"I admit that I have read this literature work through my observation which has fulfilled the scope and quality in order to be qualified for the conferment the degree of Bachelor in Electrical Engineering (Industrial Power)."

Signature : ....

Supervisor's Name : Prof Madya Dr Mohammad Rohmanuddin

Date : 21/11/2005

BATTERY CHARGING CONTROLLER FOR SMALL MOTOR LOAD

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This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in Electrical Engineering (Industrial Power)

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November 2005

"I admitted that this thesis is written by me and is my own effort except as cited in references."

Signature : ....

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Date : 21/11/2005..........................

To my dearest father and mother

For continuous love, motivation, support and encouragement.

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ABSTRACT

This project is to build a battery charging controller that can be used for small motor loads. The application of this project is the battery that is charged by the PV panel needs a battery charging controller so that it can control the battery from exceeding the maximum charging and discharging level to protect the battery from damage. Apart from that, the energy from the battery can be used to drive a small motor load which is connected to the PV panel to move the panel either forward or reverse depending on the sun's position. The movement of the panel will then be controlled by a circuit which is connected to the output of the battery charger controller that is the motor controller circuit.

ABSTRAK

Projek ini adalah untuk membangunkan sebuah pengawal pengecas bateri yang dapat digunakan untuk motor beban rendah. Aplikasi daripada projek yang dijalankan ini adalah bateri yang dicas oleh panel PV memerlukan pengawal pengecas bateri supaya dapat mengawal bateri daripada melebihi tahap maximum cas dan maksimum nyahcas untuk melindungi bateri daripada mudah rosak. Selain daripada itu, tenaga daripada bateri akan dapat digunakan untuk menggerakkan motor beban rendah yang disambungkan kepada panel PV untuk menggerakkan panel samada ke hadapan atau ke belakang mengikut kedudukan matahari. Pergerakan panel ini pula akan dikawal oleh satu litar yang telah disambungkan kepada keluaran pengawal pengecas bateri iaitu litar kawalan motor.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Stand-alone photovoltaic (PV) systems are becoming increasingly viable and cost effective for utility grid power requirements. Thousands of PV systems are being installed annually with typical applications including lighting, telecommunications and other battery charging requirements. In general, a stand-alone PV system consists of a PV array, which converts sunlight to direct-current electricity, energy storage in the form of secondary batteries, loads or appliances, a control system, which regulates battery charging and operation of the load. While PV module development over the past decade has resulted in a highly reliable product, performance of battery and charge controller sub-system have indicated a need for improvement. The areas include proper specification of charging requirements and control set points for the battery type and environment.

The charge controller must shut down the load when the battery reaches a prescribed state of discharge and must shut down the PV array when the battery is fully charged. When the battery is really a system of batteries connected in series and parallel as needed to meet system need, the control process becomes somewhat of a challenge. The control should be adjustable to ensure optimal battery system performance under various charging, discharging and temperature conditions.

When the array is disconnected from the terminals, the terminal voltage will drop since there is no further voltage drop across the battery internal resistance. The controller thus assumes that the battery is not yet charged and the battery is once again connected to the PV array, which causes the terminal voltage and array to be disconnected. This oscillatory process continues until ultimately the battery becomes overcharged or until additional circuitry in the controller senses the oscillation and decrease the charging current.

If the controller disconnects the load, the battery terminal voltage will rise above the minimum and the load will turn on again, an oscillatory condition exist. Thus, once again an application for hysteresis is identified, and another regenerative comparator circuit is justified for the output of the controller. All that remains is to make the set points of the charging regenerative comparator temperature sensitive with the correct temperature correction coefficient and the controller is complete.

If the controller is design to reduce charging current in order to bring the batteries up to exactly full charge before shutting down, and if the controller selectively shunts down loads to ensure the battery is optimally discharged, overall system efficiency will be improved over the strictly hysteresis controlled system. A charge controller will make full use of the output power of the PV array, charge the batteries completely and stop the discharge of the batteries at exactly the prescribed set point without using any power itself.

1.2 Objective

The objective of this project is to build a battery charging controller that can serve for small motor load. The application of sun tracking system needs a controller that can store the DC energy taken from the PV panel to the battery. Further, the energy from the battery can be used to drive a small motor for moving the DC load. The outputs of the project is to develop a prototype of battery charging controller for small motor loads to be used in the sun tracking system for rotating the PV panel. This project follows the methodology as describe below:

i. Literature review on the topic
ii. Study on the battery charging controller
iii. Study on the motor controller
iv. Study on the PV system
v. Study on the small motor and the battery
vi. Design the battery charging controller for small motor
vii. Design the motor controller circuit for rotating the PV panel

1.3 Project scope

The scope in the design of this project is to control the charging and over discharging process and controlling the movement of the panel either forward or reverse. Four steps has been done to make sure that this project is successful:

i. Simulation by using Multisim7 software
ii. Build battery charging controller
iii. Build motor controller
iv. Build PV panel prototype

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses about the literature discourse and review of a photovoltaic system, battery charge controller in photovoltaic systems, voltage regulation, low voltage disconnect, batteries and DC motor. Throughout the world, there has been many researches about the concept and implementation of this system which is deemed suitable for all types of battery charging controller.

Prior to these installations, proper studies, research and developments have to be conducted to ensure the optimum implementation of various technologies, methodology or standards of practice to produce the best possible working system. Literature reviews are based on information obtained from valid sources such as books, articles, internet and one of the more famous sources for literature reviews comes from IEEE.

2.2 Battery charge controller characteristics in photovoltaic systems [1]

The primary function of a charge controller in a stand-alone PV system is to protect the battery from over charge and over discharge. Any system that has unpredictable loads, user intervention, optimized or undersized battery storage to minimize initial cost and other characteristics that would allow excessive battery over charging or over discharging requires a charge controller and low voltage load disconnect. The result will be a shortened battery lifetime and decreased load availability. Systems with small, predictable, and continuous loads may be designed to operate without a battery charge controller. If system designs incorporate oversized battery storage and battery charging currents are limited to safe finishing charge rates (U50 flooded or C/100 sealed) at an appropriate voltage for the battery technology, a charge controller may not be required in a PV system.

Proper operation of a charge controller should prevent over charge or over discharge of a battery regardless of the system sizing design, seasonal changes in the load profile and operating temperatures. The algorithm of a battery charge controller determines the effectiveness of battery charging, PV array utilization and ultimately the ability of the system to meet the load demands. Additional features such as temperature compensation, alarms, and special algorithms can enhance the ability of a charge controller to maintain the health, maximize the capacity, and extend the lifetime of a battery.

2.2.1 Voltage regulation set point (VR) [2]

Voltage regulation set point is the value that will determine the action of the controller, whether discontinue charging the battery or begin to regulate the amount of current delivered to the battery. Proper selection of this set point depends on the specific battery chemistry and operating temperature. Temperature compensation of the VR set point is often incorporated in controller design and is particularly desirable if battery temperature ranges exceed 5°C at ambient temperatures (25°C). For flooded lead-acid batteries, a widely accepted temperature compensation coefficient is 5 mV/C/cell. If the electrolyte connection has been adjusted for local ambient temperature (increase in specific gravity for cold environments, decrease in specific gravity for warm environments) and temperature variation of the batteries is minimal, compensation may not be critical factor.

2.2.2 Voltage regulation hysteresis (VRH) [2]

Voltage regulation hysteresis is the voltage span or difference between the VR set point and the voltage at which the full array current is reapplied. The greater this voltage span, the longer array current is interrupted from charging the battery. If the VRH is too small, then the control element will oscillate, inducing noise and possibly harming the switching element or any loads attached to the system. The VRH has proven to be an important factor in determining the charging effectiveness of a controller.

2.2.3 Low voltage disconnect (LVD) [2]

Low voltage disconnect is the voltage at which the load is disconnected from the battery to prevent over discharge. The LVD defines the actual allowable maximum depth-of-discharge and available capacity of the battery. The available capacity must be carefully estimated in the PV system design and sizing process. Typically, the LVD does not need to be temperature compensated unless the batteries operate below 0°C on a frequent basis. The proper LVD set point will maintain good battery health while providing the maximum available battery capacity to the system.

2.2.4 Low voltage disconnect hysteresis (LVDH) [2]

Low voltage disconnect hysteresis is the voltage span or difference between the LVD set point and the voltage at which the load is reconnected to the battery. If the LVDH is too small, the load may cycle on and off rapidly at low battery state-of-charge (SOC), possibly damaging the load and controller. If the LVDH is too large, the load may remain off for extended periods until the array fully recharges the battery. With a large LVDH, battery health may be improved due to reduced battery cycling, but with a reduction in load availability. The proper LVDH selection for a given system will depend on the battery chemistry, size and PV and load currents.

2.3 Effect of ON or OFF charger controller on stand alone PV system [3]

Most battery charge controllers in stand-alone photovoltaic power systems shed portions of the PV array in discrete steps as the battery voltage approaches full charge. Off grid photovoltaic electrical systems, such as those found in remote areas are typically equipped with battery storage systems in order to provide power at night and during overcast days. In particular, the finish charge period of valve-regulated lead-acid (VRLA) batteries requires low charge current because their ability to accept charge is limited by the oxygen recombination cycle. Such an array shedding scheme is illustrated in Figure 2.1 where the array is composed of n parts, each of which is connected to the DC bus through a separate switch. More switches are opened as the battery bank reaches a high state of charge.

When the battery reaches full charge, the entire array is disconnected from the system. Conventional photovoltaic simulation programs used for system design, such as the common PVFORM4. It is assumed that the battery charge rate is unlimited and can absorb all the power available from the entire array until it reaches full SOC. As a consequence, the results may be optimistic since in real life the controller limits the rate at which the battery charges when the SOC typically reaches above the 90% range. The effect of an on or off charge controller on a stand-alone PV system performance in terms of battery state-of-charge and unused portion of the available PV array energy.

The charge controller action of an actual life PV system is illustrated through field measurements over a 24-hour period. Finally, computer simulations of the same system are conducted over a one year period using actual weather data both with and without the representation of a charge controller. The results show that the charge controller reduces the battery SOC and PV array energy use by 10% to 15% of the values found using the conventional way.

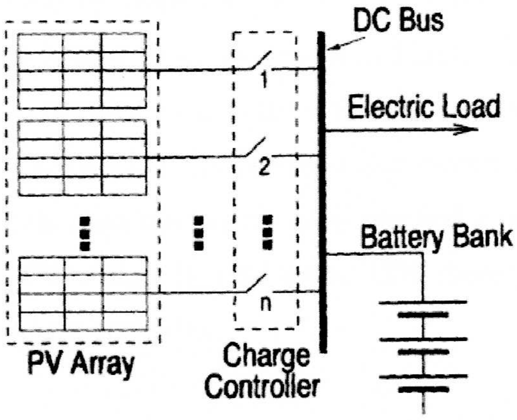

Figure 2.1: Schematic diagram of stand-alone PV system [3]

2.3.1 Model with charge controller [3]

The charge controller switches off the PV array in n sequential discrete steps as the battery SOC gets closer arrays connected to the system when switches 1,2, ... n in Figure 2.1 are switched off. Also let the corresponding battery state-of-charge, when these switches are activated be SOC, SOC2, ... The last n switch disconnects the last sub-array when the battery reaches full charge (SOC = 1). Charge control by sub-array shedding can then be simulated by adjusting the peak power according to the present state-of-charge.

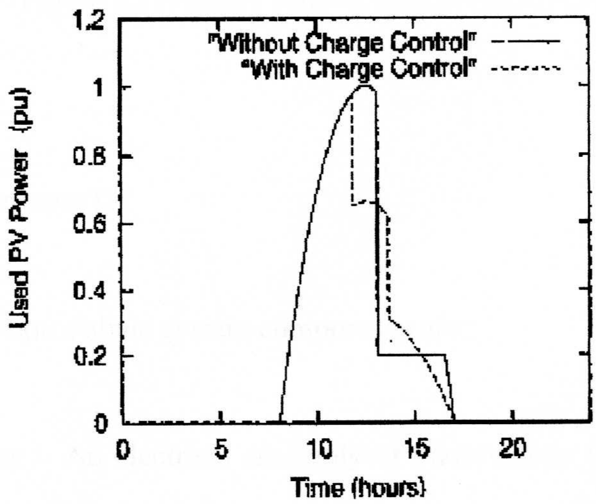

Figure 2.2: PV power used to supply load and charge battery [3]

Let the corresponding states charge be SOC, = 0.92 and SOCz =0.96. The modified PV power and battery SOC are shown in Figures 2.2 and 2.3 with dashed lines. In this case, the controller reduces the PV array capacity by one third at 11.8 hours when the SOC reaches 92%. Further reduction occurs at 13.6 hours when the SOC reaches 96%. In this case, the battery SOC reached a maximum of 98.2% and the amount of unused PV energy is 1.87 units, 12% more than the previous case without including the charge controller.

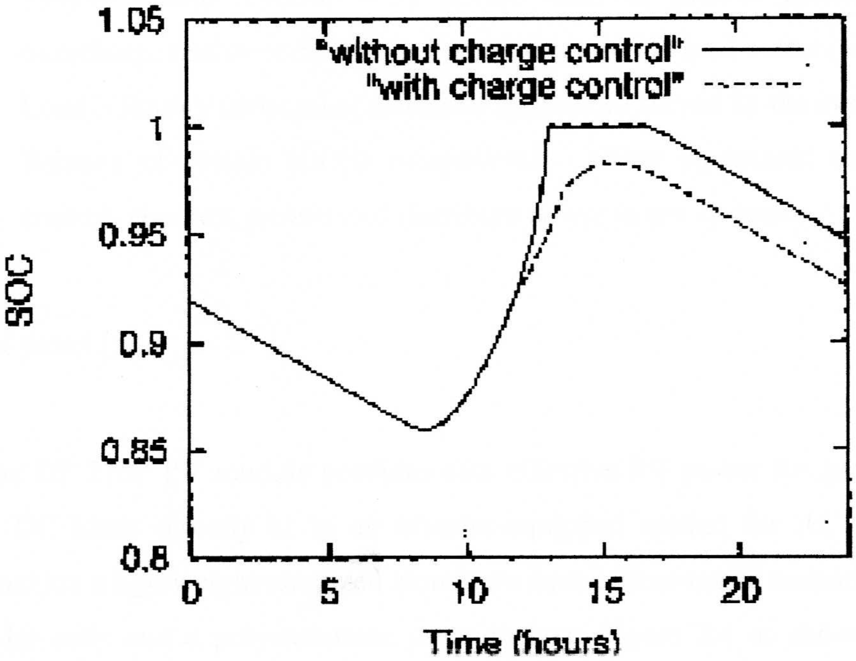

Figure 2.3: Battery state-of-charge (SOC) [3]

2.4 Photovoltaic system [3]

The general solar photovoltaic system components are:

i. PV array – An electrical assembly of photovoltaic modules that convert sunlight to DC electricity.
ii. Inverter – A device that converts DC power from batteries or PV arrays into utility-grade AC power.

iii. Converter – This device converts the DC output from the array to a voltage suited to the requirements of the battery or load. For example, a Maximum Power Point Tracker (MPPT) is a special type of converter whose function is to keep a PV generator operating at or near its maximum power point, using a built-in control logic operated by a microprocessor.

iv. Energy storage – Electrical or other storage devices, usually batteries, used to store energy produced by PV arrays for later consumption.

v. System charge control – A device used to protect batteries from overcharge and over discharge, sometimes provide load control functions.

vi. Load – Energy consuming electrical appliances served by the system.

vii. Balance of system (BOS) components – Other equipment required to control, conduct, protect and distribute power in the system.

2.4.1 PV panel [5]

The BP 275F PV module provides cost effective PV power for general use, operating DC loads directly or in an inverter-equipped system for AC loads. Its features include a lightweight anodized aluminum frame, time-tested monocrystalline silicon solar cells and a polycarbonate junction box. Figure 2.4 as shown the BP 275F PV module with nominal maximum power of 75 watts, the BP 275F is well suited to utility grid connected building facades and roof systems, telecommunication systems, pumping and irrigation, cathodic protection, remote villages and homes and land-based navigation aids. Its 36 series-connected cells charge 12V batteries efficiently in virtually any climate.

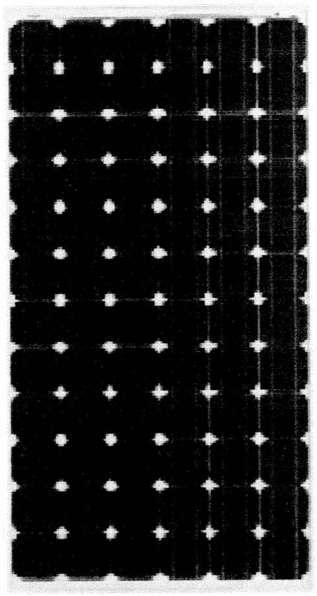

Figure 2.4: BP 275F PV panel [5]

The BP 275F is manufactured in ISO 9001 certified factories, certified by TÜV Rheinland as Class II equipment for use in systems with voltage up to 850VDC, and complies with the requirements of IEC 61215, including:

i. repetitive cycling between -40°C and 85°C at 85% relative humidity
ii. simulated impact of 25 mm one inch hail at terminal velocity
iii. a “damp heat” test, consisting of 1000 hours of exposure to 85°C and 85% relative humidity
iv. a “hot-spot” test, which determines a module’s ability to tolerate localized shadowing (which can cause reverse-biased operation and localized heating)
v. static loading front and back of 2400 Pascal (50 psf)

The electrical characteristics for BP 275F PV panel as shown in Table 2.1. So this project uses solar panel type BP 275F because this characteristics fulfills the specification for a small DC motor load. Other reason it’s use because this solar panel type is already available at the laboratory.

Table 2.1: Electrical characteristic for BP 275F PV panel [5]

Typical Electrical Characteristics	BP 275F
Maximum Power (Pmax)	75W
Voltage at Pmax (Vmp)	17.0V
Current at Pmax (lmp)	4.45A
Warranted minimum Pmax	70W
Short circuit current (lsc)	4.75A
Open-cicuit voltage (Voc)	21.4V
Temperature coefficient of lsc	(0.065±0.015)%/°C
Temperature coefficient of Voc	–(80±10)mV/°C
Temperature coefficient of Power	–(0.5±0.05)%/°C
NOCT	47±2°C
Maximum System Voltage	600V

2.4.2 PV cells [6]

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. As shown in Figure 2.5, when sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load.

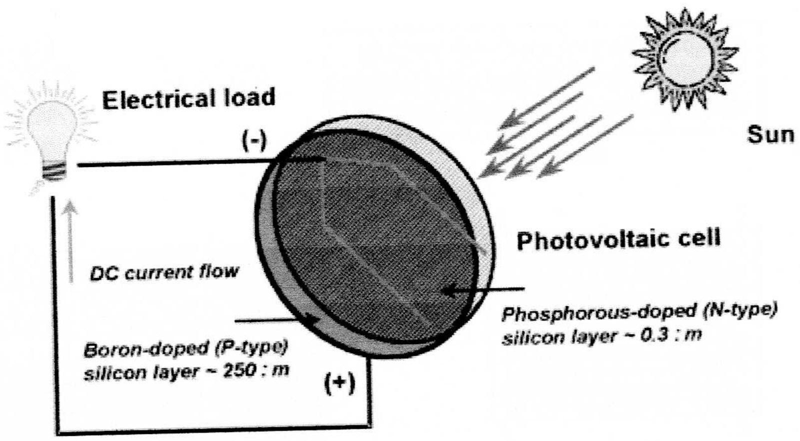

Figure 2.5: Diagram of photovoltaic cell [6]

Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit no-load conditions. The current and power output of a PV cell depends on its efficiency and size (surface area), and is proportional the intensity of sunlight striking the surface of the cell.

2.4.3 PV cells, modules and arrays [6]

Photovoltaic cells are connected electrically in series and parallel circuits to produce higher voltages, currents and power levels. As shown in Figure 2.6, photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate and are the fundamental building block of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired and field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.