A Simple Charge Controller Scheme Based on PWM for Solar Standalone Lighting Systems

Ajit Pratap Singh Negi[1], Deepak Bagai[2], Rita Mahajan[3],
[1]Master of Engineering, [2]Assistant Professor, [3]Senior Lecturer,
E&EC Dept., PEC University of Technology, Chandigarh, India

Abstract – This paper proposes an energy efficient charge controller scheme for solar power based standalone lighting systems. This concept is being given keeping in mind the necessity, cost and importance of lighting in remote areas. The proposed scheme comprises of efficient charging and discharging of battery with a very well known technique, Pulse Width Modulation (PWM). The scheme assumes d.c. operated WLED lamp as its output light source due to its high luminosity and unprecedented characteristics. Thus, the whole system operates on d.c. right away from solar panel output to battery to output light source. By varying the duty cycle of the d.c. current with PWM technique the battery can be efficiently charged and discharged through a common microcontroller circuitry thus bringing down the cost. The battery terminal voltage acts as the feedback for generation of PWM by microcontroller. As a result, light is available for longer hours, the battery works for longer life and the overall cost of the system may come out to be very low with a very bright clear WLED lighting, an ideal combination for energy efficient solar power based standalone systems for lighting.

Keywords – Battery, Charging, Discharging, Solar Energy, WLED lighting.

I. INTRODUCTION

In developing countries, there are many places and areas where there is still no availability of electricity. Also if wires are running to the places there is still no guarantee of power supply for the whole day. The people living there either uses kerosene lamps or other such options for lighting purposes. These alternatives either use conventional resources or burn fossil fuels that contribute to green house gas emissions making them the major contributors in global warming and pollution. Lighting in remote villages is still a big problem. With the price of fuels soaring high and depletion of current exhaustible natural resources, there is a great need of an inexhaustible energy resource. Table I shows how fossil fuel reserves are limited [1]. There can't be a better option than an inexhaustible resource and most of the available flow of renewable energy comes from the heat and light.

Solar energy is a non-depleting gift from the nature to the mankind. It is free, clean, safe and most important, unlimited. Solar power generation is a secure and clean technique that generates power from the sunlight falling on the earth's surface during the daytime. Solar power can be captured anywhere- buildings, offices, residential homes, street lightings etc. Power will be generated wherever and whenever the sun shines, irrespective of the remoteness of area.

TABLE I
REMAINING FOSSIL FUEL SUPPLY IN NUMBER OF YEARS AND EXTRACTIBLE VOLUME

Fossil Fuel	Petroleum	Uranium	Natural Gas	Coal
Runs out in (Date of estimate)	39.9 years (2001)	64.2 years (1999)	61 years (2001)	227 years (2001)
Extractible volume	1,046 Billion barrels	3,95 Million tons	150 Trillion cubic meters	984 Billion tons

This solar panel based technology can be used to design and develop a self-powered system that can be used for different purposes. Keeping the application in mind, a self-dependent solar power based lighting system can also be developed. Since remote areas are under consideration, so cost, energy efficiency and luminosity are the deciding parameters as cost of a single battery and a single lighting lamp plays a critical role in a family's budget.

II. PROPOSED CONCEPT

While designing a charge controller for a solar powered standalone lighting system few things are to be kept in mind. The system should be low cost, energy efficient and no compromise should be done with the intensity of the output light. So apart from optimising the charge controller circuit, proper charging and discharging of battery and selection of a suitable light lamp with bright light and high efficiency are the challenges to be faced.

TABLE II

A COMPARATIVE STUDY AMONG VARIOUS LIGHT LAMPS PRESENT TODAY

Lamp Type	Efficiency (lumens/watt)	Rated life (Hours)	Durability	Power Consumption	Correlated Colour Temperature (K) (CCT)	Colour Rendering Index (CRI)	$ After 50,000 hours
Homemade Kerosene	0.03	Supply of kerosene	Fragile & dangerous	0.04 - 0.06 litres/hour	1800 approx.	80 approx.	1251
Incandescent	5-18	1000	Very fragile	5W	2652	98	175
Compact Fluorescent	30-79	6500-15,000	Very fragile	4W	4200	62	75
WLED	25-50	50,000	Durable	1W	5000	82	20

WLED lights being energy efficient have high luminous efficiency as compared to the present conventional light lamps and are thus considered as future light source due to their unprecedented characteristics. Table II presents a comparative study among various light lamps present today [2]. The scheme thus assumes WLED lamp as its output light source. Since WLED works on d.c. thus the necessity of including a inverter circuit is avoided. Now the whole system operates on d.c. right away from solar panel output to battery to output light source and thus the charge controller becomes a simple low cost circuitry.

The PWM is applied in a manner that the battery neither remains undercharged nor gets overcharged or deep-discharged [3]. The charge content of battery is monitored and controlled with the help of a microcontroller which generates the necessary PWM by reading the voltage across the terminals of the battery and accordingly varies the duty cycle of the d.c. current supplied by the solar panel to the battery to prevent overcharging of battery. Battery when fully charged can be used for switching on a WLED lamp. The same circuitry similarly functions again to monitor the voltage across battery's terminal and controls the light intensity of lamp by varying the duty cycle of the d.c. supplied by the battery to the lamp [4]. Since human eye is not able to perceive the quick flickering in light brought out by PWM, this technique provides an efficient discharging of energy stored in battery. As soon as the battery voltage level drops below a critical discharge value, the microcontroller disconnects the lamp from the battery thus preventing drainage of battery. Thus, light is available for longer hours although of decreasing intensity but from point of view of remote areas where there is no availability of electricity, the brightness of obtained light is sufficient for proper illumination. Also since battery is efficiently utilized in both charging and discharging process through a common charge controller circuitry, the battery works for longer life and the overall cost of the system may come out to be very low with a very bright clear WLED lighting, an ideal combination for a energy efficient solar power based standalone systems for lighting.

III. BASIC CHARGE CONTROLLER MODEL

Fig. 1 shows a simple charge controller circuit. A switching device (MOSFET M in this case) along with a comparator connects or disconnects the panels from the battery terminals. The comparator measures the voltage across the battery's terminals, through a voltage divider formed by R1 and R2, and compares it continuously with a set reference value voltage. As soon as the cut-off voltage is reached the comparator switches off the MOSFET thus disconnecting the panel and the battery. This is done to prevent the overcharging of the battery. Also the battery is connected to the light lamp which when required can be turned on by switch S.

There are certain problems with this system. Since a predefined reference cut-off is set, the battery will not be charged above a certain value and thus always remains undercharged. Also, since the lamp is directly connected to the battery, it will try to extract most of power from it thus causing drainage of the battery. In both cases, the battery is used very inefficiently, undercharged in one and deep-discharged in other. This leads to battery's life getting shorter with time. If somehow, the reference voltage of the comparator can be made to vary, the battery can be charged to the full value. Also, there should be a provision to prevent overcharging of battery. Also the light source should be prevented from discharging the battery to the deep-discharge region.

IV. IMPROVED CHARGE CONTROLLER MODEL

The proposed model is totally operational on PWM technique. The charging and discharging of battery is governed by the voltage across the terminals of the battery at any instant. Both phenomena occur through the same microcontroller based circuit as shown in the Fig. 2. The

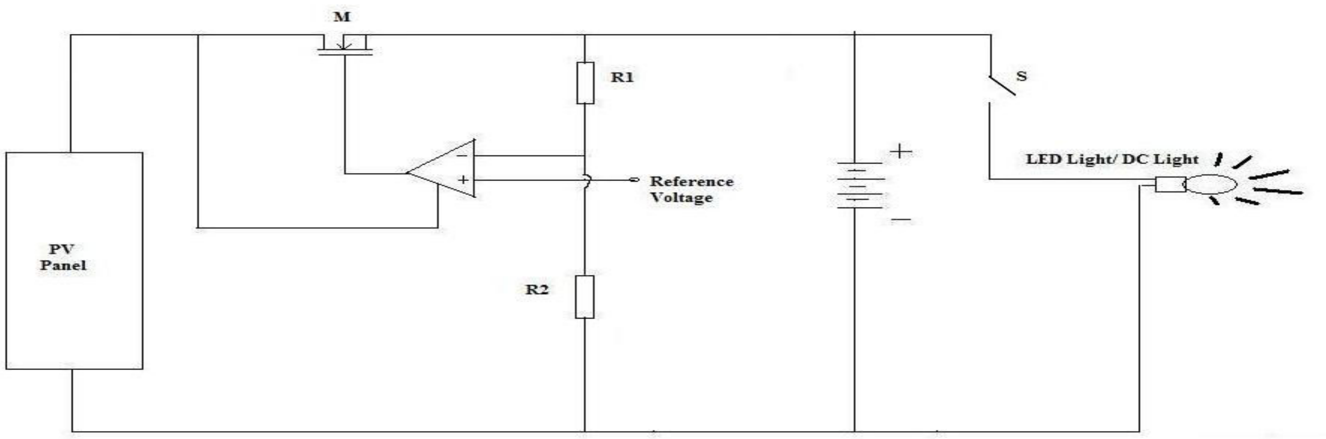

Fig.1.A Simple Charge Controller Model

MOSFET M acts as the switching device and isolates the circuits across its source and drain [5]. During charging case, it connects or disconnects the solar panel from the battery bank and during discharging, WLED lamp from the battery. The switching of MOSFET is controlled by a comparator circuit. The comparator measures the voltage across the terminals of the battery through a voltage divider, formed by R1 and R2, and compares it with the PWM signal generated by the microcontroller. R3 and C generate the necessary ramp signal to be fed as input in the comparator. The microcontroller also monitors the voltage across the battery's terminals through another voltage divider with the aid of an ADC and generates the PWM accordingly.

The idea is to control the duty cycle of the d.c. current flowing through the system with the help of PWM pulses generated by the microcontroller. The duty cycle of these PWM pulses is varied as accordance to the voltage of the battery. Initially when the battery is discharged (Switch S1 connected to PV panel and S2 to battery), its terminal voltage is less than the set reference voltage. In this case, the MOSFET is made to remain fully on by applying the PWM of duty cycle 100% to the positive terminal of comparator input thus connecting the terminals of the solar panel directly to the battery terminals. This leads to immediate or bulk charging of the battery. With time, when the charge content of the battery increases and reaches equal to the reference value, the pulse charging of battery can be accomplished. The duty cycle of the pulses can be varied by monitoring the terminal voltage of the battery. A look up table of battery voltage and PWM duty cycle can be pre-set and stored in the microcontroller. The controller will monitor the battery voltage and will generate PWM of duty cycle corresponding to that voltage. For example, for a voltage of 12.10V, duty cycle of 80%, for 12.15V duty cycle of 75% etc. The look-up table can be made more precise by breaking the voltage intervals to smaller values and so the duty cycles. As the battery voltage increases, the duty cycle is made to decrease so that battery keeps on charging with decreasing frequent pulses of current. When the battery reaches its full capacity, the duty cycle will be so small that it will help battery retain the full charge by continuously applying very short pulses of current, thus preventing the simultaneous discharging of battery. During charging, the whole circuitry is powered by the solar panel.

Now when the WLED lamp is turned on (Switch S1 connected to Battery and S2 to WLED lamp), the same whole circuitry now gets powered by the battery. The microcontroller monitors the battery terminal voltage and generates PWM of duty cycle corresponding to it. In this case also a look-up table is pre-set and stored in controller's memory. Till when the battery voltage is high, PWM pulses of large duty cycle can be sent. For example, for voltage of 12 volt, duty cycle of 90%, for 11.80 duty cycle of 85% etc. The comparator will compare the pulses with battery terminal voltage and will keep the MOSFET on accordingly. Thus, d.c. current from battery to LED lamp is not continuous but in the form of PWM pulses. These pulses will produce flickering in the WLED lamp light but they will be too quick to be perceived by a human eye. Thus what will be received is a bright white light of WLED. Now as the battery voltage decreases, the duty cycle of pulses is also made to decrease through the look-up table. This is done to utilize only a small power from the battery due to which battery discharges slowly and can supply power for a longer duration. At a certain cut-off voltage, the duty cycle is set to zero thus disconnecting battery from the light lamp. This cut-off voltage is the critical voltage below which the battery goes into deep-discharge region. Thus, by giving PWM pulses the battery is prevented from drainage condition with no compromise on the part of light intensity. Although the intensity of light decreases slowly with decrease in duty cycles the system achieve its primary goal of illuminating room for longer hours. Keeping in mind that the lighting model is being designed for standalone systems of remote areas, enough lighting may be achieved with high energy efficiency through this simple energy efficient charge controller scheme.

V. Conclusion

With the use of solar power based technologies the dependency on exhaustible natural resources can be easily

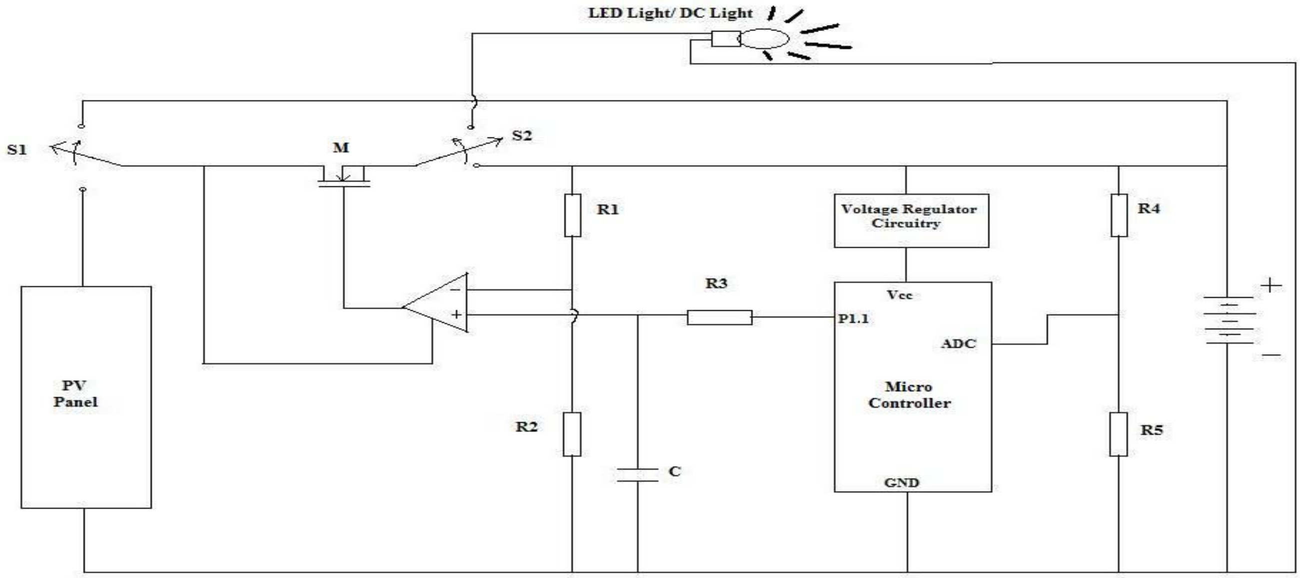

Fig.2.Improved Charge Controller Model

reduced. And with the further use of modern technology like microcontrollers and technique like PWMs in solar power based applications, these systems can be designed to provide high efficiency. Through the proposed model, the challenges of circuit optimisation, energy saving, better bright lighting altogether may be efficiently covered at low prices.

Thus, the sole purpose of providing a low cost solar power based standalone lighting system to the residents of remote villages in developing countries can be easily achieved.

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