SMART BATTERY CHARGER SYSTEM BASED ON EMBEDDED MICROCONTROLLER

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

µc	Microcontroller
µF	Micro Farad
pF	Pico Farad
A	Ampere
AC	Alternating Voltage
ADC	Analog To Digital Converter
ADCCO0	Analog To Digital Converter Control Register
Ah	Ampere Hour
C	Capacitor
CMOS	Complementary Metal–Oxide–Semiconductor
CPU	Central Processing Unit
DB	Data Bus Line
DC	Direct Voltage
E	Enable Signal
G	Ground
HEX	Hexadecimal
I	Current
I/O	Input/ Output
IC	Intermittent Charging
ICC	Interrupted Charge Control
IEEE	Institute of Electrical and Electronics Engineers
LCD	Liquid Crystal Display
LED	Light- emitting diode
MCLR	Master Clear Reset
MHz	Mega Hertz

MOSFET	Metal Oxide Semiconductor Field Effect Transistor
NC	Normally Close
NO	Normally Open
OCS	Crystal Oscillator
PCB	Print Circuit Board
PIC	Peripheral Interface Controller
PV	Photovoltaic System
R	Resistor
R/W	Read/Write Signal
RAM	Random-Access Memory
RL	Relay
ROM	Read Only Memory
RS	Register Select Signal
SC	Clock Source
SW	Switch
TMR	Timer
V	Volt
V	Voltage
V_{IN}	Input Voltage
V_{OUT}	Output Voltage
V_{REF}	Reference Voltage
W	Watt
Wh	Watt Hour
W_P	Watt Panel

Sistem Pengecas Bateri Pintar Berasaskan Pengawal Mikro Terbenam

ABSTRAK

Sebuah pengawal pengecas bateri yang cekap dan selamat adalah bahagian yang penting dalam pengecasan dan perlindungan sistem elektrik yang digunakan untuk mengecas bateri boleh dicas semula. Kebanyakan pengecas yang tidak cekap adalah kerana jalan integrasi dan caj proses pemantauan yang tidak mempunyai LCD untuk memaparkan voltan dan status semasa bagi beban dan bateri.Mereka juga tidak menyediakan perlindungan untuk bateri terhadap pengecasan berlebihan, menyahcas dan kos tinggi. Pelaksanaan teknik pengawal pengecas bateri dalam aplikasi sistem terbenam merupakan teknik baru dan aspek yang sangat penting. Oleh itu, reka bentuk di simulasikan menggunakan perisian simulasi Proteus, dan kemudian litar prototaip ditubuhkan. Pengaturcaraan yang digunakan dalam reka bentuk ini adalah perisian yang menggunakan bahasa Mikro C. Reka bentuk peranti terdiri daripada litar pengecas yang melaksanakan mengecas, LCD untuk memaparkan tahap voltan pengecasan bateri dan arus beban/voltan , sensor untuk mengesan beban voltan dan juga voltan segera bateri. The PIC16F877A Pengawal Mikro telah digunakan sebagai komponen utama untuk mengawal dan mengurus semua acara mengecas dan menyahcas dalam litar dan juga untuk menyediakan perlindungan terhadap bateri lebih dan di bawah tahap voltan. Pemodelan penukar analog ke digital (ADC) digunakan dalam PIC untuk mengukur tahap voltan bateri dan beban voltan dan arus. LED penggera kebakaran di telah digunakan dalam reka bentuk ini untuk mengesan lebih beban dan lebih mengecas. Pengawal pengecas bateri telah dibangunkan untuk mengenakan cas dan kawalan lebih daripada lima bateri dengan kapasiti yang berlainan. Setiap bateri telah dikawal secara individu oleh penyelarasan dua PIC's pengawal mikro. Serta dua LCD telah digunakan untuk menunjukkan bateri voltan, voltan dan arus beban. Transistor pensuisan penguat dikawal oleh PIC dan digunakan untuk mengawal geganti perlindungan bateri terhadap pengecasan berlebihan dan menyahcas. Sistem penggera litar telah direka bentuk dan diporgramkan di dalam kedua-dua penyelaras PIC's untuk memberi amaran apabila berlakunya arus berlebihan ke atas beban.LED juga digunakan bagi setiap bateri dalam litar ini untuk menunjukkan apabila setiap bateri dicas sepenuhnya. Kecekapan litar ialah 85%. Setiap keputusan juga telah diambil daripada simulasi dan pelaksanaan litar yang telah diplotkan untuk tujuan penjelasan. Maka, apabila voltan bateri 12V litar terputus proses pengecasan membentuk bateri. Di samping itu, apabila beban lebih itu berlaku, litar akan pemberi amaran dalam bentuk penggera dan memotong proses pengecasan.

Smart Battery Charger System Based On Embedded Microcontroller

ABSTRACT

An efficient and embedded battery charger controller is the important part in the electrical charging and protection systems which used to charge the rechargeable batteries. Most of the chargers are not efficient, due to the way of their integration and charging monitoring process due to not availability of LCD to display the voltage and current status of the load and battery, as well as they do not provide a protection for the batteries against overcharging, discharging, high cost and inaccurate. The implementation of battery charger controller techniques on an embedded system application based solar panel is a new technique and very important aspect. So, the design is simulated by Proteus simulation software, and then prototype circuit is set up. The programing software in the design which was developed by Micro C language. The designed device consists of a charger circuit which performs charging, LCD to display the battery charging voltage level, load current / voltage, sensors to sense the load voltage and current as well as the battery instant voltage. The PIC16F877A Microcontroller was used as the main component to control and manage all charging and discharging events in the circuit as well as to provide protection of battery against over and under voltage level. The modeling of analog to digital converter (ADC) was used in the PIC to measure the voltage level of the battery and load voltage and current. The alarm LEDs fires on were used in this design for over load and over charging. The embedded battery charger controller was developed to be more intelligent based on suitable DC source and used to charge and control up to five batteries with different capacities. Each battery was individually controlled by a synchronization of two PICs microcontrollers and another PIC was used to control on the batteries temperature. All the three LCDs were used to indicate the batteries voltage, load voltage, load current and batteries temperature. The switching amplifier transistors were controlled by PICs via OR gates to control the operation of relays to protect the batteries against overcharging, discharging and the temperature that produced during the charging process. The alarm system circuit was designed and programmed in both of synchronized PICs to alarm when the overcurrent is occurred at the load. LEDs were also used for each battery in this circuit to indicate when each battery is fully charged. The efficiency of the circuit was 85%. As well as, the results were collected from the simulation and implementation of the circuit and plotted for explaining purpose. So, when the battery voltage is 12V the circuit cut off the charging process form the battery. In addition, when the over load is occurred, the circuit will alarm warning and cutoff the charging process.

CHAPTER 1

INTRODUCTION

1.1 Introduction

As the source of conventional energy exhaust day by day according to the energy information administration (EIA) department of energy in the United States. They are predicted the world will face shortage of liquid fossil fuels in the next few years. As well as the population in the world and the total of fossil fuels are consumed rising at an alarming rate. Thus, after several years in the future the world's fossil fuel may not be able to cover the activities, so the restoring of alternative energy source like solar energy was needed to fill the shortage occurred (Dipayan, et al., 2010). Thus, the renewable energy source in addition to solar photovoltaic module, rechargeable batteries and chargers controller are needed to satisfy the energy demand at normal and peak load. So, this project is seek to design a smart battery charger that control the charging process applied on the battery. The inexpensive smart battery charger controller for solar panel will be beneficial to optimize the output power that demand by the load. Thus, here a PIC16F877A chip is the main processor that used in the circuit to control on the whole events and to be developed and efficient.

The PIC16F877A microcontroller is more than efficient and include properties compare with others PIC. It features 200ns execution of instruction, 256 bytes of EEPROM data memory and considered the second highest memory of PIC at this time, 10 bit analog to digital converter. All this properties are very useful and could be

programed in the C language (Wilhelm, et al., 2006). Which all the properties that are mentioned above are used to manage the charging process of the battery as well as to protect the battery from the damage that results from the overcharging and high current. The high current charging is faster to charge the battery, but it will effect on the properties of the battery (for example, battery temperature, and internal resistance of the battery and charging voltage) (Kin-Pun Wong et al., 2001). However, the battery temperature is increased as well as the gasses production (Hydrogen) related to overcharging and over current (Viera, et al., 2002). Thus, the necessary cutoff of charging process automatically if the battery charged fully to avoid the damage of the battery. Also, the LCD (Liquid Crystal Display) is used in this project to display the battery charging level, load voltage and current.

1.2 Background

Background should cover and identify new and emerging edge technologies, basic circuit operation in rich details and identify the types of component to be used in circuit layout without neglecting the effect of each part. The design of the circuit will be done part by part after the basic blocks are identified. The elements key must include the theoretical calculation of electric and electronic knowledge of the used components.

The main aim is to control smartly the charging process of the battery. In previous work there are many techniques to charge the battery, they are proposed according to (Lijun Gao, et al., 2002 & Wei Zhang et al., 2004). These methods are used to variety the characteristic (voltage, current and temperature) to obtain a safe and fast charging process. However, in this dissertation an embedded battery charger controller is programmed, simulated and constructed based on renewable energy to achieve a safe

charging process for the battery and to protect the battery against over and under voltage level limit.

1.3 Research Problem

This project strive to solve the control issue of the battery charging process. The batteries today become the main source to supply the DC voltage for electrical equipment. The charging of the battery need to be controlled to manage the charging process successfully of the battery as well as to protect the battery from the overcharging and discharging that were the main reason to damage the batteries.

The commercial battery chargers are not accurate and expensive and not display the status of battery voltage, voltage and current that drawn by the load during the charging process and uses LED to indicate the operating status of the batteries. So, it is hard to know the instant status values of the rechargeable battery on charging and discharging or overcharging of the battery and also may expose the battery to damage which could not use with sensitive devices. Thus, this problem is solved by using PIC 16F877A to control on the whole circuit events by embedded system and LCD to display the voltage status of the battery as well as protection from unwanted instants and the load based on the measurement of the battery voltage for more accuracy and sensitivity.

High current that enter into the battery will reduce the charging time, the charging time will be lower than the actual time to completely charging from no charge to fully charge battery. So, the temperature start increased rapidly when the cell is almost want to achieve full charge. Which, the main problem of charging is the heat that generated in the battery due to power dissipated. The increasing in the heat effect the increasing of battery

resistance which lead to low battery efficiency, which reduce the battery life due to voltage drop before inserting into the battery. Thus, it is important to develop the battery charger controller to charge a bank of batteries based on suitable DC source and to control smartly on the temperature of the batteries and whole circuit.

1.4 Research Objective

The main objective of this project is to design a smart battery charger controller that could charge 12V rechargeable batteries. So, there are some objectives have to be achieved as following below:

1. To design, simulate and fabricate an efficient charging circuit based on embedded system that can charge smartly 12V lead acid battery and control on the charging process by using the solar panel as DC source.
2. To protect the battery from the overcharging and discharging voltage by cutting off the charging process as well as protect the battery from the over load that may occur during discharging process.
3. To design and simulate an embedded battery charger controller based on a suitable DC source to control the charging for five batteries different capacity based on the alarm system and temperature sensors, battery voltage sensors, load current sensor and load voltage sensor.

1.5 Research Scope

The scope of this project includes studies and calculation that contained in the design, simulation, program and construct of an efficient and embedded battery charger

circuit to charge 12V lead acid battery. The LM 317T is used to regulate the voltage supply from solar cell as well as LM 7805 is used to reduce the voltage to 5V to protect the PIC from the damage. In order to use the PIC 16F877A to control the whole circuit during the operation as well as continuously monitor the status of battery voltage charging process. Also, to protect the battery from the over and under charging voltage by cutting off the charging process as well as protect the battery from the over load that may occur during discharge process.

To be batter efficiency, the battery charger controller is developed to charge five batteries with different capacities based on suitable DC source. Each battery is controlled individually depend on the cutoff voltage level and also depend on the generated temperature during the charging process. Two synchronous PICs 16F877A were used to control the whole circuit activates and the third one is used to control the charging process based on the batteries temperature via temperature sensors (LM35). As well as, three LCDs are used to monitor the batteries voltage, load current, load voltage, batteries temperature. Also, five OR gates are used to control on the operation of the PICs to clear the charging voltage in both case of temperature, overcharging or discharging of the batteries.

1.6 Organization of the Thesis

This report basically consists of five chapters. Chapter 1 is discussed the introduction which contain the problem statement, project objective and the scope of the project

Chapter 2 discuss the overall literature review. It also includes the study of charging circuit's layout, solar panel and the methods that have been use to charge the battery.

Chapter 3 mainly discuss on the methodology of the project, which include the block diagram, software part and hardware part of the project.

Chapter 4 shows the expected, achieved results from the software and hardware and also include discussion about each achieved result.

Lastly, chapter 5 conclude the project methodology and result and also the future work of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This dissertation is contained design, simulation, programing and fabrication of a smart battery charger interfacing with LCD module monitoring. So, this chapter contains the literature review article and past research about the main component and other technologies that was used to make this project reality. The literature about all the researcher that do approximately same the work such as charging-discharging, controlling and the technique that used in the circuit.

2.2 Photovoltaic (PV) System

The renewable energy in the resent years is the solution for the problems to produce a clean electrical energy, such as the photovoltaic (PV) technology. Where the PV technology is based on the conversion of sunlight into electricity (Stéphane, et al., 2009). Now, the researchers is carried out regards PV or solar penal systems that trade on this energy (Yaden, et al., 2011, Nicola, et al., 2005). By focusing on the PV system, it has many advantage to charge the batteries such as good control for charging and discharging the lead acid batteries. But there are some disadvantage suggested by (Yaden, et al., 2011) that the regulation of the voltage and control of the PV are not reliable as well as the induced losses was provided by the divergence PV panels. Also, the control of charging

and discharging of the batteries is poor and depend on the collection of illumination (Karoui et al., 2007, Mousazadeh, et al., 2009 & Alboteanu, et al., 2006).

The major problem in the PV panel systems, is losing of the supplied power in times and provide overvoltage in other times because of inaccurate desired of maximum power point (Koutroulis, et al., 2001 & El Ouariachi, et al., 2011). Regarding this, a voltage regulator LM317T is used to regulate the output voltage from the PV panel as well as a microcontroller is used to manage and control the charging and discharging of the battery. The other suggestion is produced by (Mrabti, et al., 2010) is used the maximum power point tracking (MPPT) to improve the accuracy of charging process. This method also permits to remove the disturbance of power point tracking when the panels have some maximum follow on effects of shading (Ramabadran, et al., 2009) or disequilibrium of cell (Bishop, J.W, 1988).

The battery charger is the main part of power systems that used to charge many batteries, however the supply source either from renewable energy (PV or voltaic solar panel) or utility electrical grid. The main purpose of this energy to keep a properly safe protection and fed to the battery (Teulings et al., 1993). The solar panel provide current and voltage in one direction to the battery to be charged but at night there is no sun. Thus, the panels will pass the current in the reverse direction and that will lead to the slightly discharge from the battery. So the semiconductor diode was used to prevent the discharging that occurred from battery to the solar panel (Hiyama, 1995).

2.3 Rechargeable Batteries

The rechargeable batteries are important devices for all electrical equipment. Since the emergency electrical energy is required to be supplied for these appliances. So these batteries needed to an efficient charger to control and manage the charging process. In order to design an efficient charger it should satisfy for the load and battery such as fast charging, discharge capacity, cycle life, low cost and maintenance (Sakamoto et.al, 1999).

For large scale of storage energy, there are many types of batteries were used (Wall S., et al., 1999 & Ferreira. et al., 2013). All these types contain electromechanical cells, the batteries that do not have cell so suitable for all applications. In this section, the characteristic of each battery is various according to the scale for energy storage such as lead-acid, lithium-ion, nickel-cad as well as the application of these types of batteries according to the kind of the load used (Divya., et al.,2009 & Ali, et al., 2010). The lead acid batteries technology is uncomplicated and have lower cost than other batteries. However, the lead acid batteries cannot be fully discharge and have a limited scale of charge/ discharge cycles and the ratio cycle of charger/ discharge is depending on the weight ratio to energy drawn and also their energy to size (Parker et al., 2001). The lead acid batteries do not have high toxic and safe, where it could be used as a clean energy source (Roseland. et al., 2010).

The capacity of the battery is the amount of charging that available in the battery for discharging purpose, it is related to the quantity of active material that contain such as amount of electrolyte and surface area of the electrodes this expressed the units of ampere-hour (Ah) capacity. So the capacity of the cell depends on the following factors (Ceraolo, et al., 2011).

1. The amount of discharging current from the cell and discharging time.
2. The temperature of inner cell.
3. Discharge voltage end value.
4. Storage time (self-discharge).
5. Number of charge-discharge cycles that the cell has undergone.

2.4 Methods for Charging Process

There are many techniques to charge the batteries but the most suitable and famous methods are the following below for comparison (Armstrong, et al., 2008 & Masoum, et al., 2004).

2.4.1 Intermittent Charging

The intermittent charging is the most method commonly used for commercial chargers as shown in Figure 2.1 below. When the maximum power point is achieved in the panel means the battery is charged between two predefined thresholds. When the battery voltage become over the threshold voltage, the charging process will be stopped and the battery will be stilled in open circuit. The battery voltage is continually monitored until the battery voltage is drop under the threshold voltage, then the charging process will be started again. This method usually used with PWM method to charge the batteries (Waltari, et al., 2002 & Armstrong, et al., 2008).