Maximum Power Point based Photovoltaic Charge Controller for Street Lights

K. S. Kulkarni
U.G. Student
Department of Electronics Engineering
Trinity Academy of Engineering, Pune

Abstract—Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the PV modules in a manner that allows the modules to produce all the power they are capable of. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power extracted from the modules is then made available as increased battery charge current. The system use Buck and Boost (DC-DC) converters for voltage level conversion. Buck converter is used to down convert the DC voltage. Boost converter increases the DC voltage. The algorithm used to track the maximum power point in the system is Perturb & Observe (P&O) Algorithm. PIC16F873 is used to control the system.18watts LED Street lamp is taken as the load.

Key words: Photovoltaic Charge Controller, MPPT

I. INTRODUCTION

Energy is essential for life as well as economy. Nowadays, the need for energy has increased exponentially. As the country develops, the demand in the energy also increases. The most commonly used source of energy, today, are fossil fuels such as petroleum, coal etc. But these resources cannot be replenished at the rate at which they are being consumed. This puts extra pressure on the conventional sources of energy and leads to the problem of Energy Crisis and in turn leads to Economic Crisis in the country.

The solution to this problem is found in the use of Renewable or Non-conventional energy sources. Renewable energy consists of the energy that is generated by the Sun, Wind, Tidal waves, Geothermal energy, etc. Out of these sources, the Sun is the most reliable source. The Sun provides energy to the Earth in the form of heat and light. The heat energy used is called as Solar-Thermal. The light energy used is called Solar-Photovoltaic or Solar-PV. This project is based on the Solar Photovoltaic Panel. The efficiency of the solar panel is very low when used alone. But when the panel is used along with the MPPT circuit the efficiency of the panel increases effectively.

II. LITERATURE SURVEY

1) In this Paper, the comparison of all the techniques of the photovoltaic array system is done. Paper also shows a chart of the research done on MPPT from the year 1968 till 2005. Total 19 different techniques used for tracking the maximum power point of the photovoltaic system. Each technique is discussed and also compared in a chart to choose the right MPPT technique for specific PV systems.
2) In this paper the authors have discussed about the different designing techniques of the MPPT algorithm. The Perturb and Observe algorithm and SEPIC MPPT charge controller is used in designing the circuitry. Also the authors have described the advantages and disadvantages of all the algorithms with respect to P&O Algorithm.
3) This paper consists of the different designing parameters and calculations of those parameters, like voltage, current and frequency. The author has also explained the process control using two different controllers. There are many observations regarding the output given in the paper.
4) In this paper, Sree Manju B. *et al* the author has discussed about the design concepts and parameters of the MPPT circuits. The voltage and current calculations are also shown in the paper, with the equivalent circuit of SPV Solar Panel.
5) In this paper the author have discussed about the RRC (Ripple Correlation Control) technique. Also in the paper the cost of the project is kept minimum using Analog devices in the circuit. The paper does not include other techniques which are useful but costly.
6) In this paper, Nevzat Onat has explained different classification of the MPPT algorithms which are used worldwide. The paper also includes the comparison of all the techniques and their current-voltage curves. The paper gives information on the recent researches done on the MPPT technology from past to present.
7) In this paper the author has explained the MPPT technique and the working of solar cells with very illustrative diagrams. Also the paper includes different calculations with different observation waveforms at different stages. Each stage is explained with the circuit diagram working and its waveform.
8) In this paper the author has explained the MPPT importance and designed the circuit using PIC18F2550 which will control the circuit. The circuit is also connected to the PC (Personal Computer) through USB for data acquisition.
9) In this paper the author have compared different MPPT techniques on the basis of power generated. The authors have also shown that P&O algorithm has least deviation from the ideal case scenario.

III. BLOCK DIAGRAM

Fig. 1 shows the basic block diagram of the system. The solar panel provides the power and input to the system. The charging of the battery and running of LED panel is done with the help of this power. The buck converter down-converts the DC voltage from the solar panel to be compatible with the batter voltage level. The boost converters are used to increase the voltage levels to required voltages. The opto-coupler is used to provide the electrical isolation to the gate of buck converter. I to V converter is

used to sense the voltage level for calculations. Microcontroller handles all the operations.

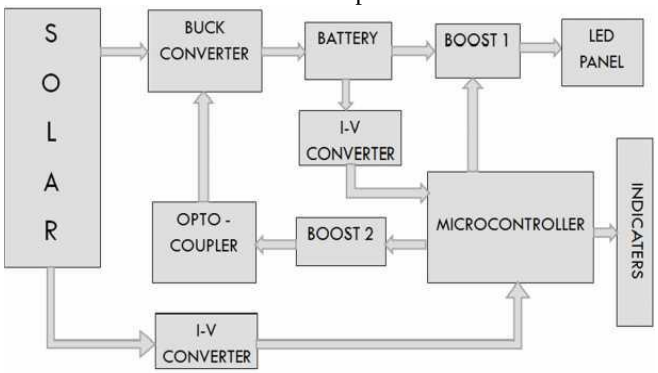

Fig. 1: Block Diagram of MPPT system for Street Lights.

The power from the solar panel is stored in the battery. This charged battery is used to provide power to the LED street lamps during night hours.

A. Solar Panel

Solar panels are devices that convert light into electricity. They are called "solar" panels because most of the time, the most powerful source of light available is the Sun, called Sol by astronomers. Some scientists call them *photovoltaic* which means, basically, "light-electricity."

Here we are using 12V, 100W solar panel which is further connected to Buck Converter and also to microcontroller through I-V Converter.

B. Buck Converter

A buck converter is a voltage step down and current step up converter. The buck converter is a very simple type of DC-DC converter that produces an output voltage that is less than its input. The buck converter is so named because the inductor always "bucks" or acts against the input voltage. The output voltage of an ideal buck converter is equal to the product of the switching duty cycle and the supply voltage. We designed the Buck Converter using MOSFET as a switch and can be operated through PWM from microcontroller. Then output of Buck Converter is given to Battery to store the charge.

C. Battery

An electric battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell contains a positive terminal, or cathode, and a negative terminal, or anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work. Here, battery is used to store the electric charge generated by solar panel.

D. Boost Converter

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. We are using two boost converters in the circuit, one is used to drive LED's (load) by boosting first PWM and another is used to drive buck converter by boosting second PWM from microcontroller.

E. Microcontroller

A microcontroller (µC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of Ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. In this circuit we are using PIC16F873 Microcontroller. PIC16F873 is 28 pin, 8-bit microcontroller PIC16F873 has 2 inbuilt PWM throughwhich the gate pulses are given to Buck and Boost converters. The maximum resolution of PWM is 10-bit. There is also in-built 10-bit multichannel ADC.

F. Opto-coupler

An opto-isolator, also called an opto-coupler, photo-coupler, or optical isolator, is a component that transfers electrical signals between two isolated circuits by using light. Optoisolators prevent high voltages from affecting the system receiving the signal. Buck converter is controlled using PWM from microcontroller. And PWM can't be given to Buck Converter directly, it needs isolation. So opto-coupler is used for electrical isolation.

G. I-V Converters

A transimpedance amplifier, (TIA) is a current-to-voltage converter, most often implemented using an operational amplifier. The TIA can be used to amplify the current output of Geiger–Müller tubes, photo multiplier tubes, accelerometers, photo detectors and other types of sensors to a usable voltage. Current-to-voltage converters are used with sensors that have a current response that is more linear than the voltage response. I-V Converter accepts current as a input and converts it in to voltage as a output. Two IV Converters are used in circuit. As the output of solar panel and battery is in current, and we cannot give current directly to ADC of microcontroller firstly it needs to be converted into voltage, that's why I-V converter is one of the major part of the circuit.

H. Indicators

Here we are using 3 LED's for indicating purpose. To indicate battery level, battery charging and fault so that user can know the status of the system.

I. LED Panel

LED panel is a load driven by MPPT. LED's are connected in series and parallel combination. Switching of these LED's will be controlled by microcontroller as per the P&O algorithm.

IV. ALGORITHM

A. System Algorithm:

The system algorithm is as follows:

1) Initialize all the I/O pins, ADC pins, PWM pins and pins to indicating LEDs.
2) Read solar voltage as well as battery voltage.
3) If solar is healthy and battery level is low, then battery charged through MPPT algorithm.

4) If solar is healthy and battery level is also healthy, then check for battery level continuously.
5) If solar is absent and battery is healthy, then start LED lamp.
6) If solar is absent and battery is low, then give battery low indication through red LED.
7) When battery gets too low, turn off LED lamp.

B. MPPT Algorithm:

There are various techniques to achieve Maximum Power Point. Three of which are compared as shown in Table 1.

Parametes	P & O Algorithm	Modified P& O	Incremental Conductance
Efficiency (%)	81.5-85	93-96	73-85
Exact MPP determina-tion	Yes	Yes	Yes
Analog or digital Control	Both	Digital	Digital
Periodic Tuning required	No	No	No
Convergence speed	Varies	Fast	Varies
Complexity	Low	Medium	Medium
Measured Parameters	Voltage, Current	Voltage, Current	Voltage, Current

Table 1: Comparison of Different MPPT Techniques

After comparing these techniques, it is seen that the Modified Perturb and Observe Algorithm is the best. Hence, it is used in the programming of Microcontroller.

V. RESULTS

The tables of voltage levels while charging and discharging time of battery are shown below.

Time	Battery Voltage
0 minutes	10.5 V
15 minutes	10.8 V
30 minutes	11 V
1 hour	11.5 V
1 hour 30 minutes	12.1 V
2 hours	12.6 V
2 hours 30 minutes	13.1 V
3 hours	13.4 V
4 hours	13.7 V
5 hours	14 V
6 hours	14 V

Table 2: Voltage Levels during Charging of Battery

Time	Battery Voltage
0 minutes	14 V
15 minutes	13.8 V
30 minutes	13.6 V
1 hour	13.2 V
1 hour 30 minutes	13 V
2 hours	12.9 V
2 hours 30 minutes	12.8 V
3 hours	12.7 V
4 hours	12.6 V
5 hours	12.5 V
6 hours	12.4 V

Table 3: Voltage levels during Discharging of Battery

VI. CONCLUSION

As seen from the results, the battery without the MPPT circuit charges about half of the battery charged with the help of MPPT circuit. This shows the increase in output efficiency of the solar panel has increased about twice it previous efficiency when the panel was used with conventional charger. Also the MPPT circuit that has been designed provides the protection to the battery from the under current and overcurrent that result from the variations in the irradiance of the Sun. The circuit has been designed with the help of components that are readily available in the market. The weighted consideration has been given to size and cost effectiveness of the system.

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