Design and Implementation of Solar Charge Controller

Kishore.B [1] , Barath.C[2]

[1] Assistant Professor [2] UG Student
[1,2] Department Of EEE, Dr.Mahalingam College Of Engineering And Technology, Pollachi-642003

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Abstract— Solar-energy utilization is growing in demand since the past decade due to the increase in energy needs and depletion of non-renewable sources. But the problem with solar energy is that it's not constant; it keeps on fluctuating depending upon the weather conditions such as, solar irradiation, temperature, thus a battery is always connected between the load and the solar panel so as to act as a secondary source. On bright sunlight the solar cells would produce more voltage and this excessive voltage could cause damage to the batteries. This necessitates protecting battery from overcharging. MPPT is one such method for extracting maximum power from PV module and also to protect the battery from overcharging. This project provides details of maximum power point tracking solar charge controller device. The design of this project says about the calculated value of converter with the help of MATLAB software.

Keywords-MPPT, Photovoltaic Cells, solar energy, MATLAB, Arduino

I.Introduction

A.Solar Panel

Solar energy is a promising source of energy for the near future. PV modules are connected in series and parallel manner so as to collect and harness the solar energy obtained and convert it into electrical energy. Generically stating, an independent PV system consists of PV arrays which convert sunlight into DC electricity. In addition, it also includes a charge controller to regulate the battery charging and discharging. A charge controller is one of the major functional components in PV systems which maintain the accurate charging voltage on the batteries. As solar energy is not evenly distributed, research is being done on various methods of collection such as thin-film devices, concentric collectors etc.

A power electronics device, Maximum Power Point Tracker (MPPT), which increases the efficiency of the system effectively, is used here. By using it, the system always operates at its Maximum Power Point (MPP), thereby producing its maximum power output. Thus, an MPPT maximizes efficiency of the array and reduces the overall cost of the system.

II.MAJOR COMPONENTS

Solar panel is formed by connecting many solar cells in series and parallel so as to get the desired output power under nominal conditions. A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels. Using this solar panel, light energy is converted into electrical energy which is transmitted to batteries. Due to excessive voltage, battery may get damaged, to avoid that, a charge controller is designed.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 03 | Mar 2019 www.irjet.net p-ISSN: 2395-0072

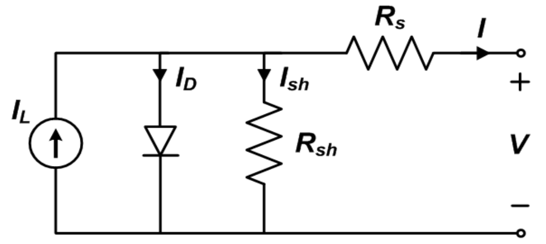

Figure 2.1 Equivalent Cell of Solar Cell

B.DC-DC BUCK-BOOST CONVERTER

A buck-boost converter is a DC - DC converter in which the output voltage is always lower or higher to the input voltage with reference to the reference voltage. MOSFET's switching is controlled by Arduino in this project.

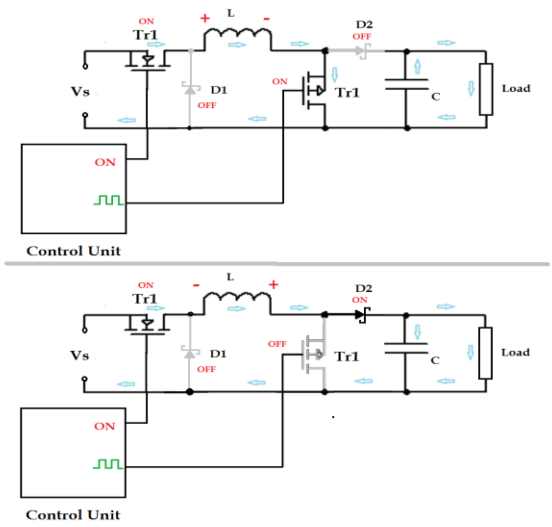

Figure 2.2 Buck-Boost Converter.

While designing the buck converter we need to find out the values of capacitor and the inductor used in it. It is a very crucial part in designing since the efficiency of the converter depends upon these values. The value of inductance and capacitance that calculated assuming the panel is working at full capacity, value of inductance L=33uH and value of capacitance C=220uF

Calculation of Inductance:

$$Vo = \alpha \, Vs / (1 - \alpha)$$

We know that Output Voltage is 28 V and the input voltage depends upon the solar panel. Hence assuming different inputs and calculated duty cycle based on duty cycle calculation it resulted as 0.51 and above for Boost mode and >0.51for Buck Mode.

$$L = \alpha \, (Vs) / (Fs) \, (\Delta \, IL)$$

For this we took Fs = 10 KHz

$$L = 0.51 \, (28) / 10K \, (4.3)$$

$$L = 33 \times 10^{-6} \, H$$

By calculation we get **L = 33uH**

Calculation of Capacitance

$$C = Io \, \alpha / Fs \, \Delta \, Vc$$

$$C = 10 \times 0.51 / 10K \, 2.3V$$

$$C = 220 \times 10^{-6} \, F$$

By Calculating we get **C = 220uF**

C.Arduino UNO

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer it communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it uses the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Figure 2.3 Arduino UNO

III.Block Diagram

A.Overall Block Diagram:

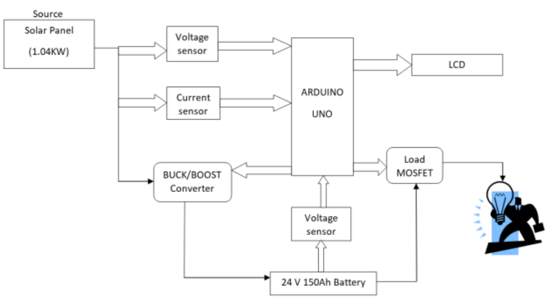

Figure 3.1 Block Diagram

In this block diagram the Arduino microcontroller is the heart of this system. The solar panel provides the input to voltage and current sensor. The microcontroller measures the current and voltage and displays on the LCD screen. Then depending upon the power level it gives PWM input to Buck-Boost converter which decides whether the solar panel is to be connected to battery or not for charging. The battery is connected to the load, the load MOSFET is given input by the microcontroller whether to connect the load to the battery or disconnect it depending upon the battery level which is sensed by the voltage sensor and its output is provided to the microcontroller.

B. Perturb and Observe Method

In the method of Perturb and Observe method, the power is measured by change in the voltage by a diminutive amount from the array by the controller. If incase, the power increases, adjustments are tried to be done in that particular direction until the power cease to increase. This is what we call the Perturb and Observe method. This method can result into an increase in the oscillations of power output, but still it is the most commonly used method. Since this method depends upon the rise in the power curve against voltage below its maximum power point and the fall which is above that particular point, this is referred to as the Hill Climbing Method. This algorithm of Perturb and Observe (P&O) increases or decreases the output terminal voltage of the Photo Voltaic Cell periodically and then it simultaneously compares the power obtained in the current cycle with the power obtained in the previous cycle. If the power is comparatively more than the previous value, then it indicates that it has moved the operating point closer to the maximum power point (MPP). Thus, further voltage perturbations if in the same direction, should move the operating point, even closer to the MPP. If the power decreases, the operating point moves away from the Maximum Power Point (MPP), and the direction of the perturbation has to be changed and reversed to move back towards the MPP.

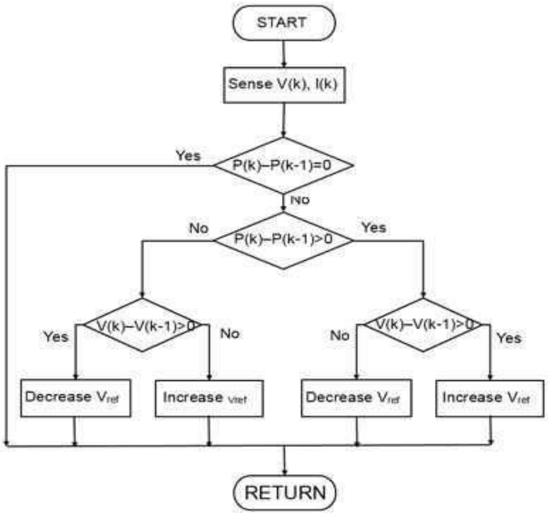

Figure 3.2 Flow Chart

IV. SIMULATION & RESULTS

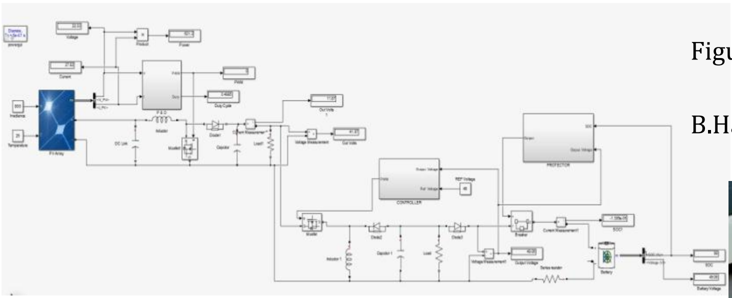

Figure 4.1 Overall Simulation.

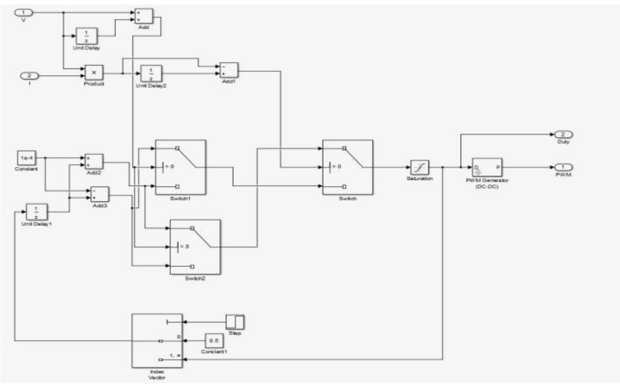

Figure 4.2 MPPT Simulation

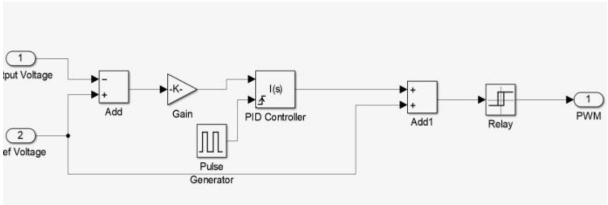

Figure 4.3 Buck-Boost Controller Design

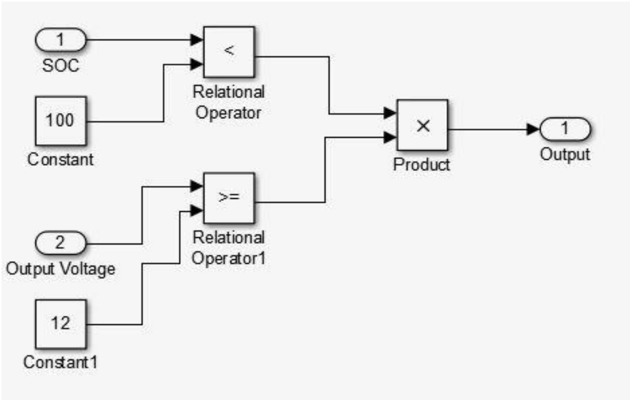

Figure 4.4 Protection Design

B.Hardware Results

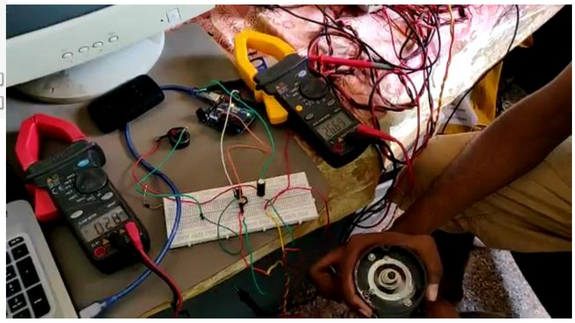

Figure 4.5 Overall Hardware Results

VI.Conclusion

In this project a simple low cost prototype model are made. Though battery over voltage protection has been avoided, but due to continuous charging of the battery it may result in swelling of battery. The MPPT charge controller was tested with two of the algorithms, P&O and open circuit voltage, at different solar irradiation levels and it was able to follow closely the output characteristic of the solar array. This means that using an MPPT charge controller, the solar system can produce more electricity and thus, the investment cost in the PV systems being easily amortized. Using this Solar charge controller the waste age of solar energy can be avoided by adding more batteries in series connection.

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