technology ▪ These controllers are inexpensive. ▪ PWM controllers are available in sizes up to 60Amps. ▪ PWM controllers are durable, most with passive heat sink style cooling. ▪ Can control high current and voltage. ▪ Longer expected lifespan [3].	▪ MPPT solar charge controllers offer an increase in efficiency up to 30%. ▪ These controllers also offer the potential ability to have an array with higher input voltage than the battery bank. ▪ Used to correct for detecting the variations in the I-V characteristics of solar cell. ▪ It forces PV module to operate at voltage close to maximum power point to draw maximum available power. ▪ Reduces complexity of system while output of system is highly efficient [2].

Table 2: Disadvantages of PWM and MPPT

PWM	MPPT
▪ The Solar input nominal voltage must match the battery bank nominal voltage if we are going to use PWM. ▪ There is no single controller sized over 60 amps DC as of yet. ▪ PWM controllers have limited capacity for system growth. ▪ Cannot be used effectively with 60A panels.	▪ MPPT controllers are more expensive. ▪ MPPT units are generally larger in physical size. ▪ Sizing an appropriate solar array can be challenging without MPPT controller manufacturer guides. ▪ Using an MPPT controller forces the solar array to be comprised of like photovoltaic modules in like strings [10].

PWM charge controller's work is to match the voltage of the panel to battery voltage and pulls down the panel output voltage in doing so. Whereas MPPT is the latest technology meant to extract maximum from solar panel. They operate according to the panel voltage and converts extra voltage of panel into current which increases the output from the solar system.

MPPT controller is at least 30% more efficient than PWM controller i.e. with MPPT we get 30% more output of the solar power system.

5. Conclusion

In this paper, a detailed review of PWM and MPPT is presented. It is understood that the major role of renewable energy like solar energy in today's world is going to play a role in the global energy sector. Renewable energy sources are cost effective, highly efficient and easy to install. With better use of charge controllers the lighting systems' efficiency will be increase. These charge controllers prevent reverse-current flow. When solar panels are not generating electricity, electricity flows backward from the batteries through solar panels. Hence, when the controller detects no energy from the solar panels, it disconnects the solar panels and hence stops the reverse current flow. The comparison between the two types of controllers shows the superiority of MPPT as compared to PWM.

References

[1] W. Thounaojam, V. Ebenezer and A. Balekundri, "Design and Development of Microcontroller Based Solar Charge Controller", *International Journal of Emerging Technology and Advanced Engineering*, Vol. 4, Issue No. 5, May 2014, pp. 510-513. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.637.8094&rep=rep1&type=pdf

[2] A. Pradhan, S. M. Ali, S. P. Mishra and S. Mishra, "Design of Solar Charge controller by the use of MPPT Tracking System", *International Journal of Advance Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 1, Issue No. 4, 2012, pp. 256-261.

[3] B. Swarnakar and A. Datta, "Design and Implementation of PWM charge controller and Solar Tracking system", *International Journal of Science and Research (IJSR)*, Vol. 5, Issue No. 5, May 2016, pp. 1214 – 1217. Retrieved from https://www.ijsr.net/archive/v5i5/v5i5.php

[4] Morningstar Corporation, "Why PWM?", *14th NREL Photovoltaic Program Review*, November 1996. Retrieved from https://www.morningstarcorp.com/wp-content/uploads/2014/02/8.-Why-PWM1.pdf

[5] A. S. Hiwale, M. V. Patil and H. Vinchurkar, "An Efficient MPPT Solar Charge Controller", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 3, Issue No. 7, July 2014, pp. 10505-10511. Retrieved from http://www.ijareeie.com/upload/2014/july/14_AnEfficient.pdf

[6] M. R. Hamid, J. Rahimi, S. Chowdhury and T. M. M. Sunny, "Design and Development of a Maximum Power Point Tracking (MPPT) charge controller for Photo-Voltaic(PV) power generation system", *American Journal of Engineering Research (AJER)*, Vol. 5, Issue No. 5, 2016, pp-15-22. Retrieved from http://www.ajer.org/papers/v5(05)/C0505015022.pdf

[7] K. S. Awale, A. U. Kumbhar, V. A. Kole and J. B. Kamate, "Arduino Based MPPT charge controller", *Journal of Electrical & Electronic Systems*, Vol. 6, Issue No. 2, April 2017. Doi: 10.4172/2332-0796.1000221

[8] M. S. B. Talib, *Battery Monitoring System using Arduino in solar Battery Charger*, B.E. Project Report, Universiti Teknikal Malaysia, Melaka, Malaysia, 2015. Retrieved from http://eprints.utem.edu.my/id/eprint/17464

[9] S. K. Patil and D. K. Mahadik, "Design of Maximum Power Point Tracking (MPPT) Based PV charger", *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, Second International Conference on Emerging Trends in Engineering' 2013, Vol. 7, 2013, pp. 27-33. Retrieved from http://www.iosrjournals.org/iosr-jece/papers/sicete-volume7/82.pdf

[10] F. Sani, H. N. Yahya, M. Momoh,, I. G. Saidu and D. O. Akpootu, "Design and construction Of Microcontroller Based charger for Photo Voltaic Application", *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, Vol. 9, Issue No. 1, 2014, pp. 92-97.

[11] J. A. Agresta and N. A. Mikolajczak, *An MPPT charge Controller for solar powered portable devices*, Polytechnic Major Qualifying Project Report, Worcester Polytechnic Institute, Massachusetts, USA, April 2017. Retrieved from https://web.wpi.edu/Pubs/E-project/Available/E-project-042617-162303/unrestricted/Agresta_Mikolajczak_MQP_MPPT_Solar_Charger_1.pdf

[12] M. S. Islam, "Thin Film Solar Charge controller: A research paper for commercialization of Thin film Solar Cell," *Advances in Energy and Power*, Vol. 3, Issue No. 2, 2015, pp. 29-60.

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