ACHIEVING CONTROLLED AND EFFICIENT STORAGE POWER REPLENISHING IN A SOLAR ENERGY SYSTEM

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ABSTRACT

In a solar energy system, the stored power is replenished via charging. It is important that the process be controlled, as overcharging can be destructive to the battery. To do this, a charge controller is required. It is an electronic device used to transfer the electrical energy available from a solar panel to the battery, allowing current to flow from the panel to the battery when it is not fully charged while disconnecting the battery from the solar panel when it reaches a preset threshold value, thus, maintaining the battery voltage at a level suitable to keep the battery in full charge state. Most charge controllers are imported. In this paper, a charge controller is developed locally for the purpose of controlling the charging activity of the battery in the solar energy system. It incorporates a PIC16F72 microcontroller, the system's brain and also manager of its operation. The charge state of the battery is determined by converting the taken analog samples of the battery voltage into digital values. Current flow is allowed into the battery under charge from the solar panel, this leads to a steady increase in voltage across the battery until it reaches an upper threshold value set in the source code embedded in the microcontroller. A MOSFET was used as the switching device in the controller and the microcontroller displays the battery voltage on a liquid crystal display. The circuit was tested using simulation software and the results were excellent. A prototype was constructed using a bread board and tested, thereafter the circuit was transferred to a printed circuit board layout.

Keywords: Microcontroller, charging, solar, MOSFET and prototype.

1.0 INTRODUCTION

Solar energy is the free energy derived from the particles of light called photons, solar energy can be used for heating application, by concentrating rays light onto a spot via mirrors and/or energy harnessing as in photovoltaic cells, this cell then converts the harnessed energy, derived from the photons, to electricity by its semiconductor action (Gaur & Tiwari, 2013). This energy is enormous, its power reaching 1.2×10^{17} W on the earth's surface.

Photovoltaic systems, also called, solar systems is composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that uses energy from the sun to generate electricity (Taye & Gajjar, 2018), (Chu, 2011).

The Outputs of solar panels are usually within the range of 16 V to 20 V, so if there is no regulation the batteries will be damaged. The battery voltage rises and reaches the gassing voltage. If the battery charging is left unattended, the excessive gassing will lead to water loss and will cause the battery to be overcharged, this causes severe damage to the cells. Continuous exposure of the battery to this condition will make the battery to deteriorate and eventually unserviceable. The charge controller will maintain the battery at its highest state of charge and prevent overcharge. The heart of the solar energy system is the charge controller, it determines how much of the sun's energy can be converted into electrical currents to charge the batteries (Noor, J. and Ayumi, 2009), (Mallika, Sivakumar, Engineering, & Engineering, 2017). Artificially powered chargers like converters, inverters, engine alternators have unlimited power backing them, either from electricity at a power plant or an engine. Charge controllers imported into Nigerian market includes (Mallika & Sivakumar, 2017), PWM (Pulse Width Modulation) charge controllers, MPPT (Maximum Power Point Tracking) charge controllers (Gupta & Kumar, 2015), Shunt Charge Controllers and Series Charge Controllers (Marufa, 2012). This paper considers the development of a charge controller locally for the purpose of controlling the charging activity of the battery in the photovoltaic system. Hence, battery charging is regulated to elongate the lifespan of the power storage of the solar energy system and returns the maximum amount of energy to the battery at the shortest possible time.

2.0 Materials and Methods

This section is presented in two sections, namely; hardware and software. The hardware is the section that highlights the procedure of selection of the various electronic components, while the software section elucidates on the software development for the charge controller.

Hardware

The charge controller designed system model is as shown in Fig. 1. It is comprised of six stages.

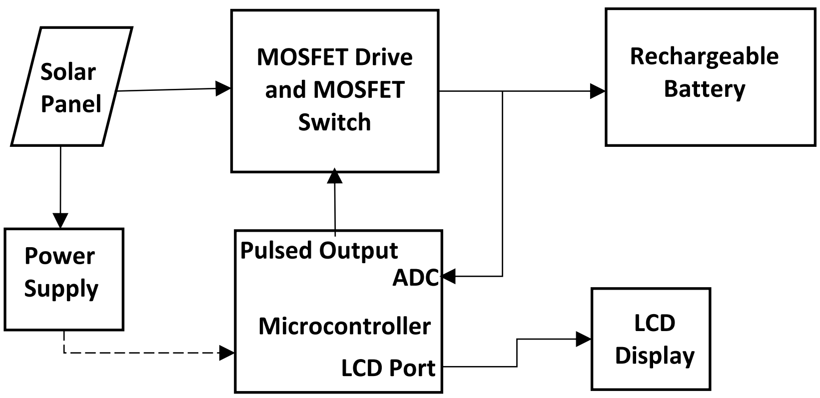

Figure 1: System model

Power Supply Stage

This is the stage of the system that provides V_{DD} to the entire stages in the system, particularly, the microcontroller stage requires a 5 V dc supply. The input to this stage is obtained from the PV panel, a 12 V, it is regulated by an integrated circuit (IC), 7805. Capacitors are chosen to stabilize the 5 V output voltage. The designed circuit is as shown in Fig. 2.

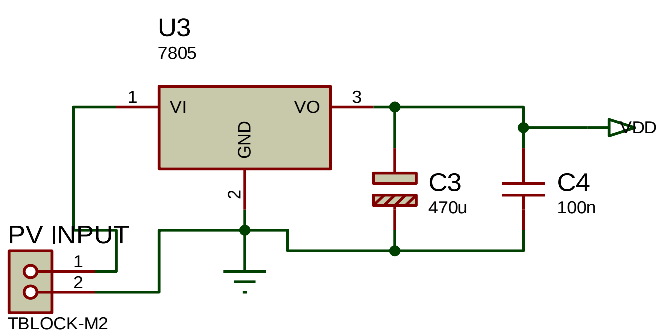

Figure 2: Power supply circuit

Drive and Switch Stage

The maximum current chosen for this design is 20 A, therefore, the switching device to selected should be able to pass the required current and a little more during temporary surge. Based on these parameters the metal oxide semiconductor field effect transistor (MOSFET) serves as the best device for passing such a high current with little or no power dissipated as heat. The IRF3205 was implemented since it can handle about 80A at 55V across the drain source.

To properly harness the perfect switching capability of the MOSFET a driver is necessary to convert the 5V logic level available at the output of the microcontroller to voltage level required to ensure full turn-on of the MOSFET, this is usually a minimum of 8V between the gate and source terminal. A totem pole driver was used consisting of adjacent pair of bipolar junction transistor. The circuit design is as shown in Figure 3.

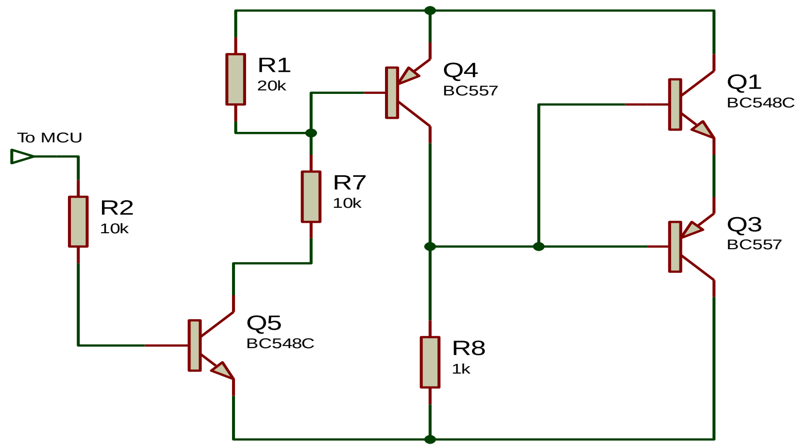

Figure 3: Driver circuit

Microcontroller Stage

The controller stage in any system is important as it governs all the process of achieving the desired output. It is required that the system be intelligent or smart, hence, control must be through an embedded program. Such a control is called microcontroller. The choice of the microcontroller was based on the speed of operation of the target system, number of input and output to be sensed and controlled, the size of memory storage for program data and the cost of the controller. The microcontroller implemented is the PIC16F72A which contains 2K words, which translate to 2048 instructions, since each 14-bit program memory word is the same width as each device instruction. The data memory (RAM) contains 128 bytes. There are 22 I/O pins that are user configurable on a pin-to-pin basis, A/D converter, SPI and I2C. The charge controller requires I/O pin configured as analogue measurement input and two output ports (one to pulse the MOSFET and LED and the other to write status messages to the LCD screen).

The oscillator selection bits in this application were configured as high speed in the source code this allows for the connection of a 16 MHz crystal to the physical oscillator input. Watchdog Timer and Power up Timer were both disabled. The pin configuration implemented of the PIC16F72A microcontroller is shown in Fig. 4.

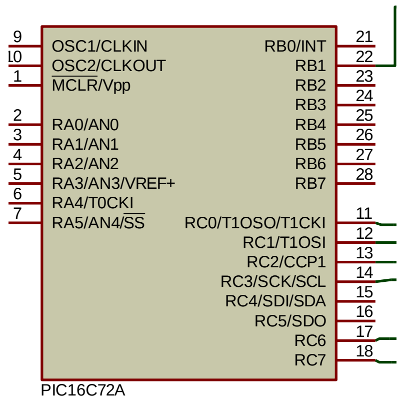

Figure 4:PIC16C72A pin configuration

Recharging output Stage

Since the source of the microcontroller dc power is not at the same reference with the ground circuit of the microcontroller, it is required to translate the voltage level at the battery terminal to the microcontroller analogue input. The opto-isolator, 4N35 was introduced to achieve this. The opto-isolator system allows the use of an N type MOSFET, which is a perfect switching device choice. It transforms the value of the voltage across the battery into current flow into the input of the photo diode used to control the voltage across a resistor at the output of the microcontroller circuit. Thus, the voltage at the terminals of the battery is translated to the analogue input of the microcontroller. The circuit design of this stage is shown in Fig. 5.

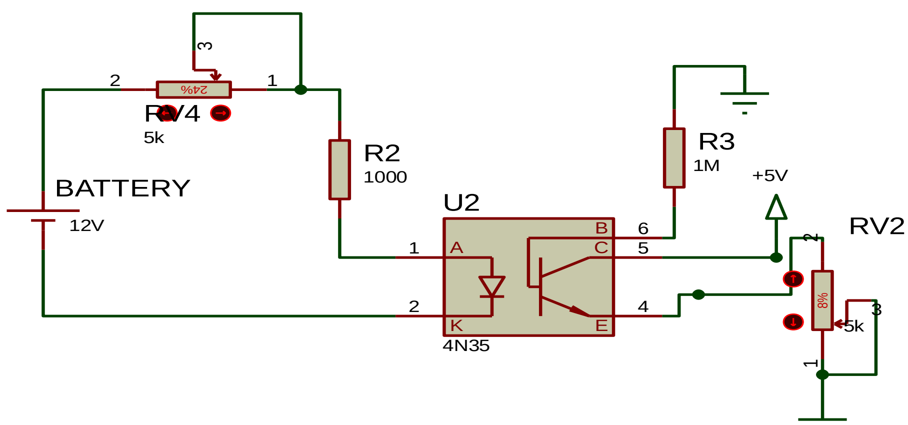

Figure 5: Output circuit

LCD display stage

To display welcome messages and write the status of the Charge controller an LCD, 1620A was used. The microcontroller is configured to write display messages to the LCD using 4 bit mode so only the upper nibble in the data line is connected; the connection is as shown in Fig. 6.

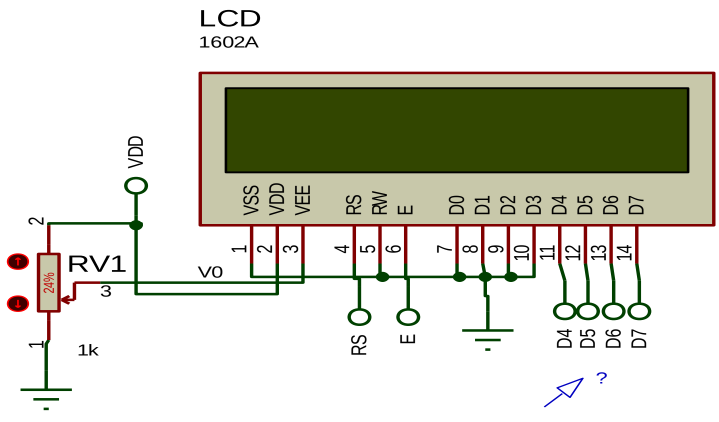

Figure 6: Display circuit

The overall circuit design is as shown in Fig. 7.

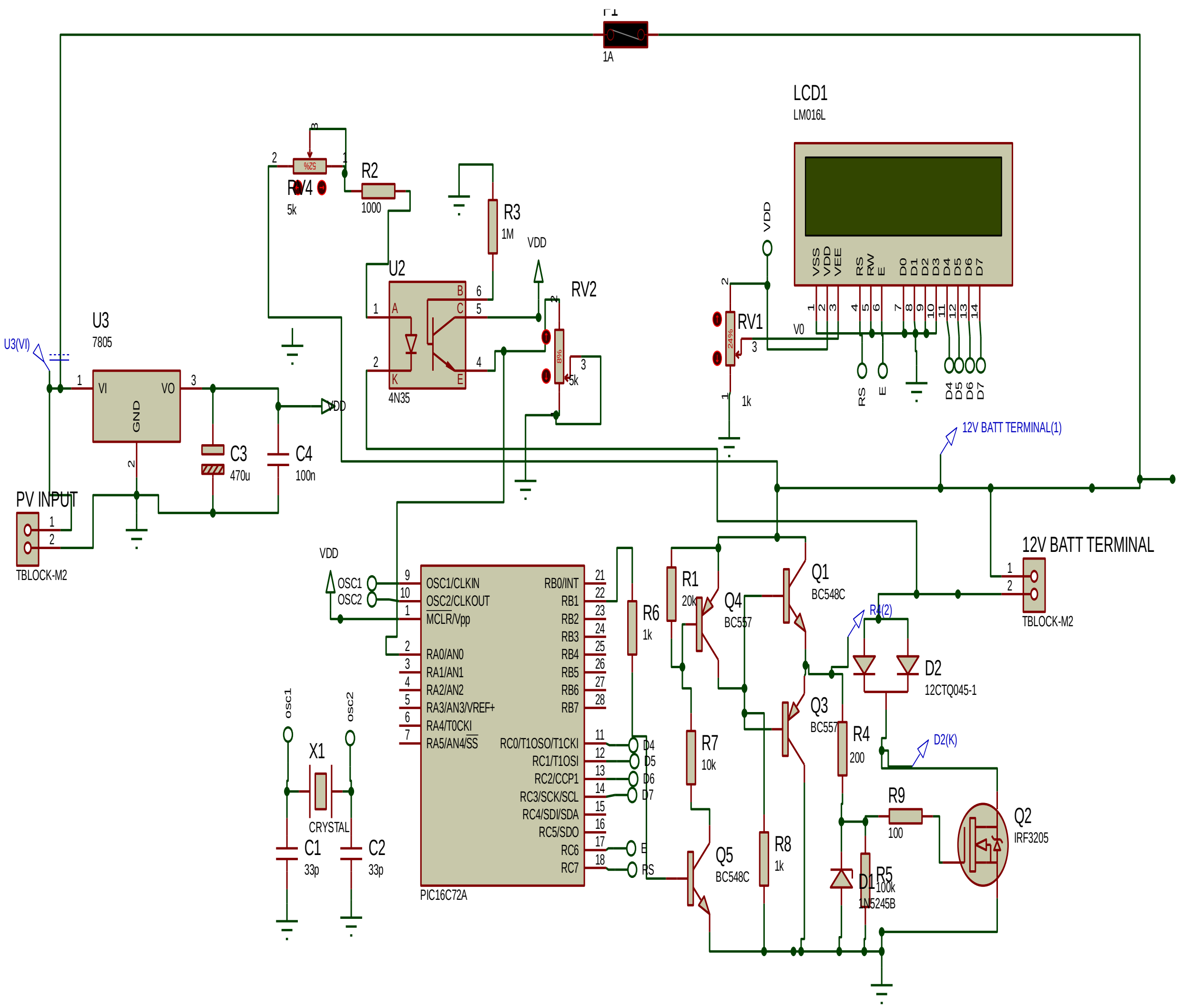

Figure 7: Charge controller circuit design

Software

The flowchart for the development of the program is as shown in Fig. 8.

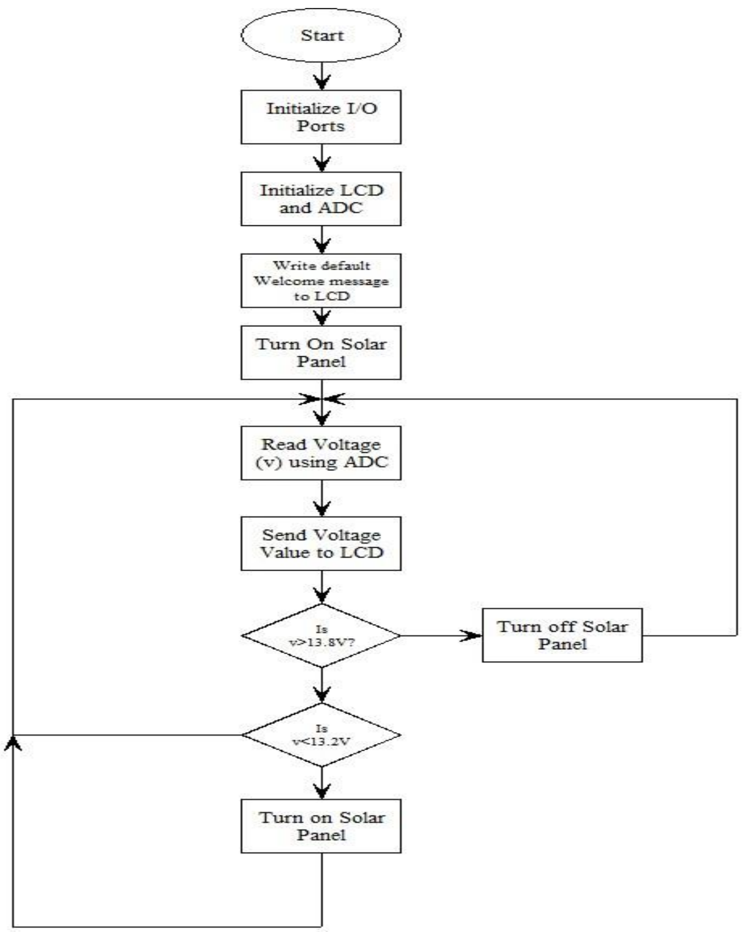

Figure 8: Charge control flowchart

The source code for the controller was developed using C language and compiled using microchip XC8 C compiler.

Results and Discussion

The Proteus Design Suite is an Electronic Design Automation (EDA) tool including schematic capture, simulation and PCB Layout modules. The source code was written and compiled in the code work space. The simulation showed the voltages and currents on the various probes and also displayed the logic state of pins. The LCD module displayed the status of the battery under charge as shown in Fig. 9.

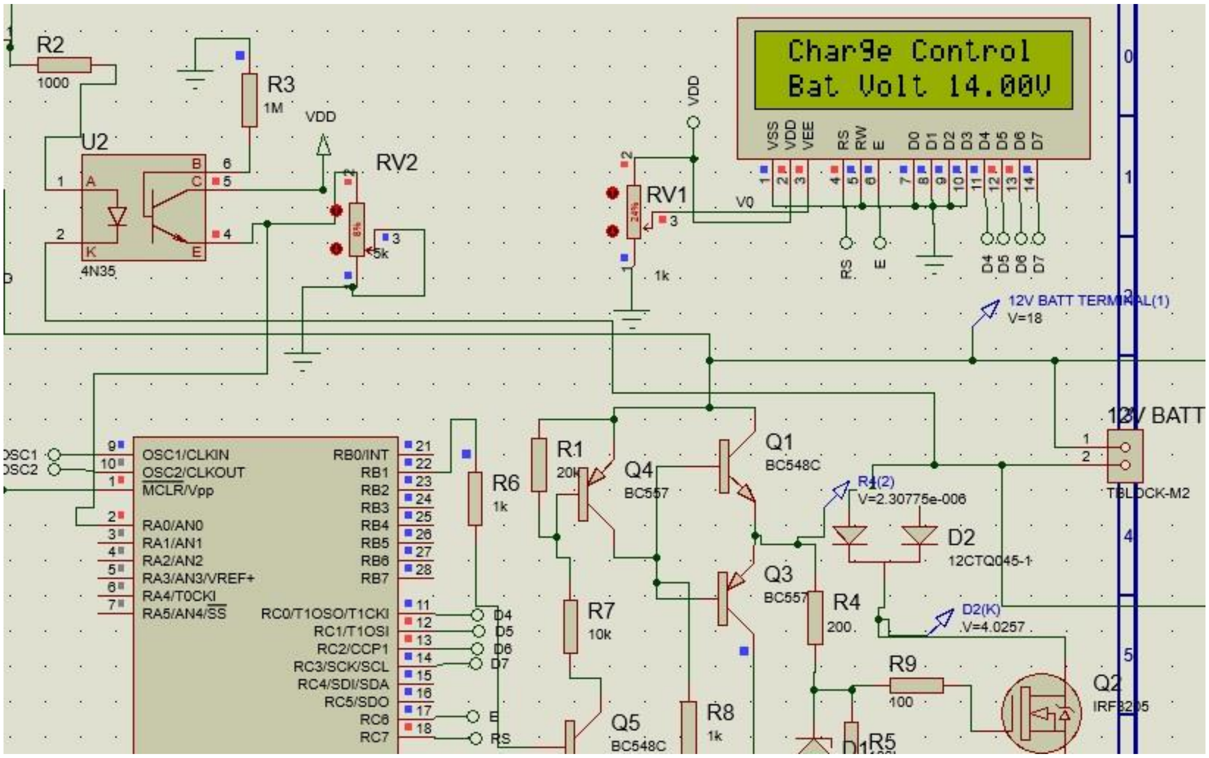

Figure 9: Proteus design result

The charge controller was used to charge a 50AH battery using a 200W solar panel. The battery was completely discharged prior to the experiment the battery voltage as measured using a standard digital voltmeter was 11.80V. The charge controller was connected to the solar panel and to the battery, measurement of voltages and currents was done every thirty minutes.

Voltage result discussion

The voltage readings at every thirty (30) minutes interval was taken using a voltmeter and plotted as shown in Fig. 10.

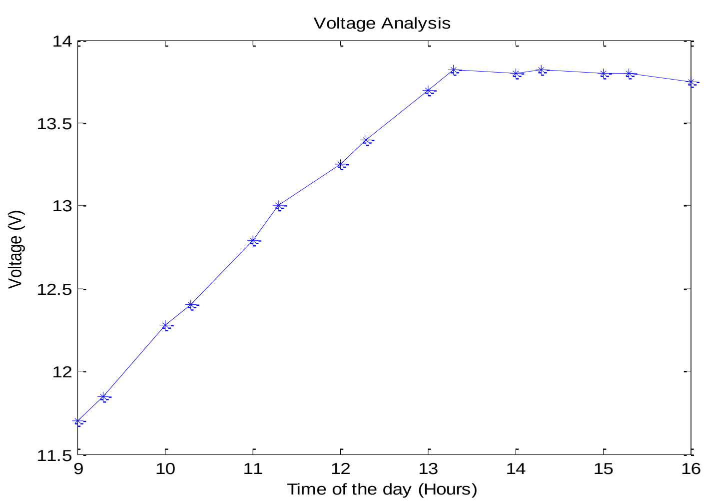

Figure 10: Charge voltage plot

The system is seen to charge the battery from 9am to 1pm. At 1 pm the battery was fully charged from 11.7 V at 9am to 13.82 V at 1pm. Above this time (1pm), the voltage did not increase any longer. The charge controller keeps the voltage and stops charging.

Current result Analysis

The current readings at every thirty (30) minutes interval was taken using an ammeter and plotted as shown in Fig. 11.

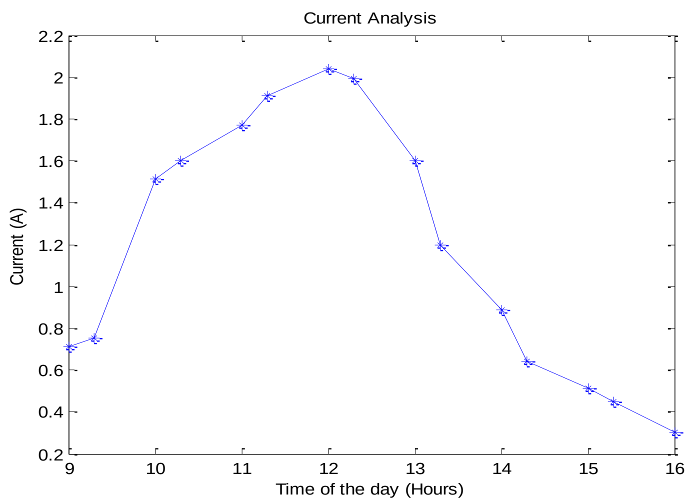

Figure 11: Charge current plot

The charge controller starts the charging with a current of 0.71 A at 9am and reaches 2.04 A at 1.30pm. Having reached a charged stage, the charge controllers current starts reducing until it reaches 0.3 A. This reveals that when battery is fully charged, charge controller's current output is reduced until it is put out completely.

3.0 Conclusion and Recommendation

The design of a pulse width modulated charge controller with MOSFET as switching device has been accomplished a program was developed from an algorithm and later converted to source code in c programming language. The design employed the use of an OPTO coupler to translate the battery voltage to the range necessary for measurement by the analogue to digital conversion circuitry. The prototype was built and successfully tested on breadboard before final assembly on the printed circuit board. The controller was able to modulate the battery voltage within a suitable level that prevented overcharging and water loss.

Charging current demand depends on battery capacity and size of solar panel, as these parameters increase there would be need for more current flow it is important to therefore increase the copper track width to reduce track resistance and voltage drops. Two or more MOSFET can be arranged in parallel to reduce conduction loss in the switching device

The use of a high current schottky diode is important to reduce power loss in the reverse protection device.

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