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Development of Constant Current Charge Controller for 3KW Wind Turbine

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***Abstract*— This paper describes the development of constant current charge controller for 3kW wind turbine designing with 48VAC PM alternator. As the wind speed is not constant, the output voltage from the wind turbine is always changing. In the circuit design, the changing voltage is sent to the 48V battery bank (series connection with 12V 200Ah batteries) by using the constant current charging method to extend the battery life. It does not only provide the two-step charging; the first step for the slow charging and the second step for the fast charging, but also use the overheat sensing circuit to prevent the damage of the expensive battery bank. In this work, the controller circuit operates properly switching first stage or second stage alternately depending on the full/low battery voltage. Unfortunately, if the overheating condition appears in the circuit, the cut-out circuit using temperature sensor decides to stop charging. To indicate clearly the battery charging conditions, the LCD display unit using the microcontroller is provided in the circuit design. The current sensing circuit is also added to show the battery charging current on the LCD display through the microcontroller. In this paper, the voltage comparator circuit, the two-step charging circuit, the overheating sensing circuit and the LCD display are described by simulating with Proteus (ISIS) software.**

***Keywords*— Charge Controller, Wind Turbine, Lead-Acid Battery, Circuit Simulation, Proteus (ISIS) software**

I. INTRODUCTION

Harnessing the renewable energy is substantially increasing to generate the electricity as some other energy sources can cause the environmental problems. Wind energy is also becoming popular building the wind turbines to generate the electricity for both homes and industries. At the same time, batteries are also becoming necessary to store the energy for the off grid consumers. As the batteries are expensive, it needs to maintain a long life for them without damage. So, the battery charger and control unit are used between the wind power source and the expensive battery bank to be able to charge these batteries at a healthy and efficient way.

The purpose of a charge controller is to supply the energy to the battery in a manner which fully recharges the battery without overcharging. If the batteries are fully charged, the controller decides to disconnect the battery terminals from the power source or to hold at the slow charge condition or to send the excess power to the dump load. If the batteries reach the level below the normal voltage condition, the controller is to connect the battery terminals to the power source to recharge again.

The objective of this paper is to develop a lead-acid battery charge controller for wind turbine. To be able to charge safely and fully the batteries, this control circuit design is proposed with high performance and multi functions.

II. CIRCUIT DESCRIPTION

The system proposed in this paper is a constant current charge controller (48V, 10A) for 3kW wind turbine. Figure 1 shows the system configuration with separate blocks required to build a battery charging control system.

First, 3-phase variable AC input voltage depending on the variable wind speed is received from the power box of the wind turbine. A 3-phase bridge rectifier is used to convert AC (48V) to DC voltage (≈65V), and to feed the voltage regulator which regulates the DC voltage (5V) to be able to supply the suitable voltage to other control circuit portions. The overheat sensing circuit which also is the cut-out circuit disconnects the battery terminals from the DC voltage source to stop the charging when the temperature sensor gives the data of high temperature condition. In the normal temperature condition, the whole circuit operates safely again. The current sensor is also used to know easily which current rate is at the batteries. The overheating condition in the circuit and the current values of the battery bank are indicated on the LCD display by using the microcontroller.

The main goal of the controller circuit is to decide either to recharge the batteries again when the battery voltage is below 13.5V×4 which is the required voltage level for the battery bank or to stop the charging when the battery bank has the full condition. The voltage comparator circuit operates in order to reach this goal. It always monitors the battery voltage and compares with the reference voltage. And then, it decides whether to send the energy to the battery bank or not, depending on the compared results. In this work, the two-step charging method is also added to extend the battery life. The first step is the slow charging to the batteries and its job is to

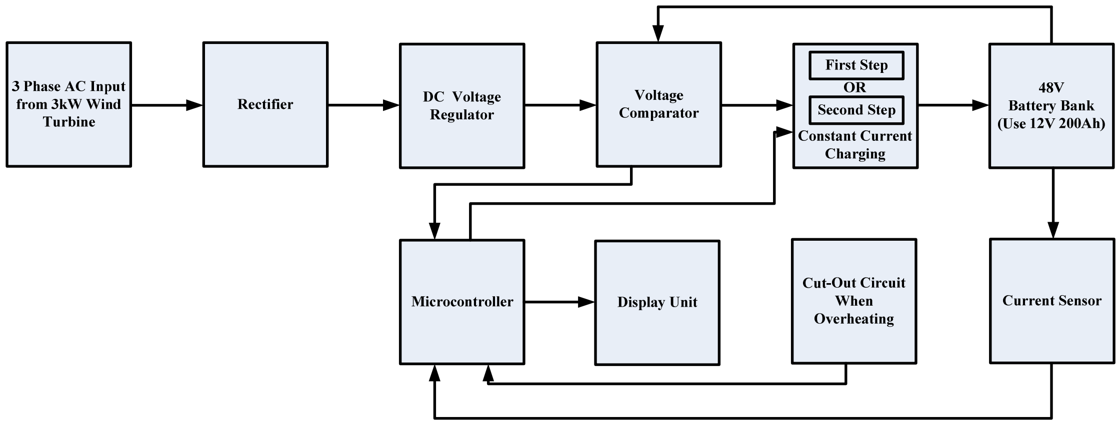

Fig. 1 Battery charge controller block diagram

charge the batteries with current 2A rate at the battery-full condition. The second step is the fast charging to the batteries. Because of this method, the battery has a chance to charge with 10A constant current after one minute slow charging step at the initialization time and it is charged until the fully-charged condition is reached. After that, the batteries are maintained at the slow charging step again until before they reach at the low voltage condition. The microcontroller helps to start with the slow charging at the initialization time and then to be able to operate as the decision of the comparator circuit at the later time. At that time, the stage which now reaches at the first step (2A) or the second step (10A) is shown on the LCD display.

Now, the voltage comparator circuit, the two-step charging circuit and the overheating sensing circuit are described.

A. *Voltage Comparator Circuit*

The voltage comparator circuit is designed by using two operational amplifiers, UA741 and one CMOS dual D-type flip flop, CD4013BE. One operational amplifier is used as the clock oscillator for synchronization to D-type flip flop so that it can operate properly in two halves of it and another for comparison to compare the battery voltage and the reference voltage. The battery voltage is monitored from the inverting input of the operational amplifier and the reference voltage from the non inverting input.

When the battery voltage is greater than the reference voltage, the batteries are charged with low current. So, the comparator output must be low to be able to do the first step charging as is connected to the first step charging circuit portion. The values of R_5, R_6, R_7, R_8 and R_9 are adjusted to set the required input ranges for the comparator circuit portion. The desired output conditions can be created according to the input voltages of the comparator which are designed with the simple voltage divider formula. Figure 2 shows the voltage comparator circuit.

When the battery voltage reaches below 54V, the batteries are charged with high current. So, the comparator output must be high to be able to do the second step charging as the output Q is sent to the second step charging circuit. CD4013BE D type flip flop is used to drive the two-step current switching circuitry and the charging state indicator. The yellow colour LED is for the first step and the red colour LED is for the second step.

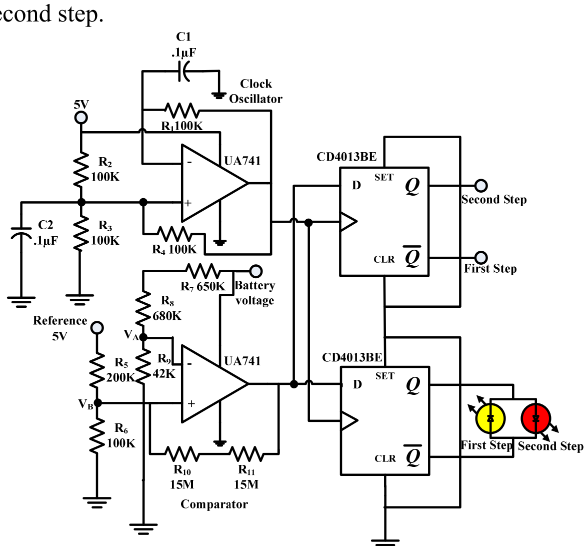

Fig. 2 Voltage comparator circuit

B. *Constant Current Charging Method*

In the constant current two-step charging circuit, four IRF3205 power MOSFETs are used to build the constant current source for the battery bank. The circuit portions of two step charging method are shown in Figure 3 and Figure 4.

1) First Step Charging: In the first stage, the output $\bar{Q}$ of D type flip flop from the comparator circuit is connected to the first step charging circuit. The charging current for the first step is 2A. To get this value, R_{13}, $D_2$and R_{14} values are designed to reach V_{GS}=3.84 V with R_{15}=0.07Ω. To test the charging current to reach its required value, a DC Ampere meter is connected in series with the battery. R_{15} and Transistor Q_5 limit the charging current if the battery terminals have errors.

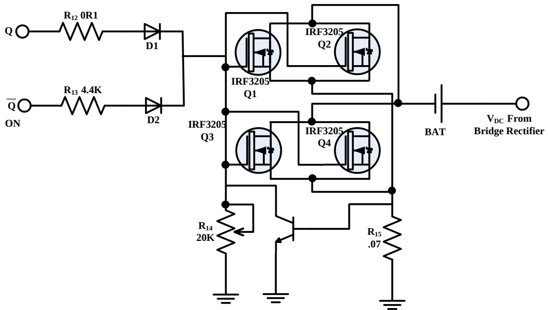

Fig. 3 Circuit diagram of the first step charging

2) Second Step Charging: In the second stage, the output Q (≈5V when Q is ON) is sent to the second step circuit through R_{12}, $D_1$and R_{14}. The batteries are charged with 10 A constant in this stage. So, the nearest standard value of R_{15} can be calculated as follows:

$$R_{15} = \frac{0.7}{\text{Safe fault current}} \quad (1)$$

The gate-source voltage (V_{GS}) of MOSFET is set 3.97V in order to be fixed the charging current.

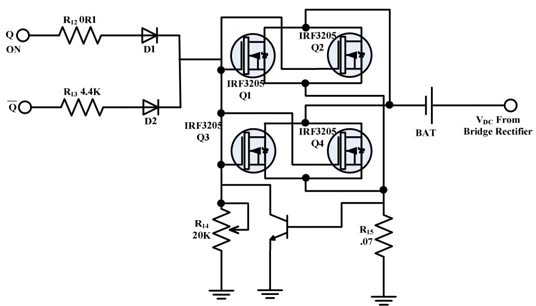

Fig. 4 Circuit diagram of the second step charging

In both stages, when V_{GS} changes, the charging current flowing to the battery also changes. Therefore, V_{GS} is set to reach the required charging current by adjusting the variable resistor R_{14}.

C. Overheat Sensing Circuit

One of the most detrimental conditions for a battery is high temperature. In this circuit, the precision integrated-circuit temperature sensor, LM35 is used to protect the high temperature of the battery bank. It is rated to operate over -55° to +150° C temperature range. Its output voltage is linearly proportional to the Celsius (Centigrade) temperature with +10mV/°C. Figure 5 shows the circuit diagram which senses the overheating of the battery bank.

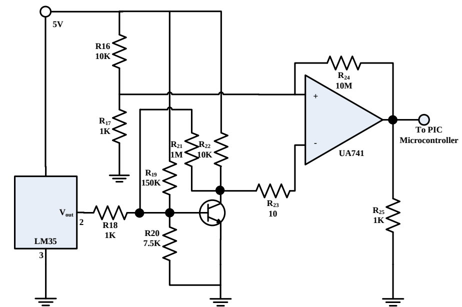

Fig. 5 Overheat sensing circuit

The output voltage of the temperature sensor is very small. So, it is amplified first and compared with the reference voltage to know whether it is the high or normal temperature condition. And then, the output of the comparator is sent to the PIC microcontroller to be able to cut out the charging path at the high temperature condition (70°C). In the normal condition (below 70°C), the charging circuit properly operates again.

III. Simulation Results

By combining the previously described the voltage comparator circuit and the two-step charging circuit, the battery charger control circuit is simulated by using Proteus (ISIS) simulation software.

In the simulation result of Fig. 6, the comparator decides to go to the second step to be able to recharge the batteries quickly as the battery voltage is low. In this stage, the batteries are charged with the constant current 10A. The comparator circuit will decide to go to the first step charging stage if the battery bank reaches the full condition.

The temperature sensor, the PIC 16F84A and the LCD display are combined to simulate for overheat condition as shown in Fig. 7. When the temperature reaches to 70° C, the microcontroller cut out the charging path to stop the charging and to protect the damage of the battery bank due to overheat-

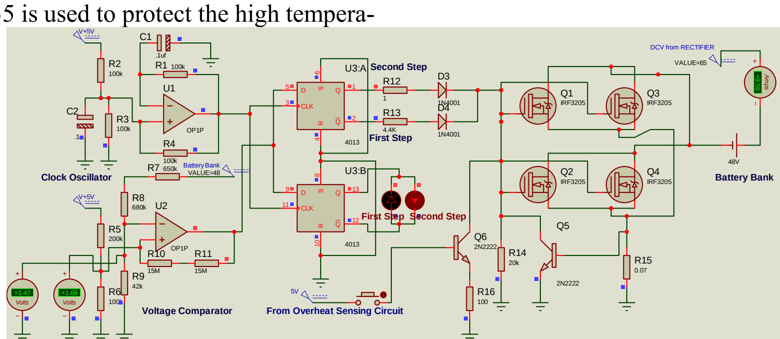

Fig. 6 Simulation of the battery charging control circuit

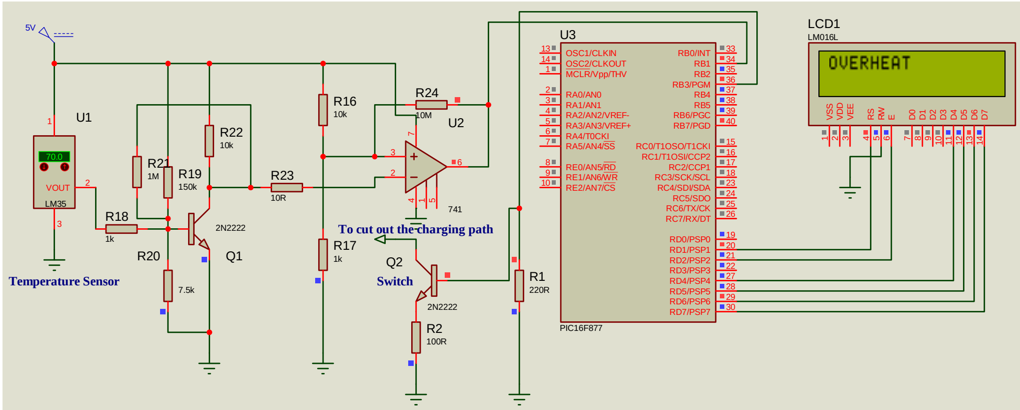

Fig. 7 Simulation of the overheat sensing circuit

ing. The LCD display indicates the overheating condition in this circuit.

To be seen the battery charging conditions easily, the LCD program for the microcontroller is written to be able to display the first step or the second step depending on the decision of the comparator circuit. This can be tested and simulated with the Proteus software as shown in Fig. 8.

IV. Conclusions

The charge controller system for Lead-Acid batteries was presented with the simulation results of the voltage comparator circuit, the constant current charging circuit, the overheating sensing circuit and the LCD display. The proposed battery charging control system can operate in constant current charging mode. The required current rate can be got by setting the Gate-Source voltage (V_{GS}). In order to monitor the operating parameters during charging/discharging processes, a PIC microcontroller with the LCD display and the current sensing circuit will also be added by analyzing the design circuit portions with the help of the Proteus simulation software and constructing the complete charge controller circuit at the practical world. The circuit construction of the voltage comparator portion is shown in Fig. 9.

The proposed system features the following multi-functions such as the two-step constant current charging, the overheat protection, the battery current sensing and the clear indication for the status of the whole circuit.

Fig. 9 Photo of the voltage comparator circuit

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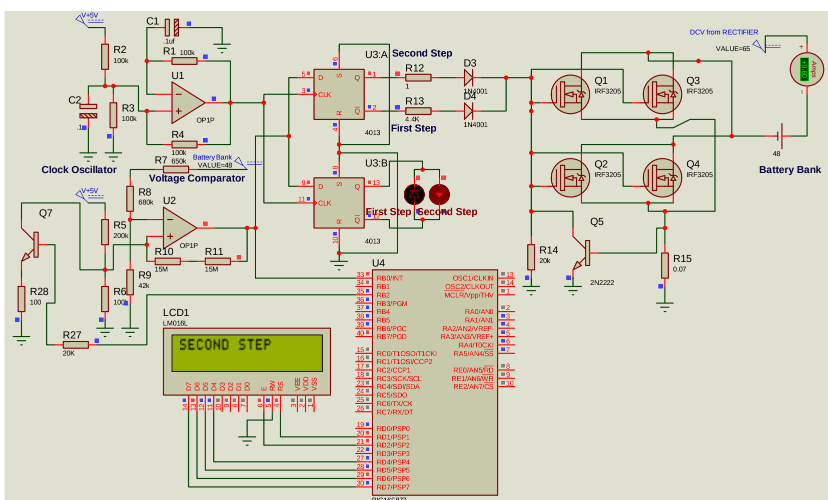

Fig. 8 Simulation of the display unit indicating the two charging steps

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