MICROCONTROLLER BASED PI BATTERY CHARGER FOR SOLAR POWER APPLICATION

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JUNE 2009

I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drives)

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Date : JUNE 2009

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DECLARATION OF THESIS

I hereby, declare that this thesis entitled "Microcontroller based PI Battery Charger for Solar Power Application" is a result of my own research, design and idea except for works that have been cited in the references.

Signature :

Name : MOHD ABID SULHY BIN MOHD ZIN

Date : JUNE 2009

DEDICATION

For my beloved parents, Mr. Mohd Zin b Mat Daud and Mdm.Rashidah binti Zakaria and all contributors.

ACKNOWLEDGEMENT

Alhamdulillah…

I have a sign of relief after finished up my report of Final Year Project 2 successfully. Although I felt very pleasure but I do not forget to express my appreciation to those who have helped me a lot in my final project. First of all, I would like to express my gratitude and thanks to my supervisor, PM. Dr. Zulkifilie bin Ibrahim for his invaluable advice and guidance throughout the period of this semester. His guidance in this project will remain forever. My appreciation also to my parents, Mr. Mohd Zin b Mat Daud and Mdm. Rashidah binti Zakaria, who have been so tolerant and supports me all these years. Thanks for the encouragement, love and emotional supports. I would also like to thanks Faculty of Electrical Engineering Staff and Technician for co-operations, guidance and helps towards the successful of this project. Nevertheless, my great appreciation dedicated to all my friends and those whom involve directly or indirectly in the development of this project. There is no such meaningful word than thank you.

ABSTRACT

This project is about the design and implementation of Microcontroller based PI Battery Charger for Solar Power Application. It comprise of using microcontroller based on Proportional-Integral (PI) to control the charging algorithms. This project consists of solar panel, PI controller charger, microcontroller and 12V sealed lead acid (SLA) battery. This project converts the voltage and current outputted by the solar panel into values appropriate for charging a 12V sealed lead acid battery by using PWM technique. The continuing improvements in battery technology calls for more sophisticated charging algorithms to ensure fast and secure charging. Higher accuracy monitoring of the charging process is required to minimize charging time and utilize maximum capacity of the battery while avoiding battery damage. This project can be divided into two main parts which are hardware and software development. The hardware development includes the solar panel connection, charging and control circuit, and microcontroller. The software developments include the microcontroller programming of PWM technique, A/D converter and PI controller algorithms.

ABSTRAK

Projek ini adalah berhubung dengan rekaan dan pengaplikasian Pengecas Bateri berasaskan pengawal PI untuk Aplikasi Kuasa Solar. Ia meliputi penggunaan *microcontroller* dengan mengunakan Pengawal *Proportional-Integral* (PI) untuk mengawal proses pengecasan. Projek ini merangkumi panel solar, litar kawalan pengecas PI, *microcontroller*, dan bateri *sealed lead acid* (SLA) 12V. Projek ini mengubah voltan dan arus keluaran panel solar kepada nilai yang sesuai untuk mengecas bateri SLA 12V menggunakan teknik PWM. Peningkatan berterusan dalam teknologi bateri memerlukan proses pengecasan yang lebih dinamik untuk mempercepatkan pengecasan dan selamat digunakan. Ketepatan penilaian proses pengecasan diperlukan dalam meminimumkan masa dan memastikan pengecasan pada kadar maksimum tanpa merosakkan bateri. Projek ini dibahagikan kepada dua bahagian iaitu pembangunan perkakasan dan perisian. Pembangunan perkakasan ini meliputi sambungan panel solar, litar pengecas dan pengawal, dan *microcontroller*. Pembangunan perisian pula meliputi pengaturcaraan *microcontroller* meliputi teknik PWM, pengubah A/D dan pengawal PI.

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DC	Direct Current
AC	Alternating current
SLA	Sealed lead acid battery
NicD	Nickel Cadmium
Li-Ion	Lithium ion
A/DC	Analog to Digital Converter
COM	Common
PI	Proportional- Integral
PID	propotional-integral-derivative

CHAPTER 1

INTRODUCTION

1.1 Project Background

Nowadays, our problem is the ever rising costs of non-renewable energy from natural resources and the resulting energy crisis facing our planet. Solar energy is not a revolutionary technology by any means and has long been criticized for its inefficiency and other shortcomings. Photovoltaic solar cells convert light energy to high voltage and low current which can be manipulated to provide power to our modern electrical devices and homes. With the ever rising costs of fossil fuels, the need for an efficient and affordable solar energy system has never been greater. The photovoltaic systems make possible to exploit the sun energy at various ends. They are highly reliable and constitute a nonpolluting source of electricity, which can be appropriate for many applications. The autonomy of these systems will require batteries to store the electrical energy produced by the PV modules and to restore it during the night periods and those of weak irradiation. The lead acid battery, although known for more than one hundred years, has currently offered the best response in terms of price, energetic efficiency and lifetime.

This project is essentially all of the technology that must be in place in order to interfaces the power-generating solar cells to the power-storing batteries. In order to accomplish this, a microcontroller AVR ATMega168 has been chosen to generate its necessary control signals. This microcontroller is important for monitoring the voltages and currents coming off both from the 12V 7Ah batteries and solar panels, and use to control the switching of buck converter. This will manipulate the output voltages and currents according to PI controller that been implement in the microcontroller.

The main component of the Microcontroller-based PI battery charger system is the proportional-integral controller. The controller is use to provide a closed loop control and monitoring capability for stable operation. The proposed battery charger is designed to support two modes of operation. That are constant current with voltage limited and constant voltage with current limited. The type and capacity of the battery determines the mode of operation of the battery controller.

The parameters, current and voltage, are controlled using the pulse width modulation (PWM) technique. In the PWM technique, the frequency of the signal is maintained constant, and the width of the pulse or the duty cycle of the signal is varied. This variation is reflected as a change in voltage or current at the output. The switching regulator reads the parameters through a feedback circuit, and the battery controller operates based on the control algorithm. The PWM output is obtained by comparing the actual value of the parameter under control with the corresponding set point. The feedback loop maintains the converter voltage or the converter current constant depending on the selected mode of operation

Controllers are differentiated based on the method of regulation of parameters in accordance with the corresponding set points. In a proportional controller, the actual value and the set value are compared, and the resulting error value is used. The drawback of a proportional controller is the possibility of a steady state error. Adding an integral component to the control algorithm eliminates this error. The charging algorithms are designed based on the type of battery and the current state of charge for that battery.

1.2 Problem Statement

Research on charging sealed lead acid battery using solar power has been done for years but the technology still need to be improves. Engineers have been work out to increase the efficiency of charging and improve the charging time as well as optimizing the solar power. As battery technology improves, there is a growing need to give the user more control and feedback during the battery charging process while preventing battery damage due to overcharging. For an example, conventional methods of sealed lead acid battery charging use a simple on and off regulator without feedback control have a lot of disadvantages. This type of charging requires longer charging time and has been proven for early battery failures. This method also is not efficient and growing user dissatisfaction. High quality sealed lead acid battery chargers on the other hands generally are very expensive and only available with AC mains powered. It is not suitable to use with solar power and not available for outdoor usage.

1.3 Project Objectives

The objective of this project is to design and implement the microcontroller based proportional-integral (PI) control in a battery charger. This battery charger is design to be powered by a solar panel which produces DC output voltage and being control using pulse width modulation (PWM) technique to obtain maximum charging efficiency at fastest time.

Solar power can be used to charge 12 V sealed lead acid battery using fast charging method consist of constant current and constant voltage mode. Fast charging method needs a precise termination technique to ensure the battery is not being overcharge that can lead to battery damages. A wrong charging algorithm will result in getting less life and capacity than what the battery can offer.

This project is divided into two major objectives:-

1. To design and develop a solar power battery charger that use DC/DC converter and microcontroller to control the charging algorithm which consists of usage proportional-integral (PI) controller.

2. To design the software that can control the entire charging algorithm including mode of charging, monitoring battery parameter, PWM technique, and charging termination.

Project Sub-Objectives

a) To implement a suitable charging algorithm to ensure the shortest charging time while maintaining maximum battery lifespan and capacity.

b) To program a microcontroller for SLA battery charger that can operate a high frequency switching of DC-DC power converter and monitoring battery charging parameter.

c) To develop a solar battery charger prototype that suitable for all battery application.

1.4 Project Scope

In designing this battery charger, a lot of research has been done on solar power, battery charging algorithm, type of battery and type of controller. There are many issues must be considered to produce an efficient battery chargers. The scopes of this project are:

a) Analysis of solar panel characteristic and battery charging technology.

b) Demonstrate conventional method of SLA battery charging.

c) Design PI controller for charging algorithm to produce feedback loop which gain faster charging time while maintaining battery lifespan.

d) Develop DC-DC converter (buck converter) as a charger circuit that use Pulse width modulation (PWM) as the switching control.

e) Design the A/D converter that can perform monitoring of output voltage and current during charging process.

f) Develop software (C programming) to control the charging process.

CHAPTER 2

LITERATURE REVIEW

This chapter is consisting of explanation and revision of the past research and projects that been done by other people regarding the solar power system, battery charger technology and sealed lead acid battery chemistry.

2.1 Photovoltaic Power System

Due to the convenience and robustness of the solar energy, photovoltaic power system is gaining its importance. Solar power systems have the advantages over all other alternative energies such as robustness, convenience and availability, environmental friendly, and renewable. The long term running cost for photovoltaic supply is lower regardless of the high initial cost. The power output from a photovoltaic array relies on many environmental conditions such as temperature of the cells, intensity of the sunlight as well as cell area. [7]

Solar panel works on the principle of photovoltaic effect which is the conversion from sunlight into electricity. Photovoltaic (PV) cells are made of special materials called semiconductors such as silicon. [7,8] Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose, allowing them to flow freely. PV cells also all have one or more electric fields that act to force electrons to be free by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, that current can be draw off to use externally. This current, together with the cell's voltage defines the power that the solar cell can produce. [9]

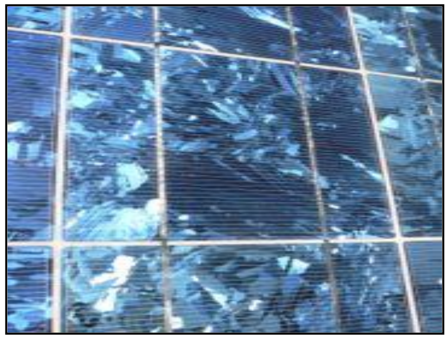

Figure 2.1: Polycrystalline PV cells

The amorphous silicon solar plate is a monolithic construction consisting of several layers of conducting and semi-conducting materials deposited onto a solar grade glass. Each plate comes unframed with integral flying lead. The main features of the panel are full laser patterning to interconnect all the solar cells, laser isolation, black appearances and tin-oxide glass coating that offers exceptionally uniform conductivity and light absorption. A polycrystalline panel consists of high efficiency polycrystalline silicon wafer bonded to aluminum substrate. Each module come complete with a plastic back frame, integral stand and flying leads. Polycrystalline cell each give approximately 0.45V when illuminated dependent upon the light intensity and the load but independent of the surface area. [9] The important characteristic which makes solar panel suitable for supplying electrical power is that the builds up quickly at very low light levels. This means that voltage suitable for charging battery is reached even on a dull day. Current however is directly proportional to both light and surface area. [7,9]

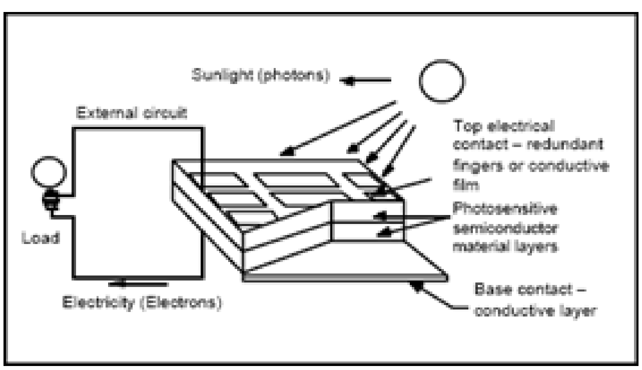

Figure 2.2: Polycrystalline cell structure

2.2 Battery Charger Controller

The battery charger technology has been improved from time to time. The earlier battery charger only uses a simple configuration by connecting a constant DC power source to the battery being charge. At present, the battery charger are capable to monitor the battery voltage, temperature and time under charge to determine the optimum charge current at that instant. This intelligent battery charger has built in controller to perform the entire task. [10] The main function of a controller in photovoltaic system is to fully charge the battery without permitting overcharge while preventing reverse current flow at night. The most recent controllers usually utilize pulse width modulation (PWM) technique to assure the battery is being fully charged. The first 70-80% of battery capacity is easily replaced, but the last 20-30% requires more attention and therefore more complexity. [3] The most common charging circuit use DC/DC buck converter but for efficiency improvement other types of DC/DC converter also can be use such as boost converter and buck-boost converter. [4]

The previous research work focus on the 12V battery charger that been designed to accept a number of different inputs from solar panel to European socket of 220VAC. This charger has four type of charging level which are very low level (trickle charge state), charging (bulk charge), almost charged (overcharging state) and fully charged (float stage). The output of the battery charger is connected to the 12V car battery with using different kind of chords attached to the case. [1]

Other research on the solar power battery charging is focusing on maximum power point tracker (MPPT). The MPPT is basically a microprocessor controlled DC-DC converter. The MPPT is used in solar panel battery charging systems to increase the efficiency of the system by closing matching the input voltage of the solar panel to the output voltage of the battery. Solar panels designed for charging 12V batteries actually generate the most watts running at around 17V. The DC-DC converter was use to connect the solar panel to the battery which allows the solar panel to run at the higher voltage or at maximum power output (maximum power point, MPP). [2]

If the MPP of the solar panel was fixed then it would be simple to design a DC-DC converter with a fixed conversion ratio to convert the MPP voltage down to the battery voltage. However, the MPP changes depending on the amount of light and the temperature of the solar panel. The microprocessor takes care of this by measuring the input watts from the solar panel and changing the conversion ratio to keep the solar panel at its MPP. The operation of MPPT controller is microprocessor controls the conversion ratio of the of the DC-DC converter. The microprocessor generates a PWM signal and the duty cycle of the PWM signal sets the ratio of the on time for the high side MOSFET switch versus the on time of the low side MOSFET switch. The ratio of the on time of the switches sets the conversion ratio of the input to the output voltage of the DC-DC converter. [2]

An alternative battery charging control technique also has been developed based on fuzzy logic for photovoltaic (PV) applications. Photovoltaic module is use as power source and connected to a buck type DC/DC power converter. A microcontroller based unit is used to control the lead acid battery charging voltage. The fuzzy control is used due to the simplicity of implementation, robustness and independence from the complex mathematical representation of the battery. The digital architecture is implemented with Microchip microcontroller, PIC16F877, where the fuzzy controller reads the voltage of the battery to determine the state of charge and then controls the amount of current flowing into the battery by using a DC/DC buck converter. [4]

From another review on the previous research, an intelligent lead acid battery charger was designed with use of the PIC14C000. The charger was designed to charge a sealed 12V-7AH lead acid battery, however the charge parameters were easily modified to work with different rating of lead acid batteries. The typical method of charging lead acid batteries use in this design is a constant voltage with current limited source. That method allows a high initial charge current that taper off until the battery reaches full charge. The charge current is then turned off to prevent overcharging. This high initial charge current quickly brings the battery to a full charge and a low maintenance charge current was needed to maintain the full charge. [6]