DESIGN OF A MICRO-CONTROLLER BASED CHARGE CONTROLLER FOR ELECTRIC RICKSHAW

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DECLARATION

We thereby declare that thesis work is our work. Wherever contribution of others are involved, every effort has been made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussion. This paper is made for academic purpose and has not been submitted before any other objective.

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CERTIFICATION OF APPROVAL

The thesis titled "Design of a microcontroller based charge controller for Electric Rickshaw" submitted by Kamruzzaman Mithu (201416009) , Ehsanul Hauqe (201416020) and Md. Shakil Hasan (201416054) , has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical, Electronic & Communication Engineering.

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DEDICATION

“And lower to them the wing of humility out of mercy and say, "My Lord, have mercy upon them as they brought me up [when I was] small."

To our Parent**s………………..**

ACKNOWLEDGEMENT

All praises be to Allah, the merciful, the beneficent.

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We would like to thank our parents and dedicate our thesis to them. They have been the encouragement behind our every successful endeavor. This thesis work is not an exception and this would not have been completed without their constant support and inspiration.

Finally, we put forward our humble gratitude to all our colleagues, friends and well-wishers for their help, supports and words of encouragements during our thesis work.

ABSTRACT

The design of a cost effective efficient charge controller for the electric rickshaw in Bangladesh has been done in this work. Electric Rickshaw are one of the most common form of electric vehicles in Bangladesh. Due to its several advantages, it has become very popular in rural areas. As electric rickshaw is run by the battery, charge controller plays an important role. The charge controllers need to have a high efficiency and different protection systems. Due to the inefficiency of charge controller, electric rickshaw consumes a lot of power that creates problems in the power sector. Quality of charge controller available in Bangladesh has been studied here to evaluate their performance. Designing is done in such a way that it senses how much charge is stored in the battery and according to it, charging voltage changes. Various safety features have been incorporated in the design to protect the battery as well as the charger itself. Simulation has been done using PROTEUS software. Tap changing transformer has been used for controlling in collaboration with Micro-Controller. The simulation results show that the design system is efficient and effective in charging the batteries. The charging system can be used to minimize the energy losses while charging and lengthen the life of the batteries in the electric rickshaws of Bangladesh.

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CHAPTER 1

INTRODUCTION

Energy is a very important factor in developing the economy and the standard of living of a country. Electricity is the most common form of energy. Generally it is generated using the national resources. Electricity can be produced by using natural resources like oil, natural gas, fuel etc. Countries which have access to large amount of natural resources can produce electricity to large amount. But natural resources will be gone one day. Worldwide all the countries are facing this problem.

Like many countries in the world, Bangladesh is a developing country which largely depends on natural gas and fossil fuel to generate major portion of power. The country lags behind than its expected production capacity. Though many power generation units have been added to the national grid to solve the power crisis issue, they are not enough. High demand and increasing need of power have created challenge for the power stations to meet the demand. In our country, a major portion of total population still does not have the access to electricity. Only 10% of the rural households have electricity connection and there are some parts of Bangladesh which will not get the access of electricity connection from the national grid within next 30 years [1].

To solve this energy crisis, the Government is focusing on the renewable energy sources. Renewable energy technologies enable us to create electricity, heat and fuel from renewable sources. Solar, wind, hydro, wave, heat-exchange, tidal, wave and bioenergy technologies are all powered by the sun, directly or indirectly. Bio-energy technologies has been used to convert the solar energy stored in plants. Energy stored in food wastes, farm wastes, forest wastes, sewage, and algae can be converted into heat by using a variety of approaches. Use of renewable energy has brought a large change in transportation sector as well. Electric cars are one of the best example of this.

Conventional electric vehicle is not that common in Bangladesh. But the motor driven Electric rickshaw and three wheelers are very popular here. These can also be considered as electric vehicle. But their charging creates a problem in our power system due to heavy loads in rural areas. This occurs mainly due to the inefficiency of the charge controller that is used there. The charge controller available in the market also do not have necessary safety features so they are not good for the batteries. By increasing the efficiency and adding others features the power consumption can be reduced as well as the lifetime of battery can be increased.

1.1 Background of The Study

Electric rickshaw is the most common form of electric vehicle in Bangladesh. Charge controllers are used there for charging the lead acid batteries. Various researches have been done on different aspect of the charge controller used in Electric vehicles. But very few have focused the problems that exists in charge controller of rickshaw.

A lead acid battery charger which is driven by AC power source, there must be an AC/DC converter, a PFC (power factor correction) device, an isolated DC-DC converter. With the increasing demand of Electric vehicle, the charger topologies had been developed to increase the overall efficiency.

As a low cost and simple solution, Ferro resonant voltage regulation technology has been widely used in battery charger for EV for decades. This solution relies on the magnetic properties of transformer to regulate AC voltage. Regulating transformers operate on a resonant principle. But this Ferro-resonant battery chargers tend to excessively overcharge the battery banks due to an old formula of change in voltage over change in time and it creates much noise on the system. To solve this problem, with the low frequency transformer, MOSFETS, schocttky diode has been approached in [2]. But due to the weight and volume of low frequency transformer this approach steps backward.

Another topology which is mostly used is phase-shift full-bridge (PSFB) topology with a full-bridge rectifier is suitable for the DC-DC converter n EV battery chargers due to several advantages.it has significant disadvantages such as the difficulty of achieving the zero-voltage-switching (ZVS) operation of the lagging-leg switches at light load condition, the demand of a large output filter inductor, and the significant conduction power loss coming from the circulating current during freewheeling region.[3,4].

The other candidate is the full-bridge LLC series-resonant converter (SRC) because it has high efficiency in high voltage and high power conversion applications. But when the wide variation of the output voltage is required, the switching frequency needs to be varied extremely wide, the operation and the component design can be impractical. To overcome the problem due to the variable frequency control, some researches have been conducted by applying the phase-shift control manner to the resonant converter with fixed frequency [5, 6]. However, the severe conduction loss occurs due to the circulating current during the freewheeling period.

In [7], the other solution is proposed by moving a resonant circuit to the secondary side. It can decrease the circulating current, but power is transferred to the output only during the positive half cycle, there upon the very many output capacitor is required for low voltage ripple .To overcome these disadvantages of the PSFB converter and the LLC SRC, the hybrid-type converters derived from the PSFB converter have been studied [8-16]. The basic characteristic of the hybrid structure is that the input energy is transferred to the output stage during not only the power in region but also the freewheeling region. As a result, the voltage applied to the output filter inductor has low variation, which reduces current ripple so that the inductor can be designed with low value, thereupon, it is possible to reduce the inductor size. The wide ZVS range can be achieved since the additional converter operates as an external inductor. However, several hybrid-type converters still suffer from the large conduction power loss coming from the circulating current, which is non-powering current [8, 10]. In order to reduce the circulating current, several methods using an additional circuit or control scheme have been researched, but it is inevitable to use a sophisticated control scheme according to the load condition described in [11] or to use many components [12-14]. Hence, the converters only using the components consisting of the PSFB converter and the LLC series-resonant converter (SRC) have been researched [15, 16]. The converters have the common advantages of the hybrid-type converters presented before, such as ZVS operation in whole load range for all the switches and reduced output filter inductor size. In addition, the converter scan reset the circulating current and the output rectifier diodes can operate with zero-current-switching (ZCS). However, they need many components, and the transformer utilization is also poor.

The design in [17] uses a dedicated diode bridge to rectify the ac input voltage to dc, which is followed by the boost section. The bridgeless boost PFC topology avoids the need for the rectifier input bridge yet maintains this boost topology [18]. The converter solves the problem of heat management in the input rectifier diode bridge inherent to the conventional boost PFC, but increases electromagnetic interference (EMI) [19]. Interleaving has been proposed to reduce battery charging current ripple and inductor size [20, 21]; a unidirectional configuration presented in [22] is being illustrated. It consists of two boost converters in parallel operating 180◦ out of phase [23]. The interleaved boost converter has the advantage of paralleled semiconductors. With ripple cancellation at the output, it also reduces stress on output capacitors. However, similar to the boost, this topology must be limited to power levels up to approximately 3.5 kW [24]. A bridge less interleaved topology was proposed for power levels more than 3.5 kW described in [25]. Multilevel converters can reduce size, switching frequency, and stress on devices and are suitable for fast EV chargers. They allow for a smaller and less expensive filter. But the added complexity and additional components increase the cost and required control circuitry [26]. Currently, most EV (electric Vehicle) use a single-phase on-board charger to recharge their batteries [27].

1.2 Motivation:

Electric rickshaw is available in Bangladesh that is a form of electric vehicle Due to lack of sufficient efficiency, very much power is consumed by charge controller which is very costly for the rickshaw puller. At the same time, the quality of the chargers available in the market is not satisfactory. The lifetime of battery is also decreased due to this poor charging system. This results in gassing of the battery electrolyte and pollute the environment. However the buying capacity of the rickshaw pullers are not sufficient enough to afford a high performance charge controllers available in the market.

Very few works have been done on the charge controller of electric rickshaw. So it is necessary to design a proper and cost effective charge controller for electric rickshaw.

1.3 Objectives of The Study

The main objectives of this thesis are:

- To investigate the charger available in market and tests its functionality.
- To design a micro-controller based charge controller with tap-changing transformer for electric rickshaw.
- To provide various sensing unit to make the charge controller more efficient.

1.4 Thesis Methodology

The thesis has been conducted by following a step by step set of methodologies. At first, a design of charge controller has been developed in proteus environment. The performances of the proposed circuit has been investigated under various conditions such has output voltage, input current etc. Various sensing circuits and their characteristics has been checked. Operation of the full circuit at various abnormal parameters has been analyzed. Equipment's and their description has been given elaborately. Current range and voltage ranges has been checked to find out the operating characteristics of the designed circuit.

1.5 Outline of The Paper

In this paper a design of a charge controller is investigated. Chapter 1 introduces the necessity of improving of charge controller for lead acid batteries and review of earlier research works on Electric Vehicle charger and discusses the objectives of the study. Chapter 2 starts with the overview of Electric Rickshaw. Then it briefly discuss on its battery .A detailed discussion on various battery charging methods. This chapter also focuses on the charging stages of battery. Chapter 3 gives a view of battery charger of Electric Rickshaw, its characteristics. The Chargers we have tested, how tested are done, what are the tests are described elaborately here. Chapter 4 presents proposed system design of a charge controller for Electric Rickshaw. Advantages and protection system of the proposed system. Chapter 5 provides the simulation results which shows the accuracy and various output graphs of the designed model. Chapter 6 concludes the thesis work summarizing the achievement from the thesis work and providing suggestion on future work.

CHAPTER 2

ELECTRIC RICKSHAW & IT'S BATTERY CHARGING SYSTEM

In Bangladesh, electric rickshaw is more conventional in rural areas. For small transportation, it is basically used. Since it is cost-effective and requires less physical work, it has become very popular. Rickshaw drivers use electric rickshaw as an alternative of tricycle rickshaw and auto rickshaw.

2.1 Electric Rickshaw

Electric rickshaws (also known as electric tuk-tuks or e-rickshaws) have been becoming more popular in some cities since 2008 as an alternative to auto rickshaws and pulled rickshaws because of their low fuel cost, and less human effort compared to pulled rickshaws. They are being widely accepted as an alternative to petrol/diesel/CNG auto rickshaws. They are 3 wheelers pulled by an electric motor ranging from 650-1400 Watts. They are mostly manufactured in India and China, only a few other countries manufacture these vehicles. Battery-run rickshaws could be a low-emitter complementary transport for the low-income people, who suffer most from a lack of transport facility, if introduced in a systematic manner according to experts.

These rickshaws have a M.S(Mild Steel) tubular Chassis, consist of 3 wheels with a differential mechanism at rear wheels. The motor is brushless DC motor manufactured mostly in India and China. The electrical system used in Indian version is 48V and Bangladesh is 60V. The body design from most popular Chinese version is of very thin iron or aluminum sheets. Vehicles made in fiber are also popular because of their strength and durability, resulting in low maintenance, especially in India. Body design is varied from load carriers, passenger vehicles with no roof, to full body with windshield for drivers comfort It consist of a controller unit. They are sold on the basis of voltage supplied and current output, also the number of MOSFET (metal oxide field effect transistor) used. The battery used is mostly lead acid battery with life of 6–12 months [28]. These rickshaws do not emit smoke and thus, will not contribute to the increasing air pollution. The batteries which will be used for the functioning of these rickshaws can be effectively recycled. It involve less risk when compared to the other fuel operating vehicles. They can cause less accident as they are slower and lighter than an auto -rickshaw. There is a chance of explosion in the case of fuel operating vehicles. As they use electricity, they do not require fuel to operate the engines.

Fig 2.1: Electric Rickshaw (a) Side View (b) Motor and Battery parts.

2.1.1 Types of Electric Rickshaw

There are basically 2 types of electric rickshaw available .They are:

01. Load carrier: These are load carrying versions of these rickshaws differ in their upper body, load carrying capacity, motor power, controller and other structural aspects sometimes motor power is also increased in order to carry loads up to 500–1000 kg.

02. Passenger carrier: In these type of rickshaw, there is a passenger carrying capacity of 5-6 persons. The charging process of these batteries is to remove them from the rickshaw and charged independently from AC power source. Alternatively, batteries can be charged while the vehicle is parked, although this may limit daytime usage.

2.1.2 Battery Used In Electric Rickshaw

Battery is the main power source of electric rickshaw. Electric-rickshaw battery is gaining more and more popularity these days as it is designed keeping all the necessary points in mind that are related to users and their requirements. Each and every battery undergoes some specific test so as to confirm the uninterrupted services to users. Products are beautifully designed and tested up to the extent so as they excel the most as far as its performance is concerned. The quality products manufactured under this hoop uses latest technology and defines an unbeatable standard for its parallel companion. Depending on the types and the purposes, various types of battery is used. Among them, lead acid battery is popular as they have several advantages over other batteries. In a lead acid battery, the electrodes and grids are made from lead. Usually there is some other additive mixed in with the lead, like calcium to give it mechanical strength. The polarity of the plate is determined by the active material that is placed in physical contact with the grid. The active material is some formulation of lead oxides. Every battery manufacturer has its own proprietary formulation, usually optimized for one performance characteristic or another. The electrolyte is sulfuric acid. Hence the name “Lead-Acid”. The basic lead acid battery chemistry has been the workhorse of the automotive engine start and traction vehicle industries for a long, long time.

There are various types of lead acid battery available. They are:

- **Flooded Lead Acid Batteries**

  This is the traditional engine start and traction style battery (shown in Figure 2.2). The liquid electrolyte is free to move in the cell compartment. The user has access to the individual cells and can add distilled water as the battery dries out.

Fig 2.2: Flooded Lead Acid Battery [29].

- **Sealed lead acid battery (SLA)**

  The Figure 2.3 shows SLA which is a slight modification to the flooded style. In that case, even though the user does not have access to the cell compartments, the internal structure is still basically the same as a flooded battery. The only difference is that the manufacturer has ensured that a sufficient amount of acid is the battery to sustain the chemical reaction under normal use throughout the battery warranty period.

Fig 2.3: Sealed Lead Acid Battery. [30**]**

- **VRLA(valve regulated lead acid)**

  This stands for Valve Regulated Lead Acid battery (shown in Figure 2.4). This is also a sealed battery. The valve regulating mechanism allows for a safe escape of hydrogen and oxygen gasses during charging.

Fig 2.4: VRLA Battery. [31]

- **AGM (Absorbed Glass Matt) Sealed Lead Acid Battery**

The Absorbed Glass Matte construction allows the electrolyte to be suspended in close proximity with the plate's active material. In theory, this enhances both the discharge and recharge efficiency. Actually, the AGM batteries (shown in Figure 2.5) are a variant of Sealed VRLA batteries. This particular style has recently become very popular in many engine start and power sports applications.

Fig 2.5: AGM sealed lead acid battery. [32]

- **Gel Sealed Lead Acid Batteries**

  The gel cell is similar to the AGM style because the electrolyte is suspended, but different because technically the AGM battery is still considered to be a wet cell. The electrolyte in a gel cell has a silica additive that causes it to set up or stiffen, first like Jell-O, then after subsequent discharge/charge cycles more like peanut brittle. Micro cracks form in the gelled electrolyte that provide paths for the oxygen recombination reactions between the positive and negative plates. The recharge voltages on this type of cell are lower than the other styles of lead acid battery. This is probably the most sensitive cell in terms of adverse reactions to over-voltage charging. Gel Batteries are best used in very deep cycle application and may last a bit longer in hot weather applications. If the incorrect battery charger is used on a gel cell battery, poor performance and premature failure is certain.

- **Standby Lead Acid Batteries:**

  It is designed only for standby applications where they operate on a float (very low) load, maintaining Uninterrupted Power Supplies (UPS), Alarm Systems, Telecommunications and Network Systems. Standby batteries are generally of AGM variety [33].

Among them Sealed lead acid battery (Figure 2.6) is mostly used in electric rickshaw Bangladesh because of its several advantages.

Fig 2.6: Lead acid battery of an Electric Rickshaw.

2.2 Charging Stages of Lead Acid Battery

A completely discharged battery is comprised of two electrodes that have been transformed into lead sulfate and an electrolyte that is almost 100 percent water. To charge a discharged battery, a voltage greater than the battery voltage is applied to the battery terminals. During the course of charge cycle, the chemical reaction that occurred during the discharge is being reversed. Charging and thus the chemical reaction continues until the battery becomes 100 percent charged. The battery that is completely charged will once again have a negative electrode made of lead, a positive electrode made of lead dioxide, and an electrolyte that is made of sulfuric acid and water. When the battery is connected to the load, the chemical reaction between lead plate and sulfuric acid occurs. Then the discharge cycle starts. When the battery is not used, there is also a discharging mechanism occurs, that is call self-discharge process. During the charging and discharging process, battery changes its voltage like changing from one stage to another. If the battery charger cannot capable of sensing these voltages charges, the battery life will be in decreased.

In a three stage battery charger ,there is a three charging stages that is need to maintain for the safety of battery as well as to make the battery fully charged in a good way.

These stages are given below:

Stage 1: Constant Current Mode/Bulk Stage

The first stage in a three stage charge cycle is known as the constant current charge. In this stage, the battery charger will rapidly return the battery to an 80 to 90 percent state of charge. It accomplishes this by maintaining a constant relatively high current. The current is held constant against the rising internal resistance to charge current by raising the battery voltage. Consider Ohms Law where Voltage = I (current in Amps) x R (resistance in Ohms).A quick survey of this equation shows that if we want to maintain a constant current in a circuit with rising resistance, we must raise the voltage. This charge continues until the voltage output by the charger reaches a specific level. At that point, it switches to the absorption charge. This stage is shown in Figure 2.7.

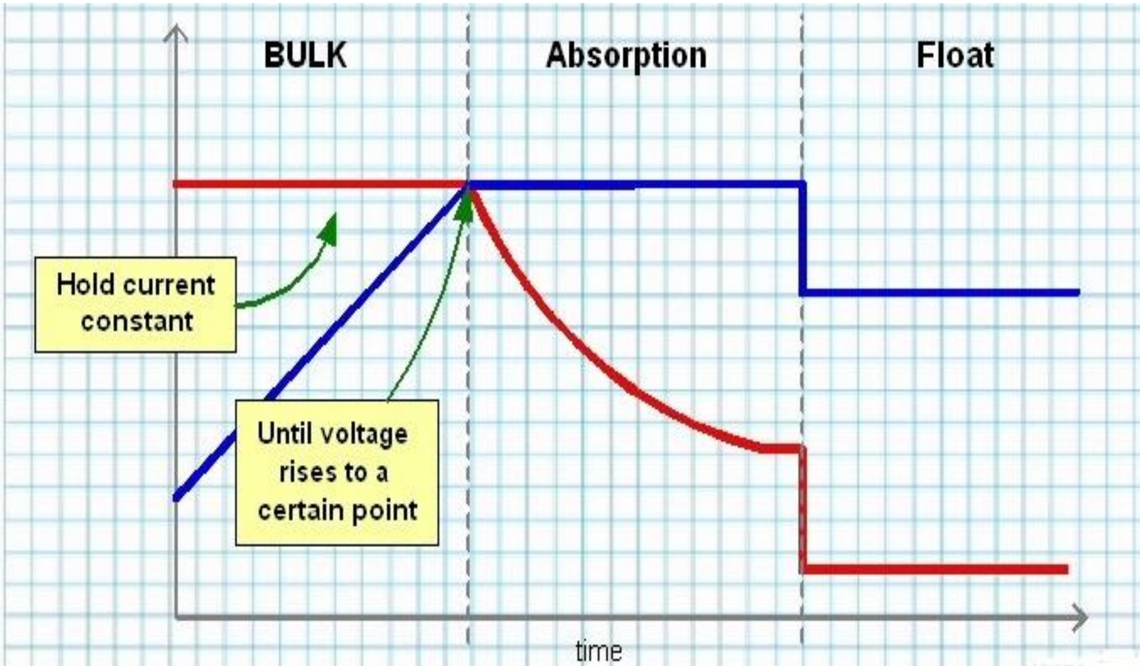


Fig 2.7: Bulk stage (Constant Current Mode) [34]

The Figure shows that in the constant current mode (CC mode), current remains constant until voltage rises to a certain point. In this stage, the voltage of the battery rises in a rapid way.

Stage 2: Constant Voltage Mode (CV)/Absorption Charge Stage

In this stage, the voltage applied to the battery by the charger is held at a constant level. As the charger holds this level, it is also monitoring the current being supplied. As the battery becomes increasing charged, its opposition or resistance to a charge current increases. This will cause the current flow to tail off. Consider Ohms Law once again where Voltage = I (current in amps) x R (resistance in ohms).If voltage is held constant and resistance increases, current must decrease. During this stage, the three stage charger monitors the falling current until a specified point is reached that indicates that the battery is about ninety eight percent charged. When this specified level of current is reached, the three stage battery charged will switch to the float charge stage. In Figure 2.8, it is shown.

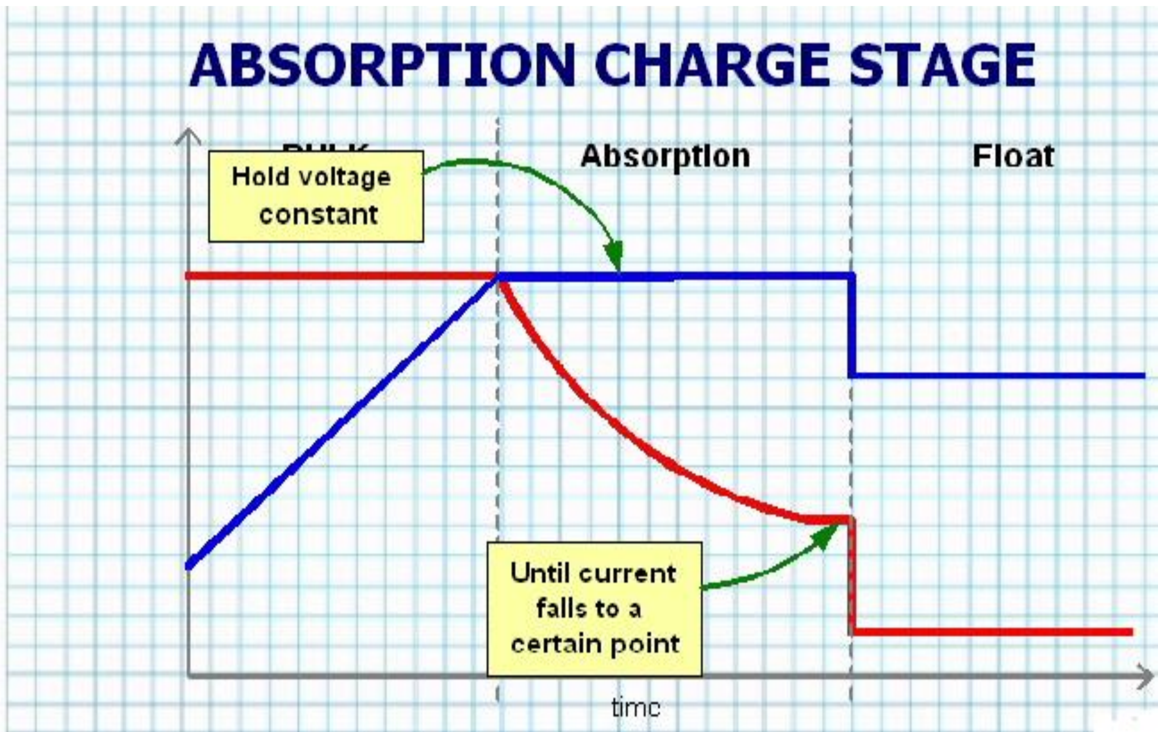


Fig 2.8: Constant Voltage Mode (CV)/Absorption Charge Stage [34].

The Figure shows that voltage will remain constant until current fails to a certain point. As battery started charging in the previous stage, in this stage the opposition of charge current increase and this will make the current decreases.

Stage 3: Float charge Mode

During the float charge, the voltage is dropped to a level lower than what was applied during the absorption charge. The float charge serves two purposes. First, it brings the battery from a 98 percent state of charge to a 100 percent state of charge. Second, it maintains the battery in a 100 percent state of charge condition. In the second stage, there are two things happens. It applies a voltage that is theoretically ideal to the type of battery being charged. The idea is that this voltage is low enough to keep the electrolyte from boiling off, yet high enough to counteract the phenomenon known as self-discharge. . The problem with this is that it does not account for the affect that temperature has on batteries, nor does it account for those small differences caused by battery age and construction.

And it is to actually monitor the state of charge and apply voltage when it's needed. Indeed, some of the smarter chargers use temperature sensors. Others monitor the voltage of the cells and send a short pulse of charge using a technique called and a pulse width modulation. This stage is shown in figure 2.9.

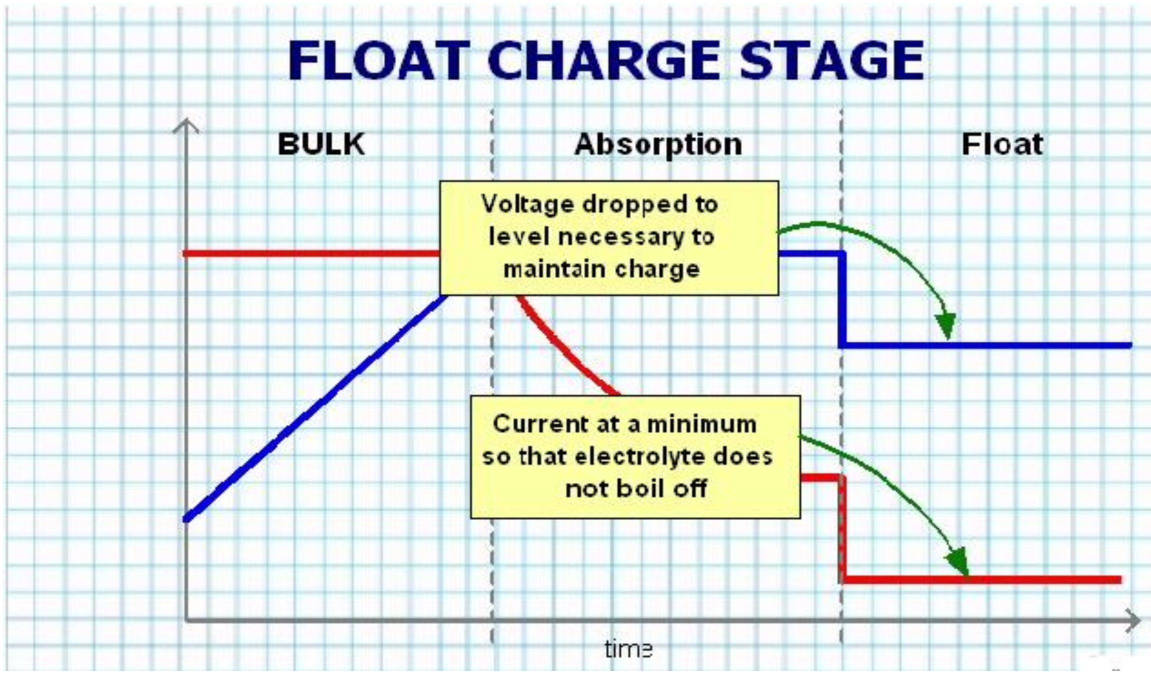


Fig 2.9: Float charge stage [34].

The Figure shows that a voltage drops to a certain level to maintain a specific charge. Current must be at a minimum level to avoid sulfation, acid stratification. These type of problems occurs if the battery voltages decreases below a certain level.

Recharging

If the battery voltage drops to 13.8V, the charger changes from any mode to Constant Current mode and restart charging. The charging cycle will go through Stage 1 to Stage3. The switch from Stage 1 to 2 occurs seamlessly and happens when the battery reaches the set voltage limit. The current begins to drop as the battery starts to saturate; full charge is reached when the current decreases to 3–5 percent of the Ah rating. A battery with high leakage may never attain this low saturation current, and a plateau timer takes over to end the charge.

The correct setting of the charge voltage limit is critical and ranges from 2.30V to 2.45V per cell. Setting the voltage threshold is a compromise and battery experts refer to this as "dancing on the head of a needle." On one hand, the battery wants to be fully charged to get maximum capacity and avoid sulfation on the negative plate; on the other hand, over-saturation by not switching to float charge causes grid corrosion on the positive plate. This also leads to gassing and water-loss.

In order to investigate the relationship between battery behavior and remaining lifetime for a lead-acid battery**,** some factors are needed to know. They are described below:

State of Charge (SOC)

State of charge (SOC) and depth of charge (DOC) are variables that can describe the battery charge. The main difference is that the SOC describes the percentage of remaining charge relative to the nominal capacity of battery while the depth of charge represents that relative to the actual capacity under a specific discharge current. These two variables can be achieved by calculating the charge consumed and the battery capacity:

$$SOC = \frac{Q_e}{C_{10}} \text{..............................} \text{ (i)}$$

$$DOC = 1 - \frac{Q_e}{C_1} \text{.................} \text{ (ii)}$$

Here, Qe is the charge consumed by the load.

C_{IO} is the nominal capacity (Ah).

C_I is the actual capacity under the discharge current I (Ah).

The nominal capacity is given by the manufacturer and represents the maximum amount of charge that can be stored in the battery.

Knowing SOC is very important in the charging process of lead acid batteries because it determines the value of instantaneous charging current to prevent the overcharging and gassing problems. Whereas the SOC is increased during the charging process and the battery is near from fully charging condition, the charging current must be decreased gradually to overcome the gassing and electrolyte losses and to increase the useful service life for the battery. [35]

Effect of Specific Gravity on the Battery State of Charge

Specific Gravity (SG) is a measurement of concentration of electrolyte solution. Specific Gravity represents the ratio of solution to the water density. Related to the state of charge (remain of full capacity) of a lead-acid battery. Whereas the battery is charging, the sulfuric acid will be produced and SG is increasing, whereas the opposite will happen during the discharge. For full charge capacity of a lead-acid battery, SG of electrolyte is in the range of 1.25 (kg/L) to 1.28 (kg/L) at27℃. Therefore the SG is considered as one of the methods to calculate the state of charge of lead-acid batteries.

Electromotive Force of a Lead-Acid Battery

The electromotive force or the open circuit voltage of a lead-acid battery cell can be obtained by using the Nernst's equation. Because the concentration or specific gravity of the electrolyte solution varies through the charging and discharging of the lead-acid battery, the relative activity of H_2SO_4will also be changed in the Nernst's equation. Due to this, the open circuit voltage of a lead-acid battery is changed proportionally with respect to temperature and specific gravity of electrolyte solution. Therefore, by knowing the open circuit voltage of lead acid battery and temperature, specific gravity of electrolyte solution can be determined and thus determine the state of charge.

2.3 Charging Techniques of Lead Acid Battery

Charging a lead acid battery is a matter of replenishing the depleted supply of energy that the battery had lost during use. The traditional charging techniques such as Constant Voltage (CV), Constant Current (CC), the two-step (CCCV), and the pulse method are mentioned. Besides, the negative pulse discharge method and the superimposed pulse frequency technique are explained thoroughly. The intermittent technique is also included from two different sources. Each of these approaches has its advantages and disadvantages that need to be compared and weighed to see which one would be the most practical and realistic to fit with our requirements. Charging techniques may vary depending on the battery types. Focusing one the particular perspective, various techniques have been introduced.

1. Constant Current/Voltage Method

Constant Current, Constant Voltage, and Two Step or Constant Current-Constant Voltage, are traditional charging techniques for lead acid batteries.

(a)Constant Current method

This charging method depends on constant currents [36]. However, small charging current will prolong the charging time in addition to overcharging that will affect the life of the battery. This technique does not considerably change in magnitude despite the battery's voltage or temperature [37].Because of this problem, this technique is not suggested. It may damage the battery.

(b) Constant Voltage method

A constant value of voltage is specified for this method. This voltage depends on the manufacturer's specifications. When the battery's voltage reaches the default, the charging current decreases [36]. The float current is sufficient to overcome self-discharge, for this reason some people call this method float charging [38]. However, an excess float current would cause overcharge therefore grid corrosion will occur which affects the behavior and lifetime of the battery. The charger should be combined with temperature sensors in the battery to avoid overcharge or thermal runaway.

(c) Two Step Method

This method is combination of constant voltage and constant current. The current is often determined by the power limitations [39]. This technique is divided in two stages of charging. In the first stage, the charger provides constant charging current until the battery's voltage reaches a preset voltage [36]. In the second stage, the current decreases until the battery is fully charged [37]. An important parameter in this method is the voltage regulation. In this method, by checking the output voltage of the battery, the charger decides what type of charging is needed. This method is very much helpful but sometimes it takes time to give the signals to the charger and it take time to response for the charger about which type of charging it is going to provide.

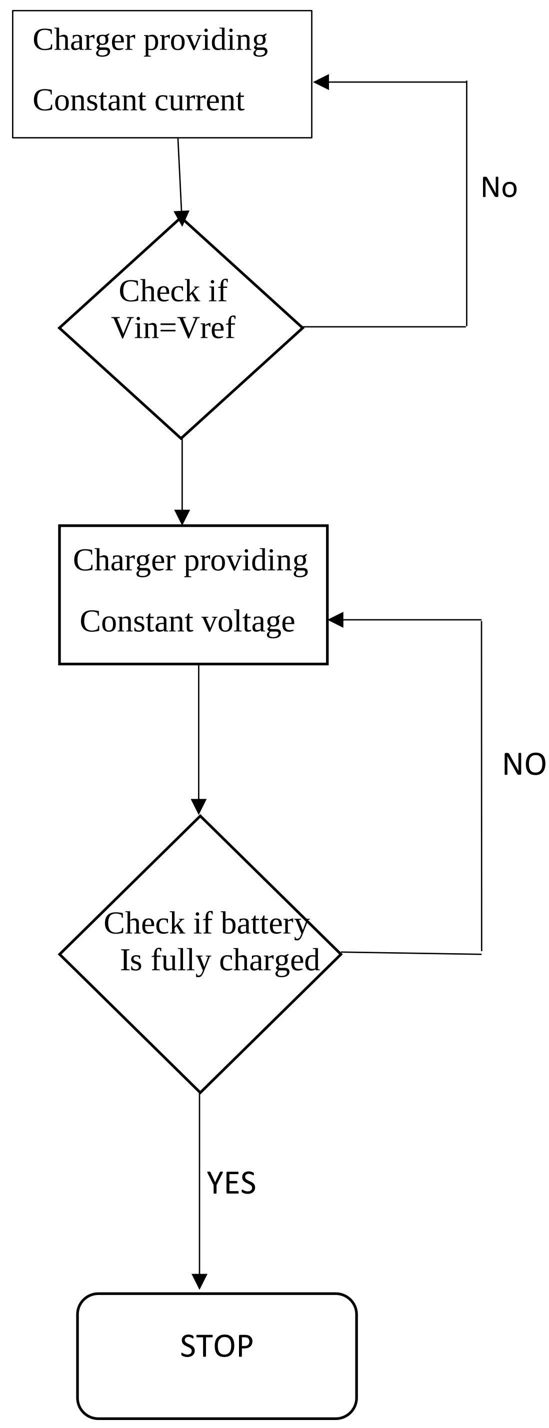


Fig. 2.10: Chart of the Two-Step Method.

The Figure 2.10 shows that at first charger is providing the constant current to the battery. Then it will check if the battery voltage have reached a certain level or not. If this criteria fulfilled, then it will provide constant voltage to the charger. After that, charger will check whether the battery get full charge or not. If the battery gets full charge, then the charging process stops, if not charger will provide constant voltage to the battery until the battery becomes fully charged.

2. Pulse Method

This method applies a periodically pulsed current to the battery [36]. It includes a pulse charge followed by a short deep discharge and finally a waiting period. These three steps are repeated until the battery is fully charged. The Figure 2.11 shows the circuit of the pulse charging method. However, the major disadvantage of this method is the efficiency in the circuit.

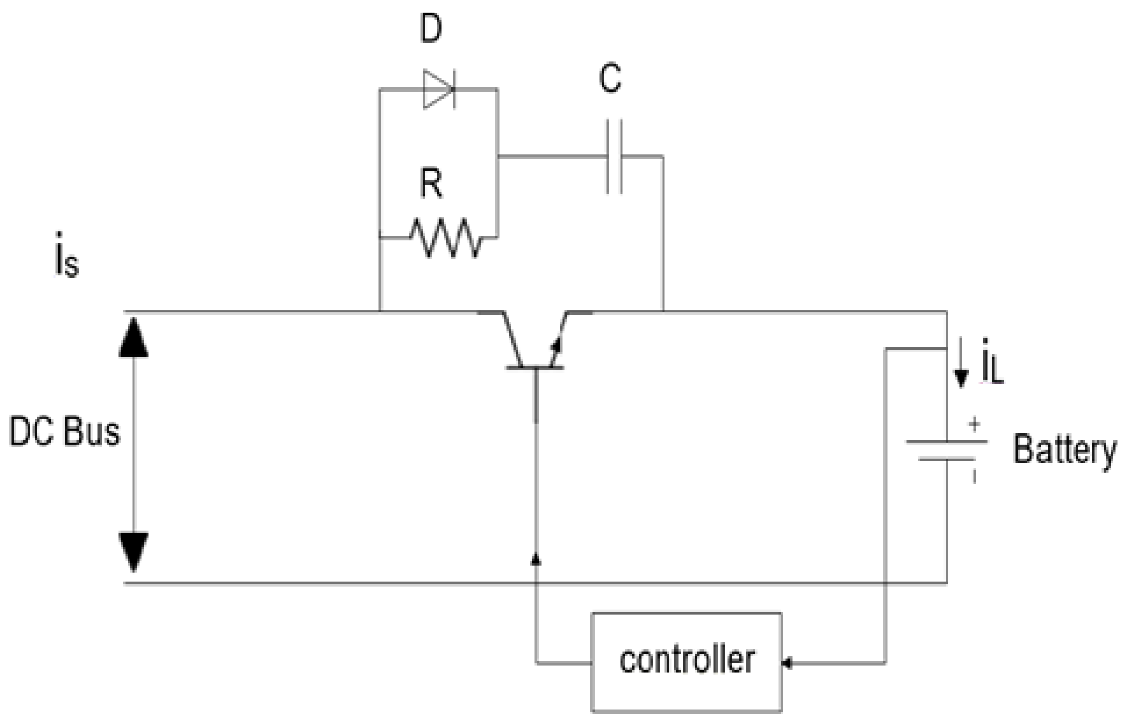


Fig. 2.11: Pulse charging circuit**.**

The new pulse method approach includes three modes. The first mode is the active charge mode. In this mode, triangular current with high dc component is applied. The second is the active discharge mode, in which depolarization triangular current is applied to pull away electrolytes from the plates. Finally, the third is the inactive rest mode. This mode is used to position the ions at a suitable distance from the plates.

The circuit of this technique includes MOSFET, capacitors, diodes, and switches. This circuit works in forward and reverse mode. In the forward it acts as a buck converter while in the reverse it acts as boost converter. This allows a bidirectional power conversion between the power source and the battery. The circuit is shown in Figure 2.12

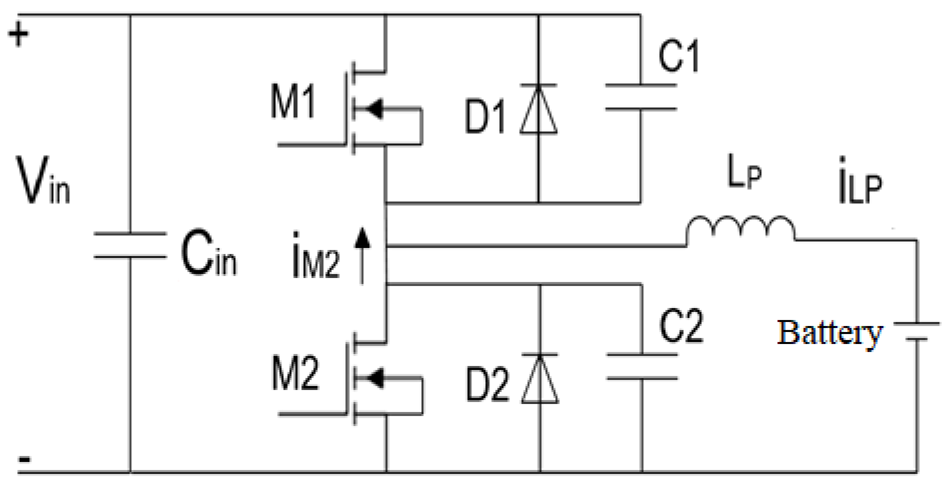


Fig. 2.12: Fast charging pulse method.

3. Negative Pulse Discharge Method:

One of the major targets while designing a charger for any type of battery is the charging speed. The charging speed, in other words the charging time, affects the life cycle of the battery especially the lead acid. From this perspective, the negative pulse discharge method showed up [39].

To increase any battery's charge rate, the charge current must be increased. In this method, when a negative pulse is added for discharge, most of the charge current is made for the charging reaction. The discharge participates in stirring the electrolyte and alleviating the polarization concentration. Then, depolarization at this stage could be improved in a way to provide the battery, while charging, with a larger charging current.

As mentioned previously, the charge current and the charge rate are proportional. However, there are certain limits for the acceptable charge current of each battery. For this reason, two important parameters of this technique must be determined. The needed discharge time and capacity are the parameters that can improve the acceptable charge current. The release capacity *C* is:

$$C = \frac{i}{kLOG(KId)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

K and *k* are two constants with values 15 and 10, respectively, *Id* is the discharge current, and *I* the rated current on the battery's labeling.

The needed discharge time is the ratio of the capacity *C* and the discharge current *Id*.

$$t = C/Id \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

To test how effective this method is, some experiments were made [40]. The results came to give specific values of the two essentials parameters. The amplitude of the negative pulse should be 85 to 115% of the battery's capacity. In addition, the time taken for discharge should be between 100- 600ms.The negative pulse discharge technique has several privileges. One of them is that the parameters of such method could be used for different lead acid batteries' capacities.

4. Superimposed Pulse Frequency Method:

One of the main concerns while designing any battery charger is the battery's lifetime. Sulfation is the direct cause of shortening the life of lead acid batteries. This phenomenon occurs when sulfate sticks on the electrode plates thus affecting the area used to complete the battery's chemical reaction. From this perspective, a recent technique called superimposed pulse frequency (SPF) was introduced [41]. The SPF circuit is added to any conventional charger and used on batteries having sulphation. A DC/DC converter creates the superimposed pulse frequency, which in its turn generate a mechanical resonance at the sulfated plates. The resonance causes vibration thus the pore attached to this sulfated plate is removed. After this process, a simple CCCV charger might be used.

In their research [41], the charger was composed of two converters, a main one and an auxiliary. The main converter takes the role of a traditional charger by controlling the current level and dc voltage. On the other hand, to create the SPF the auxiliary converter was utilized. Its output voltage is added to the dc voltage at the output of the main converter, by this the charge capacity increased and the battery's lifetime is extended.

To test whether or not this method is functioning correcting an experiment was made [41]. SPF was performed five times on a lead acid battery. Results came to prove that every cell of the battery's pack has a higher V/cell as the number of SPF increases. In addition, the testing proved that the internal impedance of the battery inversely responds to the increase in the number of SPF. At the end, it has been proved that the performance of the battery is improved using the superimposed pulse frequency technique (shown in Figure 2.13). In addition, the battery's lifetime is extended to almost an additional year after sulfation. Furthermore, the efficiency is improved with this method.

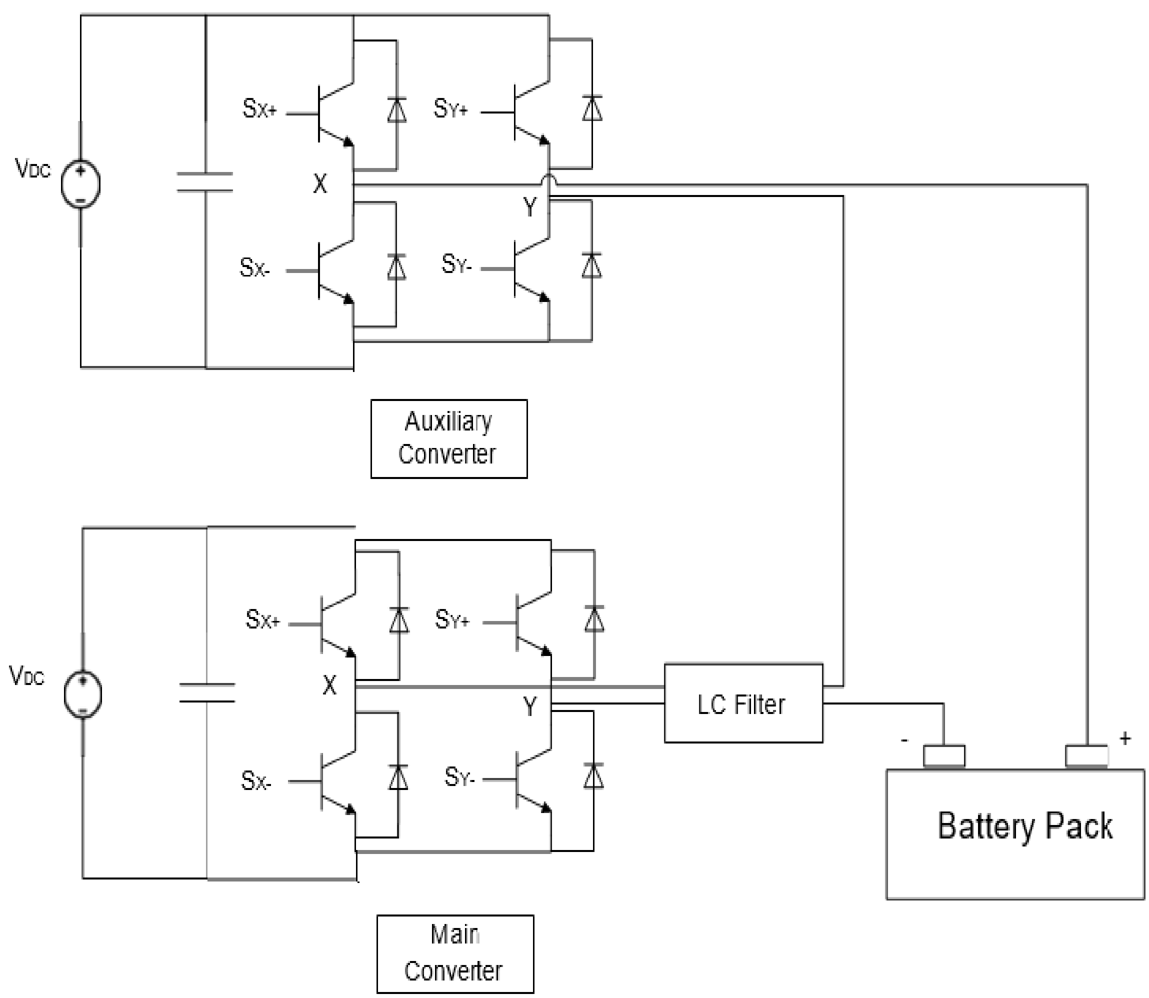


Fig 2.13: Multilevel Battery charger.

5. Intermittent Charging Method (IC Method)

Positive grid corrosion is another effect that might shorten the lifetime of any battery. Nevertheless, the charging technique affects the rate of this grid corrosion and thus affects the battery's lifetime. Intermittent charging method (IC) has been proven to be the technique that reduces grid corrosion thus extending the lifetime. In addition, it reduces overcharging which is harmful to the battery.

In IC technique, the battery is charged intermittently, in a short period of time, to its full charge capacity and then it is kept open circuited [38]. The charging is repeated whenever the battery's voltage drops below a referenced value. The aim of this technique is to maintain the electrodes fully charged whilst minimizing the positive grid corrosion [42]. When the battery is kept open circuited, it is protected from overcharging thus the battery's life is extended. To study whether or not IC extends the operating life of a lead acid battery a comparative experiment was made [36]. The compare was between the intermittent charge method and the conventional technique, constant voltage. The life of the battery was monitored with respect to its capacity using both charging methods at 55°C.

This technique has several advantages on the battery. To begin with, at float voltage, the plates are totally polarized during the period when SOC rises from 95 to 100%. Furthermore, despite the temperature full recharge takes place. Finally, thermal runaway cannot occur during the short period of this method [43]. However, the point of weakness in this technique is the sensitivity of choosing the right parameters. The parameters include the voltage threshold and the charging regime. In a similar manner, one drawback of the IC technique is the risk of undercharge.

2.4 Guidelines for Charging Lead Acid Batteries

- Charge in a well-ventilated area. Hydrogen gas generated during charging is explosive. Choose the appropriate charge program for flooded, gel and AGM batteries. Check manufacturer's specifications on recommended voltage thresholds.
- Recharge lead acid batteries after each use to prevent sulphation. Do not store on low charge.

- The plates of flooded batteries must always be fully submerged in electrolyte. Fill the battery with distilled or de-ionized water to cover the plates if low. Never add electrolyte.
- Fill water level to designated level after charging. Overfilling when the battery is on low charge can cause acid spillage during charging.
- The formation of gas bubbles in a flooded lead acid indicates that the battery is reaching full state-of-charge. (Hydrogen appears on negative plate and oxygen on positive plate).
- Lower the float charge voltage if the ambient temperature is higher than 29°C (85°F).
- Do not allow a lead acid to freeze. An empty battery freezes sooner than one that is fully charged. Never charge a frozen battery.
- Avoid charging at temperatures above 49°C (120°F) [44].

CHAPTER 3
BATTERY CHARGER OF ELECTRIC RICKSHAW

For charging a battery properly, a good charger is needed. Otherwise the life-cycle of battery may be decreased and quality of battery should also be reduced. So a good charger is required which have all types of protection. To find out the quality of battery charger which are available in Bangladesh, some experiment was taken place in LAB. The quality of those charger are not so well. In this chapter the result of quality test of different types of battery is shown with necessary figure and data.

3.1 Battery Charger

A battery charger is a device used to put energy into a cell or (rechargeable) battery by forcing an electric current through it. Lead-acid battery chargers typically have two tasks to accomplish. The first is to restore capacity, often as quickly as practical. The second is to maintain capacity by compensating for self-discharge. In both instances optimum operation requires accurate sensing of battery voltage. When a typical lead-acid cell is charged, lead sulphate is converted to lead on the battery's negative plate and lead dioxide on the positive plate. Over-charge reactions begin when the majority of lead sulphate has been converted, typically resulting in the generation of hydrogen and oxygen gas. At moderate charge rates, most of the hydrogen and oxygen will recombine in sealed batteries. In unsealed batteries however, dehydration will occur.

The onset of over-charge can be detected by monitoring battery voltage. The figure on the next page shows battery voltage verses percent of previous discharge capacity returned at various charge rates. Over charge reactions are indicated by the sharp rise in cell voltage. The point at which over-charge reactions begin is dependent on charge rate, and as charge rate is increased, the percentage of returned capacity at the onset of over-charge diminishes. For over- charge to coincide with 100% return of capacity, the charge rate must typically be less than C/100 (1/100 amps of its amp- hour capacity). At high charge rates, controlled over-charging is typically as quickly as possible.

To maintain capacity on a fully charged battery, a constant voltage is applied. The voltage must be high enough to compensate for self-discharge, yet not too high as to cause excessive over-charging.

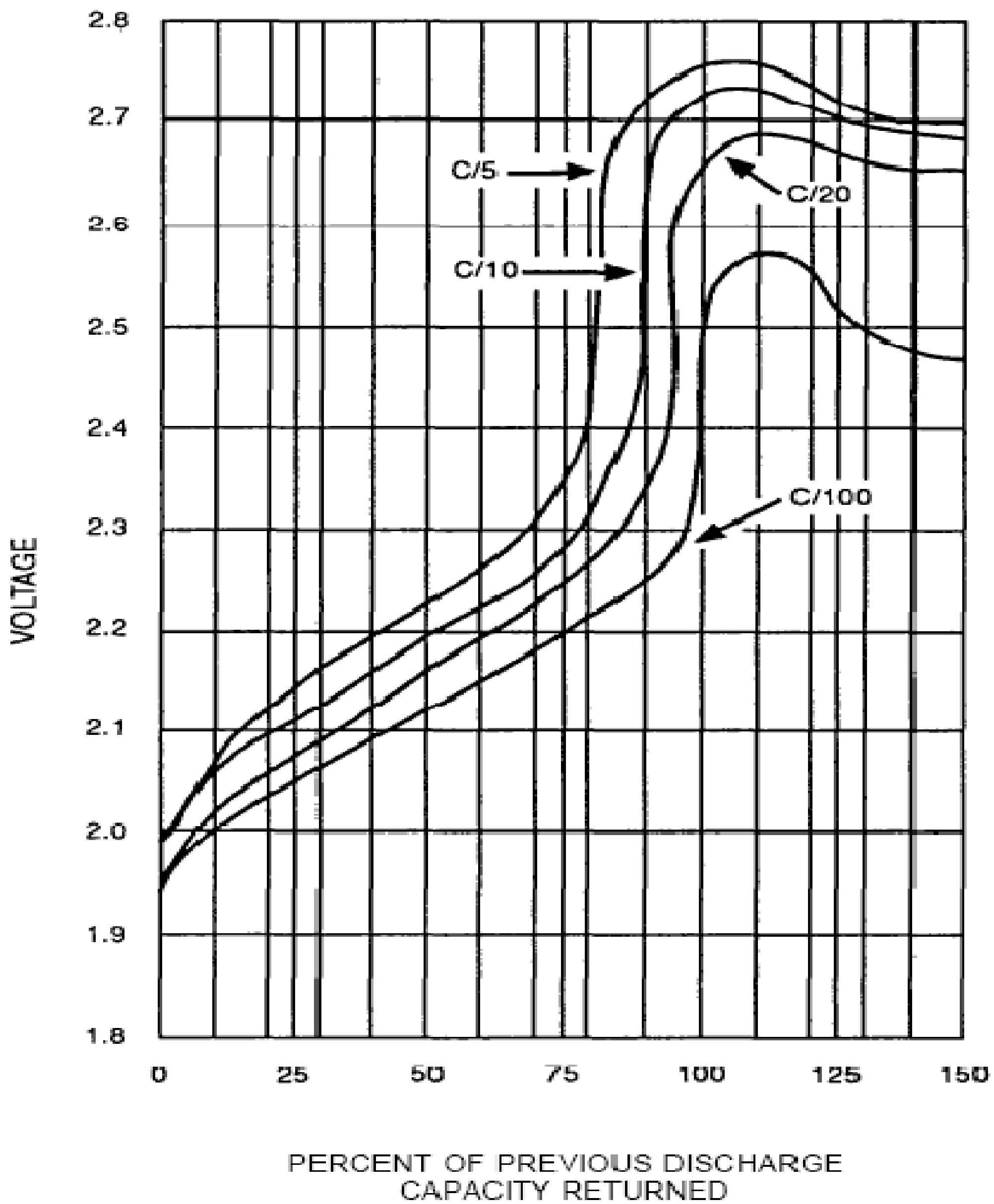


Fig 3.1: Over-charge reactions begin earlier (indicated by the sharp rise in cell voltage) when charge rate is increased. [45]

Figure 3.1 shows a graph between battery voltages verses percent of previous discharge capacity returned at various charge rates. Over charge reactions are indicated by the sharp rise in cell voltage. The point at which over-charge reactions begin is dependent on charge rate, and as charge rate is increased, the percentage of returned capacity at the onset of over-charge diminishes. For overcharge to coincide with 100% return of capacity, the charge rate must typically be less than C/100 (1/100 amps of its amp- hour capacity). At high charge rates, controlled over-charging is typically as quickly as possible.

3.2 Tests in the Laboratory

In Bangladesh, different types of charge controllers are available for electric rickshaws. Among them, the best two types of charge controllers have been collected and tested to find out the quality and various protection systems of those charge controllers. During the investigation, two main things have been focused:

(1) Measure the efficiency of charge controller and

(2) Check various protection systems of charge controller.

To find out the efficiency of charge controller, on load test and no load tests have been done. Various protection systems such as reverse pole protection, high voltage disconnect protection were examined. A battery charger of electric rickshaw has shown in fig. 3.2.

Sample-01:

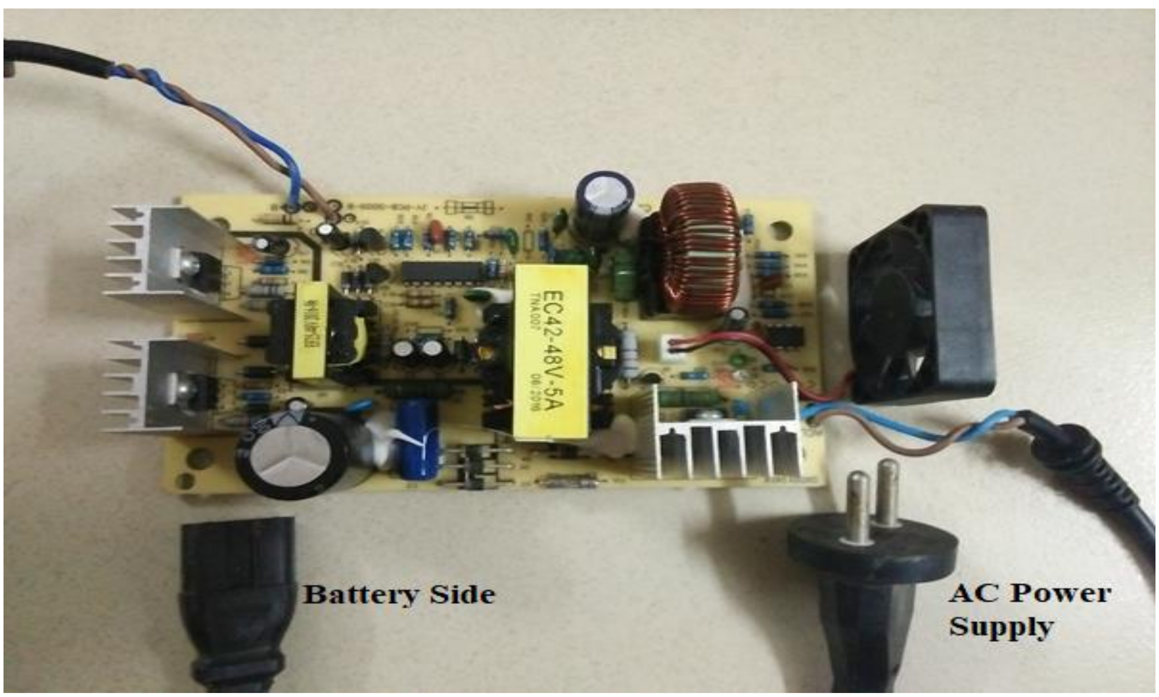


Fig 3.2: Charger controller of an Electric Rickshaw. (Sample -01)

The charge controller shown above has a combination of high frequency transformer, a step-up transformer, 400V 150μF capacitor, 80V 33μF capacitor, voltage controller, several microcontroller and other electrical components to make the circuit. To charge the batteries, one side of charge controller will be connected with Ac power supply and other side will be connected with the batteries of an electric rickshaw.

Another charger that we examined to find out its quality and protection system is shown in Fig. 3.3.

Sample-02

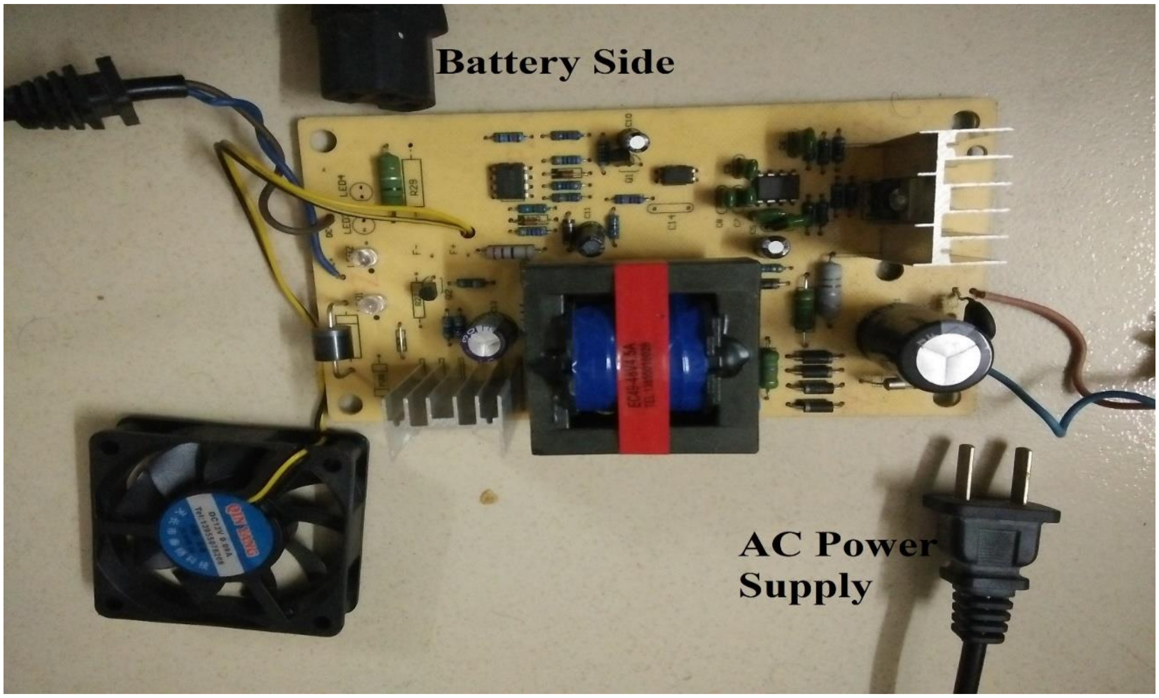


Fig 3.3: Charger controller of an Electric Rickshaw (sample-02)

The charge controller shown above has a circuitry of a step-down transformer, various capacitor, heat sinker and various microcontroller.

3.2.1 Equipment Used in Test

- Power supply
- Charge controller
- Wattmeter
- Voltmeter
- Ammeter
- Clamper
- Tap-changing transformer

3.2.2 Test at No-Load Condition

For calculating the no load loss, output voltage has been measured by opening two terminals.

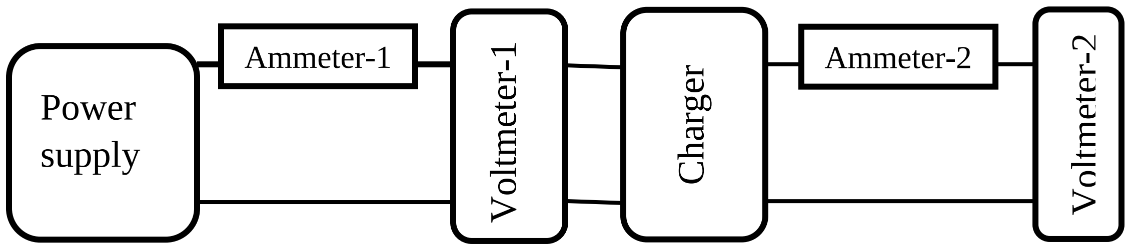


Fig 3.4: Diagram for no load test of charge controller.

Here, a wattmeter has been used for measuring the input power. Since input current is AC so it can't be possible to measure power just by multiplying current and voltage, because power factor plays an important role. The input current was negligible at no load condition. Since the charger was no loaded so there is a little current in output. The output voltage at no load was measured by replacing a voltmeter at output side. In this experiment, we use tap-changing transformer for providing different input voltage to the battery charger.

Fig 3.5: Arrangement of equipment for no-load test.

3.2.3 Result at No Load Test

(a) For Sample-1:

No-load output voltage= 56V.

Table I: Test of Charger Sample-1 at no load

V(ac) **In volt**	**P(in)** **In watt**	**V(dc)** **In volt**
220.4	2	57.01
221.2	3	58.07

(b) For Sample-2:

No-load output voltage= 58V

Table II: Test of Charger Sample-2 at no load

V(ac) **In volt**	**P(in)** **In watt**	**V(dc)** **In volt**
220.7	4	58.97
221.5	5	58.95

Fig 3.6: Charger test in Laboratory.

3.2.4 Test at Loaded Condition

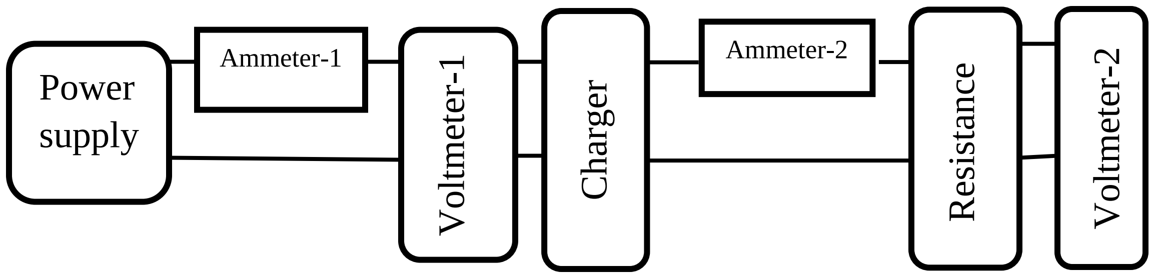


Fig 3.7: Diagram for different loads test of charger.

It is as same as before, the only difference is that, in previous part that was measured for no-load condition, but in this case same thing have been measured for various load. Then efficiency was calculated. The maximum current that can pass through these charger was also measured. At first we connected a load with the charger and then gradually decreased the load until the charger was cut off. In this way we measure the maximum current that can tolerate the battery. The Figure 3.7 & 3.8 show the arrangement of equipment in Lab test.

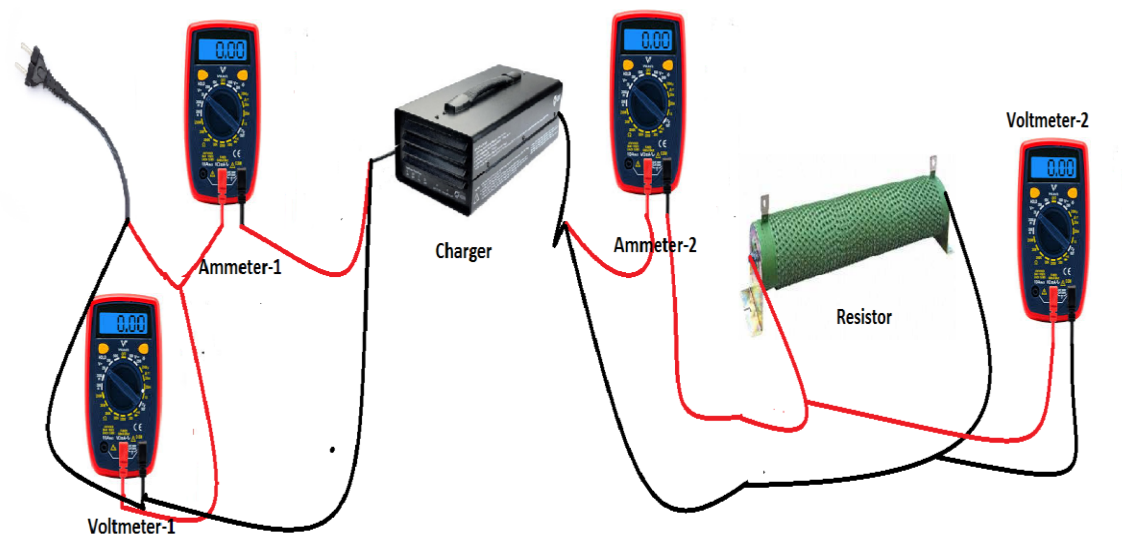


Fig 3.8: Arrangement of equipment for different-load test.

3.2.5 Result at Loaded Test

(a) Sample-1 Charger:

Table III: Efficiency of Charger (Sample-1) at various load

Resistance In ohm	**V(dc) In volt**	**I(dc) In amp**	**P(in) In watt**	**Efficiency**
6	33.367	5.26	220	79.77%
	33.52	5.31	219	81.27%
5	29.62	5.65	207	80.84%
	29.601	5.65	207	80.00%
4	25.417	6.01	195	78.33%
	25.503	6.04	196	78.59%

(b) Sample-2 charger:

Table IV: Efficiency of Charger (Sample-2) at various load

Resistance In ohm	V(dc) In volt	I(dc) In amp	P(in) In watt	Efficiency
6	30.744	4.89	184	81.7%
	30.747	4.89	183	82.1%
5	25.713	4.86	157	79.59%
	25.714	4.83	158	78.60%
4	20.513	4.85	130	76.48%
	20.491	4.85	131	75.85%
3	15.356	4.86	104	71.75%
	15.352	4.86	103	73.2%
2	10.208	4.92	77	65.22%
	10.205	4.94	77	65.4%
1	5.1358	4.93	51	49.64%
	5.1355	4.93	50	50.6%

Efficiency has been tested in different resistances such as in 6ohm, 5ohm, 4ohm in sample-1 charger (shown in Table III). When the resistance below 4ohm is applied, charger creates noise and its protection system fails**.** When this test is done for sample 2 charger, it is found that maximum 4.93 amp current can flow through it. After that, the protection system of charger fails.

Both of the charger was rated to supply 7 ampere current, but practically none of this provide 7 ampere current, which is one of the main disadvantages of these battery chargers.

3.2.6 Reverse Polarity Protection

Reverse polarity protection means protect the circuit from flowing the power in reverse direction. Reverse polarity is one of the most important feature for any charger. Without this protection charger can draw current from load side when the charger is unplug from power supply.

Reverse power polarity is tested by arranging the equipment in such a way (shown in Figure 3.9) that a voltage is supplied into the secondary side of charger. In the experiment, 48 V dc supply is connected with the secondary side of the charger as below.

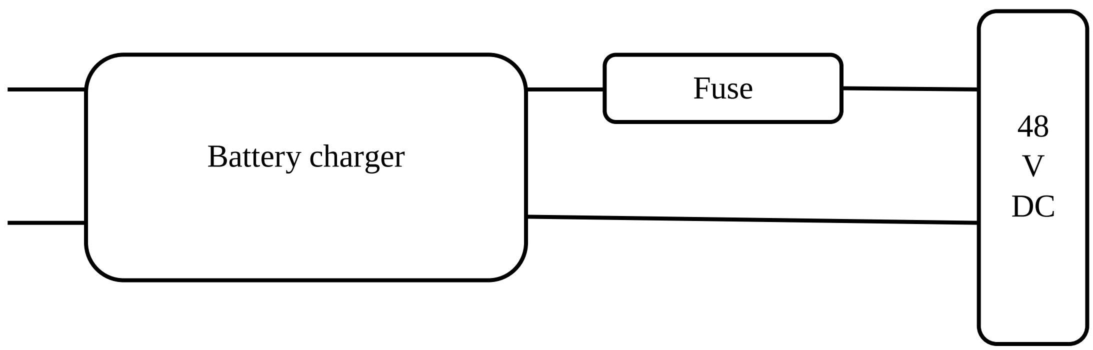


Fig 3.9: Arrangement of equipment for reverse polarity protection

A 48 V dc supply has been given in output side of charger through a fuse without any input power. When testing this experiment the fuse has been burnt out. From these it has been checked that there are no reverse polarity protection in available charger in market.

3.3 Characteristics of a Charge Controller

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. There are some characteristics that must be fulfilled by the charge controller. They are given below:

1. Voltage selection

A charge controller must be compatible with the system voltage. The standard configurations are 24, and 48 volts. If the batteries are 24 volts, a charge controller that is rated at 24 volts is needed. Some controllers are voltage specific, meaning that the voltage cannot be changed or substituted. Other more sophisticated controllers include a voltage auto-detect feature, which allows it to be used with different voltage settings.

2. Current capacity

A charge controller must have a capability to handle the maximum output current of the battery. The maximum possible current that a battery can generate is the “short circuit current,” It’s recommended to include a safety factor for isolated events as well. This will increase the short circuit current value.

3. Blocking Reverse Current

In most controllers, charge current passes through a semiconductor (a transistor) which acts like a valve to control the current. It is called a "semiconductor" because it passes current only in one direction. It prevents reverse current without any extra effort or cost. A simple diode can be used to block reverse current. A diode used for this purpose is called a "blocking diode. However a diode does not always protect a battery charger when the battery is inserted incorrectly. Sometimes when the battery is inserted backwards it can cause a large amount of current flow through the charging circuitry, possibly destroying both the battery and charger. Many battery-charger designs rely on mechanical means that only allow a battery or power plug to be inserted one way. Even the charger cord is mechanically shaped to allow insertion in one way.

4. High Voltage Disconnect (HVD)

When a battery reaches full charge, it can no longer store incoming energy. If energy continues to be applied at the full rate, the battery voltage gets too high. Water separates into hydrogen and oxygen and bubbles out rapidly. (It looks like it's boiling so we sometimes call it that, although it's not actually hot.) There is excessive loss of water, and a chance that the gasses can ignite and cause a small explosion. The battery will also degrade rapidly and may possibly overheat. Excessive voltage can also stress the loads.

Preventing overcharge is simply a matter of reducing the flow of energy to the battery when the battery reaches a specific voltage. When the voltage drops much below than its rated value, the controller again allows the maximum possible charge.. Some controllers regulate the flow of energy to the battery by switching the current fully on or fully off. This is called "on/off control." Others reduce the current gradually. This is called "pulse width modulation" (PWM). A PWM controller holds the voltage more constant. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then, it will drop the voltage lower, to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress. The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly.

5. Low Voltage Disconnect (LVD)

The deep-cycle batteries used in renewable energy systems are designed to be discharged by about 80 percent. If they are discharged 100 percent, they are immediately damaged. Every time this happens, both the capacity and the life of the battery will be reduced by a small amount. If the battery sits in this over discharged state for days or weeks at a time, it can be ruined quickly. The only way to prevent over discharge when all else fails, is to disconnect loads and then to reconnect them only when the voltage has recovered due to some substantial charging. When over discharge is approaching, a 12 volt battery drops below 11 volts (a 24 V battery drops below 22 V).A low voltage disconnect circuit will disconnect loads at that set point. It will reconnect the loads only when the battery voltage has substantially recovered due to the accumulation of some charge. A typical LVD reset point is 13 volts (26 V on a 24 V system).All modern dc power inverters (/power-inverters) have LVD built in. The inverter will turn off to protect itself and loads as well as battery. Normally, an inverter is connected directly to the batteries, not through the charge controller. The determination of set points depends on the anticipated patterns of usage, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. Some controllers have adjustable set points, while others do not.

6. Over Temperature Protection:

It is needed in case the battery temperature is high enough to damage the battery. Air-flow through a charger is essential to keep the electronic components cool.

7. Power Factor Correction (PFC):

It improves Charger Performance by reducing the wasting of electricity. This means that lesser amperage is drawn by equipment as compared to non-PFC ones. This also ensures that heating of PFC chargers is less. As the operating temperature is lower, battery charger performance increases. It also Decreased Operational Costs. As the equipment draws less power, the electricity bill is lesser. Also, due to lower operating temperature, equipment maintenance charges reduce drastically. The cost of installing Power Factor Correction unit is recovered quickly (typically within 2-3 years) due to fall in other costs. And after that, it’s win-win situation all the way.

CHAPTER 4

SYSTEM DESIGN

Various types of charger topologies have been discussed in earlier chapter. In this chapter a new charging topology has been introduced. A micro-controller based charger topology is presented here with an elaborate discussion of its working principle. In this chapter firstly proposed circuit with schematic diagram and flow chart is given. Then main two parts of this proposed circuit are controller part and rectification part has also discussed separately. The devices that are used in this system have been explored with their working principle along with corresponding figure. In rectification part, the working principle of this circuit in negative and positive half cycle is elaborated. In controller part, a tap changing transformer is used which had not been used before. So output current can be easily controlled by changing the tap of transformer. Various types of sensor like Temperature sensor, Voltage sensor, and Current sensor are used in this proposed system. So it is necessary to describe the procedure of these element and how they work in this model. Various types of protection is given which is necessary for an ideal charger. Short circuit protection, Reverse polarity protection, over temperature protection, over voltage protection is given for safety purpose of charge controller of lead acid battery.

4.1 Proposed system

The basic diagram of a battery charger is consist of rectifier circuit and controller circuit. The rectifier circuit convert the alternative current into direct current. The main criteria of a rectifier circuit is that the output current should be pure DC and the input current should be pure sinusoidal. The controller circuit control the output current and voltage which consisting of current sensing element, voltage sensing element and other sensing element for protection of charger. So if we see the basic block diagram of the charger it may be like as Fig 4.1.

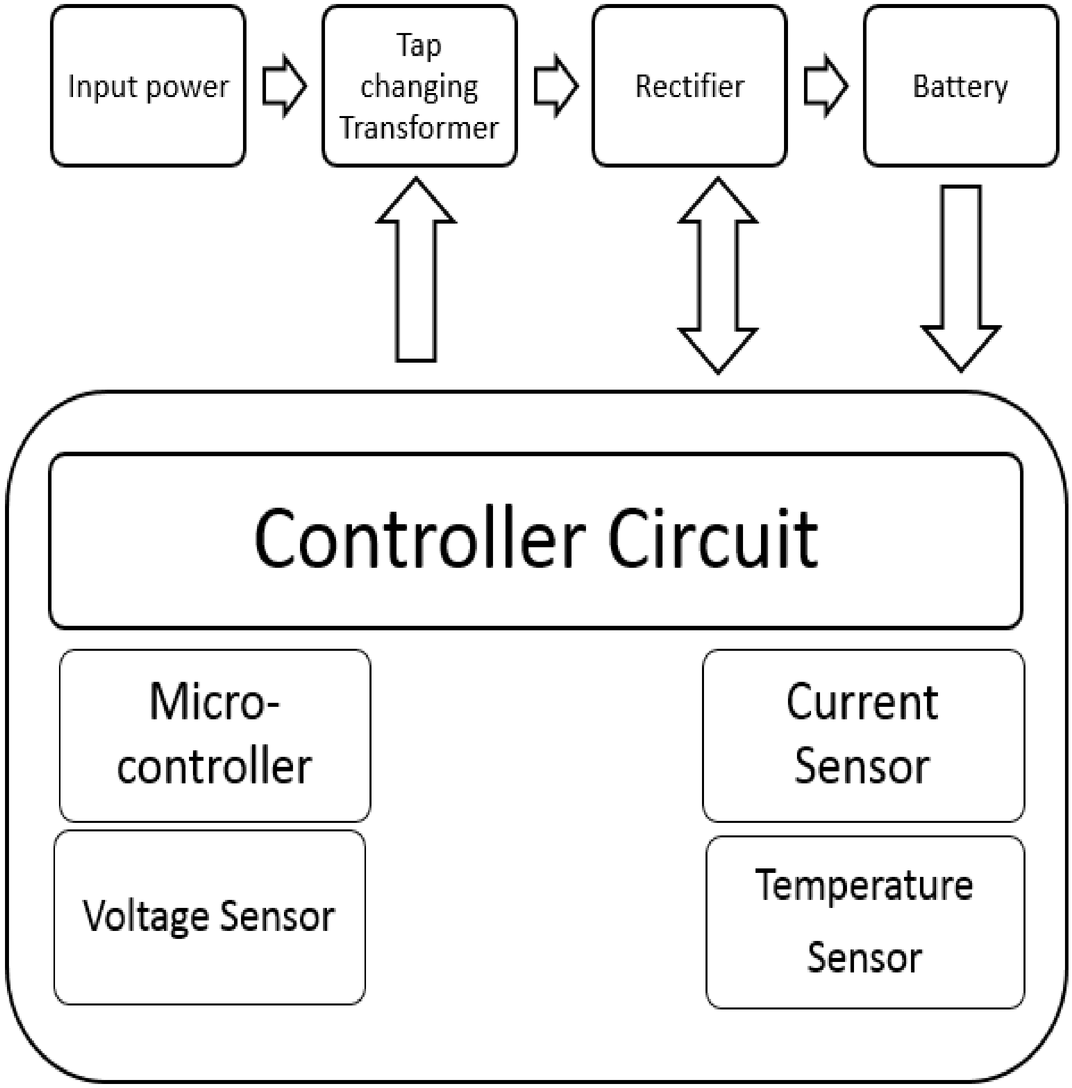


Fig 4.1: Block diagram of proposed circuit

The above figure is the basic diagram of proposed circuit which shows the major equipment of system. Input power is 220 V ac supply which is available in plug in our residential. Then this power is connected with tap-changing transformer. After transformed into lower voltage it is rectified. Various types of sensor elements are needed for safety purposes of charger.

Full structure of the circuit is shown below:

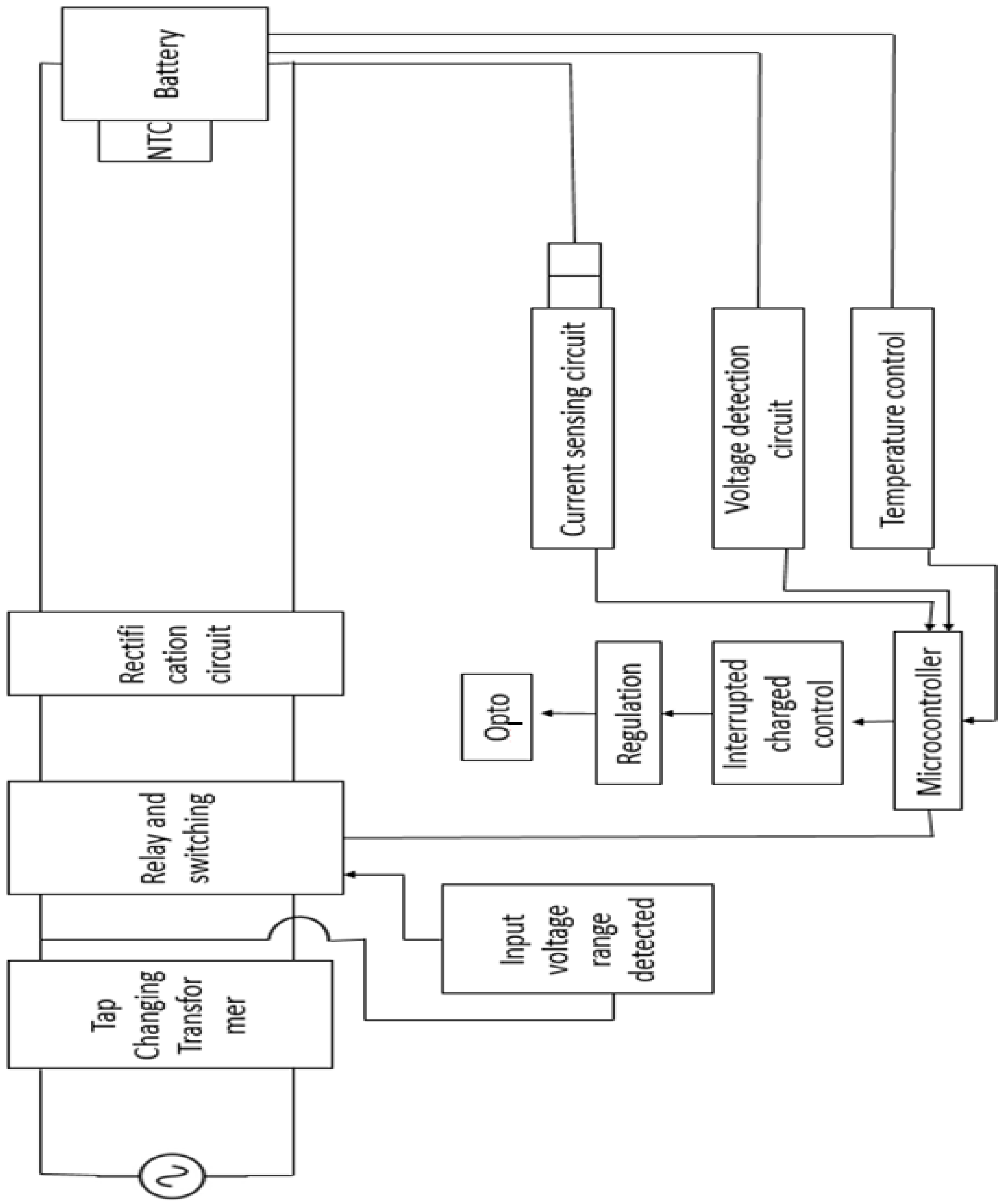


Fig 4.2: Full structure of proposed circuit

Fig 4.2 is the full structure of proposed system that show how every elements is connected in this system. The opto is LED which indicates the charging state of battery charger.

4.1.1 Proposed full circuit model

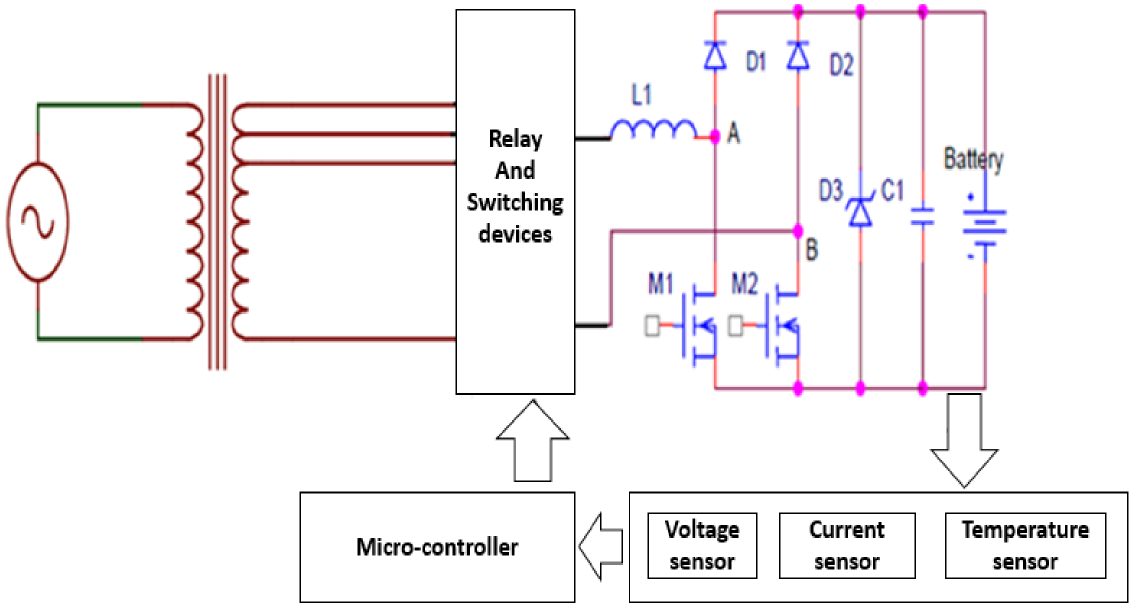


Fig 4.3: Schematic design of proposed circuit

The Fig 4.3 shows the schematic of full circuit with. Basically rectification part is elaborated here.

4.2 Working Principal of proposed circuit

We can categorize the total procedure into two part. They are namely

(1) Rectification circuit
(2) Controller circuit

4.3 Working principal of rectification circuit

To explain the rectifier circuit, it can be divided into 4 stages. For positive and negative half cycle of AC current the conduction path of current is different.

4.3.1 Stage-1 of Rectification Circuit

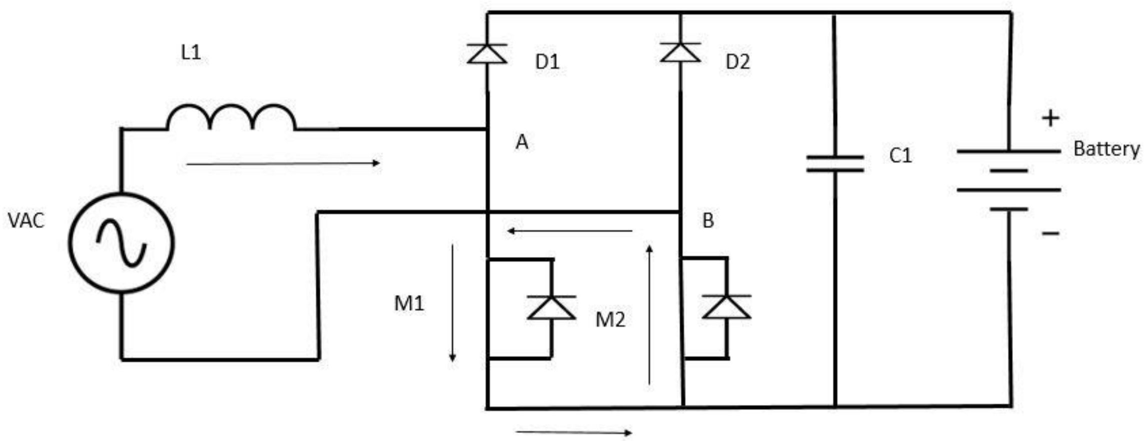


Fig 4.4: Operating stage 1

For positive half cycle, MOSFET 2 will always be in ON state and MOSFET 1 may be in ON or OFF state. In the 1st case which is shown in Fig 4.4, both MOSFET is ON. SO both are conducted at a time. So the source current passes through the conductor and passes through M1, M2. At the same time the bulk capacitor will discharge and charge the battery. The MOSFETs are switched by very high frequency. These high frequency pulse are generated by timer.

4.3.2 Stage-2 of Rectification Circuit

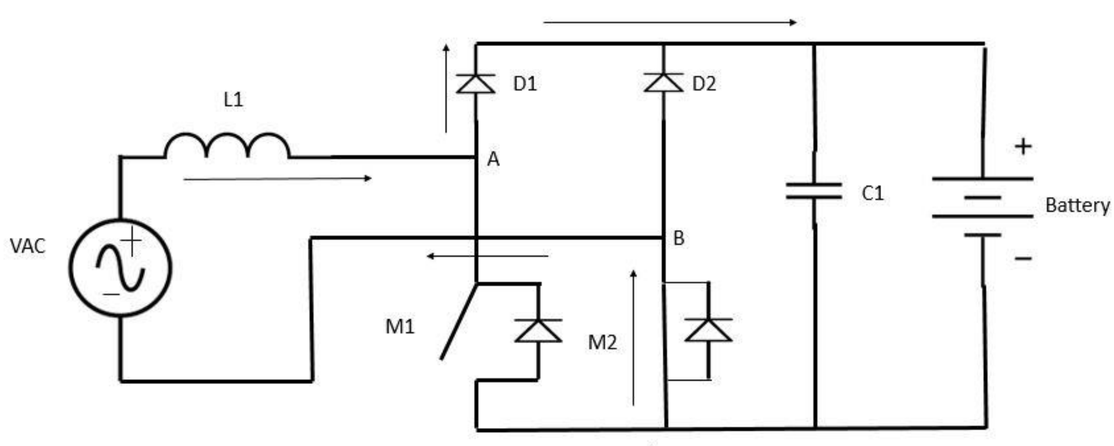


Fig 4.5: Operating stage 2

For positive half cycle, the MOSFET 2 is always ON state. In the 2nd case MOSFET 1 is OFF. SO only MOSFET 2 is conducted at that time. So the source current passes through the conductor and passes through the D1, C1. At the same time the bulk capacitor will charged.

4.3.3 Stage-3 of Rectification Circuit

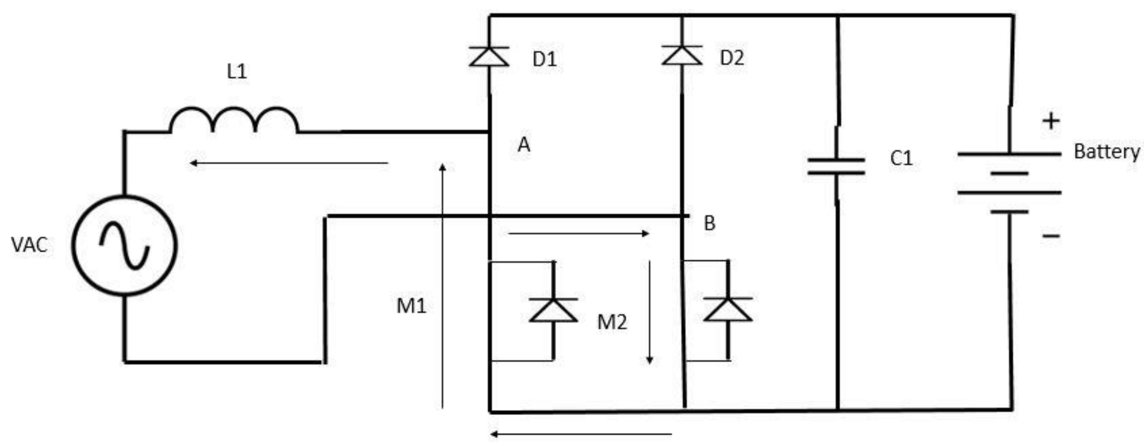


Fig 4.6: Operating stage 3

For negative half cycle the MOSFET 1 is always ON state. In this case shown in Fig 4.6 both MOSFET is ON. So the source current passes through the inductor and passes through the L1, M1 and M2.

4.3.4 Stage-4 of Rectification Circuit

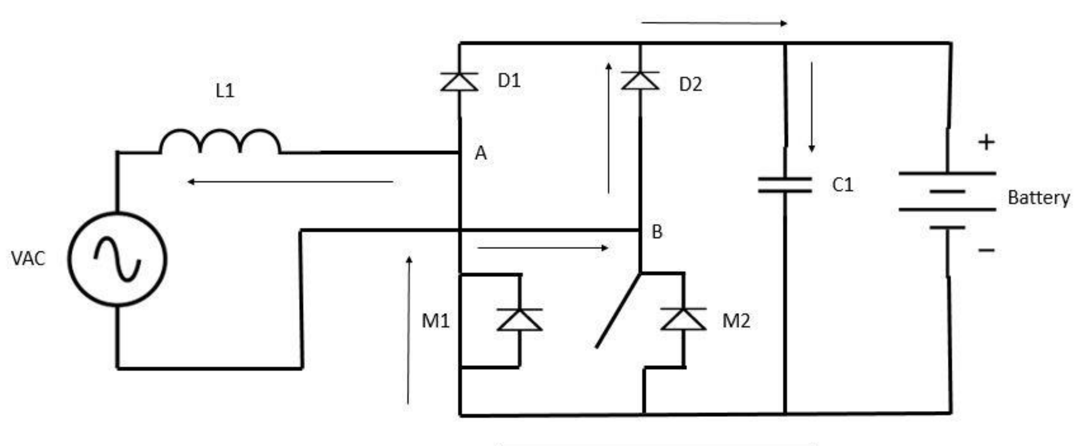


Fig 4.7: Operating stage 4

For negative half cycle the MOSFET 1 is always ON state. In this case shown in Fig 4.7 MOSFET 2 is OFF. So only MOSFET 1 is conducted at that time. So the source current passes through the conductor and passes through the D1, C1. At the same time the bulk capacitor will charged.

4.4 Elements of Controller circuit

1. Tap changing transformer.
2. Solid state relay.
3. BJT.
4. Micro-controller.

4.4.1 Tap changing Transformer

The purpose of a tap changer shown in Fig 4.8 is to regulate the output voltage of a transformer. It does this by altering the number of turns in one winding and thereby changing the turn ratio of the transformer. There are two types of transformer tap changers: an on-load tap changer (OLTC) and a reenergized tap changer (DETC).

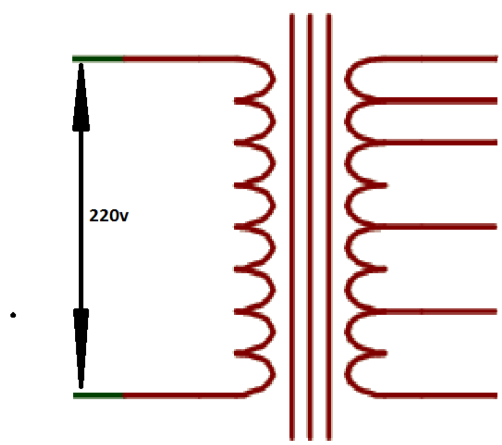


Fig 4.8: Tap-changing Transformer

An OLTC varies the transformer ratio while the transformer is energized and carrying load. The switching principle uses the “make before break” contact concept. An adjacent tap is bridged before breaking contact with the load carrying tap for the purpose of transferring load from one tap to the other without interrupting or appreciably changing the load current. While in a bridging position (i.e., contact is made with two taps), some form of impedance (resistive or reactive) is present to limit circulating current. A high speed resistive type OLTC uses a resistor pair to absorb energy and does not use the bridging position as a service position. A reactive type OLTC uses a reactor that is designed for continuous loading, e.g., a preventative autotransformer, and therefore uses the bridging position as a service position.

A DETC is a tap changer that cannot be moved while the transformer is energized. It often has 5 positions (A,B,C,D,E, or 1,2,3,4,5). If a DETC is not exercised on a regular basis, there is increased risk that the DETC will not make properly when next moved.

In the proposed system, OLTC is used because the tap should be changed at loaded condition.

4.4.2 Solid State Relay

Solid State relays shown in Figure 4.9 are normally-open semiconductor equivalents of the electromechanical relay that can be used to control electrical loads without the use of moving parts.

Unlike electro-mechanical relays (EMR) which use coils, magnetic fields, springs and mechanical contacts to operate, the solid state relay, or SSR, has no moving parts but instead uses the electrical and optical properties of solid state semiconductors to perform its input to output isolation and switching functions.

Just like a normal electro-mechanical relay, SSR’s provide complete electrical isolation between their input and output contacts with its output acting like a conventional electrical switch in that it has very high, almost infinite resistance when no conducting (open), and a very low resistance when conducting (closed). Solid state relays can be designed to switch both AC or DC currents by using an SCR, TRIAC, or switching transistor output instead of the usual mechanical normally-open (NO) contacts.

While the solid state relay and electro-mechanical relay are fundamentally similar in that their low voltage input is electrically isolated from the output that switches and controls a load, electro-mechanical relays have a limited contact life cycle, can take up a lot of room and have slower switch speeds, especially large power relays and contactors. Solid state relays have no such limitations.

Fig 4.9: Solid State Relay

Thus the main advantages solid state relays have over conventional electro-mechanical relays is that they have no moving parts to wear out, and therefore no contact bounce issues, are able to switch both "ON" and "OFF" much faster than a mechanical relays armature can move, as well as zero voltage turn-on and zero current turn-off eliminating electrical noise and transients.

Solid state relays can be bought in standard off-the-shelf packages ranging from just a few volts or amperes to many hundreds of volts and amperes of output switching capability. However, solid state relays with very high current ratings (150A plus) are still too expensive to buy due to their power semiconductor and heat sinking requirements, and as such, cheaper electro-mechanical contractors are still used.

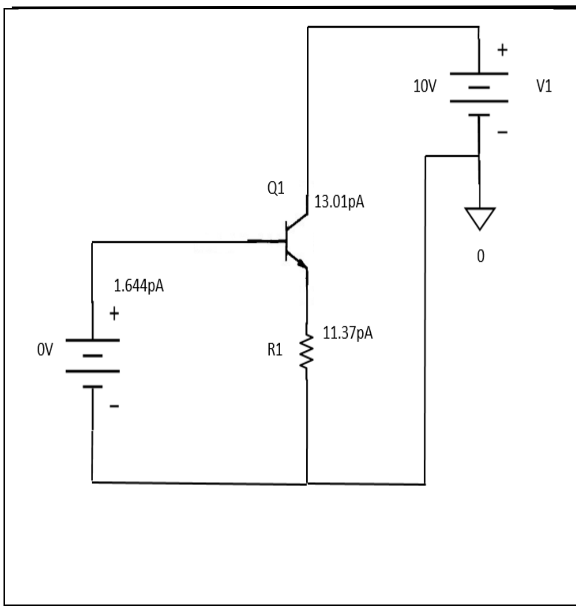
Similar to an electro-mechanical relay, a small input voltage, typically 3 to 32 volts DC, can be used to control a much large output voltage, or current. For example 240V, 10Amps. This makes them ideal for microcontroller, PIC and Arduino interfacing as a low-current, 5-volt signal from say a micro-controller or logic gate can be used to control a particular circuit load, and this is achieved with the use of opto-isolators.

In our system we use solid state relay to connect different tap of transformer into rectification circuit. These relay is operated by micro-controller via BJT.

4.4.3 Bipolar Junction Transistor

Transistors may be used as switching elements to control DC power to a load. The switched (controlled) current goes between emitter and collector; the controlling current goes between emitter and base. When a transistor has zero current through it, it is said to be in a state of cutoff (fully non conducting).

When a transistor has maximum current through it, it is said to be in a state of saturation (fully conducting).In our design BJT is used as switch. It operates solid state relay when it gets pulse from micro-controller. We know that when the base current is zero for BJT then it doesn't conduct current from emitter to collector. When the base is connected to a high signal, then current will passes from emitter to collector. Figure 4.10 & 4.11 represent the operation of BJT at no base signal and with base signal respectively.



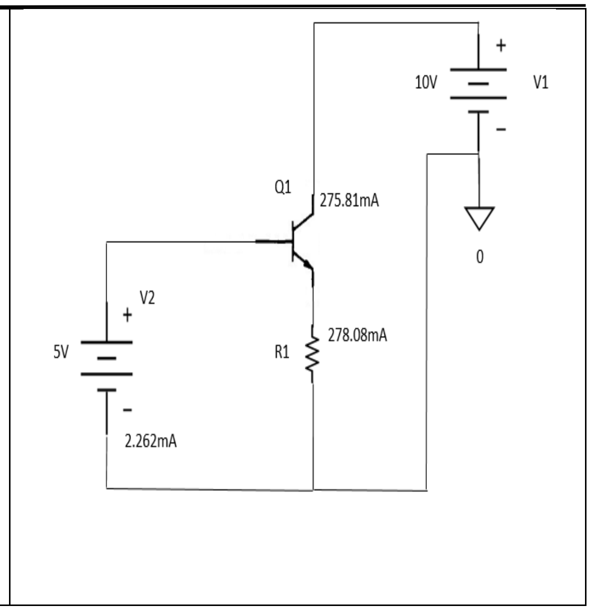


Fig 4.10: BJT at no base current **Fig 4.11:** BJT at base current

4.4.4 Operation of BJT and Relay

A number of BJTs are connected with micro-controller as fig shown below. The Base of those BJTs are connected with different output pin of micro-controller. The Collector is connected with a voltage source and the Emitter is connected with solid state relay. The input of each solid state relay is connected with different tap of transformer. The output of those relay is shorted and connected with the rectification circuit.

When the one output pin of microcontroller goes to high then a signal is send to the Base of corresponding BJT. We know that if Base current is zero then BJT is OFF mode and when Base pin is high then it becomes ON mode. Since the Base of BJT gets a signal from micro-controller then it becomes ON state and current pass through them. So corresponding Relay is triggered.

For example, As shown in Figure 4.12 when pin B7 is high then 1st BJT will ON state , so Relay 1 will be triggered and the rectification circuit get full voltage of secondary side of transformer since it is connected with topmost tap of transformer. Similarly when pin B5 is high then 3rd BJT will ON state, so Relay 3 will be triggered and the rectification circuit get f less voltage than previous since it is connected with lower tap of transformer than before.

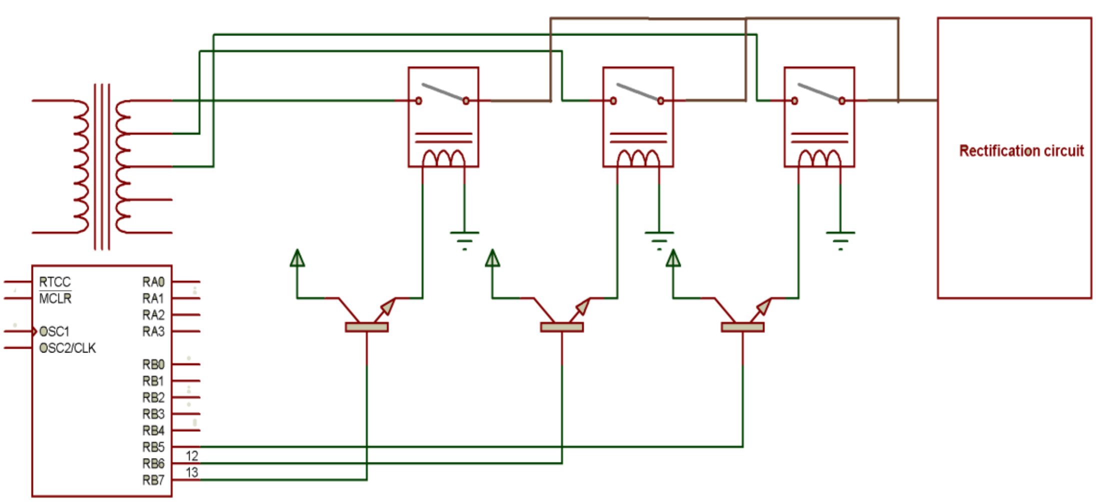


Fig 4.12: Working of BJT and Relay together

4.4.5 Micro-Controller

In our simulation we use PIC16C56. Which has 4 analog pin and 8 digital pin. Since we have to sense the voltage, current and of the charger so these analog pin is required. The digital pin is required to operate the BJT and other switching device for proper operation. The power of Micro-controller is given by L7805, which convert the input voltage into 5V that is necessary for operating the micro-controller. Figure 4.13 is a PIC165C6 micro-controller.

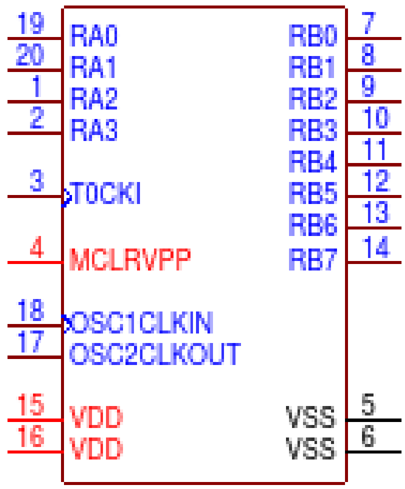


Fig 4.13: Micro-controller PIC16C56

In our simulation we use,

- Pin A0 for voltage sensor
- Pin A1 for current sensor
- Pin A2 for temperature sensor

All these pin used are input pin

- Pin RB7 is for BJT1
- Pin RB6 is for BJT2
- Pin RB5 is for BJT3
- Pin RB0 is for LED (green) which indicates that it is charging.
- Pin RB1 is for LED (red) which indicates that it is not charging

4.5 Operation of Voltage Sensor

Since the system has to control the current of charger so it is needed to sense the voltage of battery. When battery is fully charged then we have to cut off the charger line. For those reason we have to measure the battery voltage. We know that the voltage of battery is about (45~50) V. But the microcontroller can't tolerate those voltage. So maximum voltage of micro-controller is 5V. So we have to convert the battery voltage in such way so that the microcontroller can measure it. The traditional way of sensing voltage is voltage divider circuit. Which is look like as fig.

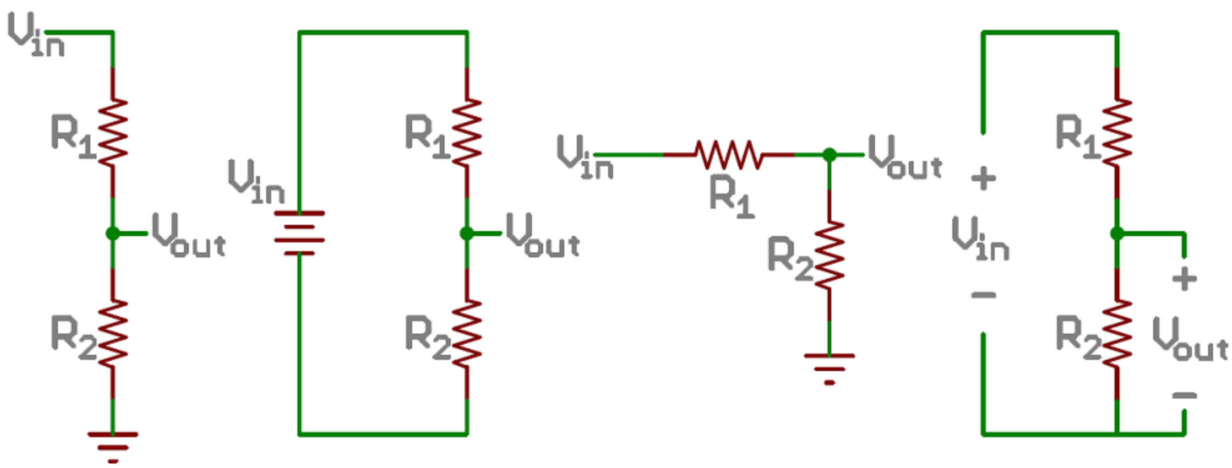


Fig 4.14: Voltage divider circuit

A voltage divider shown as Figure 4.14 involves applying a voltage source across a series of two resistors. We'll call the resistor closest to the input voltage (V_{in}) R_1, and the resistor closest to ground R_2. The voltage drop across R_2 is called V_{out}, that's the divided voltage our circuit exists to make. So to find out the output voltage we may follow this equation.

$$V_{output} = \frac{R_2}{R_1 + R_2} \times V_{input}$$

Now since we know the input voltage range and output voltage range so we can determine the ratio of R_1 and R_2 . Let the maximum voltage of battery is 50V and output voltage (which is connected with micro-controller) is 5v.

Now,

$$V_{output} = 5 \text{ V}$$

$$V_{input} = 50 \text{ V}$$

So,

$$5 = \frac{R_2}{R_1 + R_2} \times 50$$

From here, we get the ratio of R_1 and R_2 is 9.

So we select these 2 resistor in such a way so that R_2 is 9 times than other which is shown in Figure 4.15

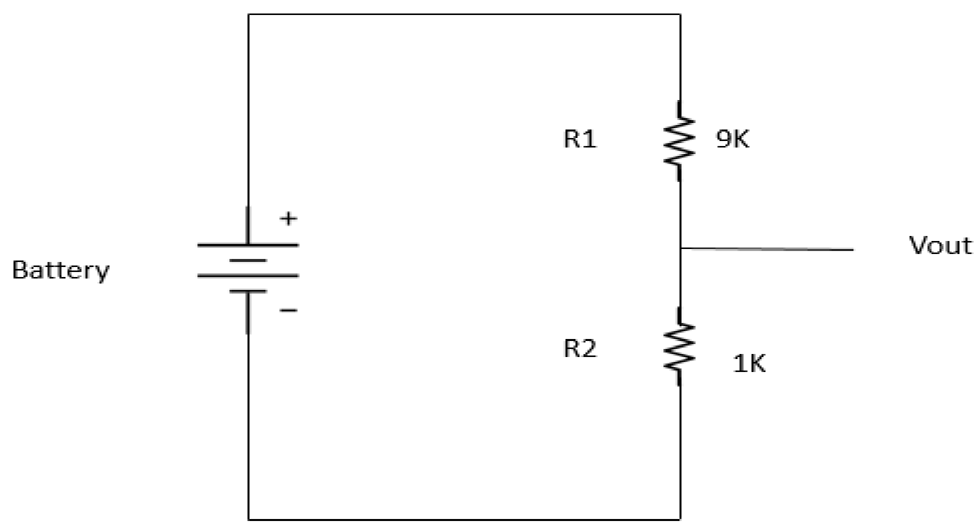


Fig 4.15: Voltage divider circuit in this system.

4.6 Operation of Current sensor

Knowing the amount of current being delivered to a load can be useful in a wide variety of applications. For example, in low-power consumer products the supply current can be monitored to understand the system's impact on battery life. The load current also can be used to make safety-critical decisions in over-current protection circuits. In motor control, knowing the magnitude and direction of the current can tell you the speed and direction of the motor. Finally, test fixtures can be developed that monitor all supply currents to gain an understanding of system subcomponent performance. Each of the aforementioned applications has different design requirements with respect to common-mode voltage, directionality, and accuracy. We can use a fuse as a current limiting. But we have to sense the current for proper tap-changing operation

There are various way to sense current in a circuit. Commonly they are

- Shunt Resistor.
- Current Transformer.
- Rogowoski Coil.
- Magneto-resistive Sensor.
- Hall Effect Sensor.
- Fluxgate Sensor.

In this design, Current is sensed by connecting a resistor series with the load as below:

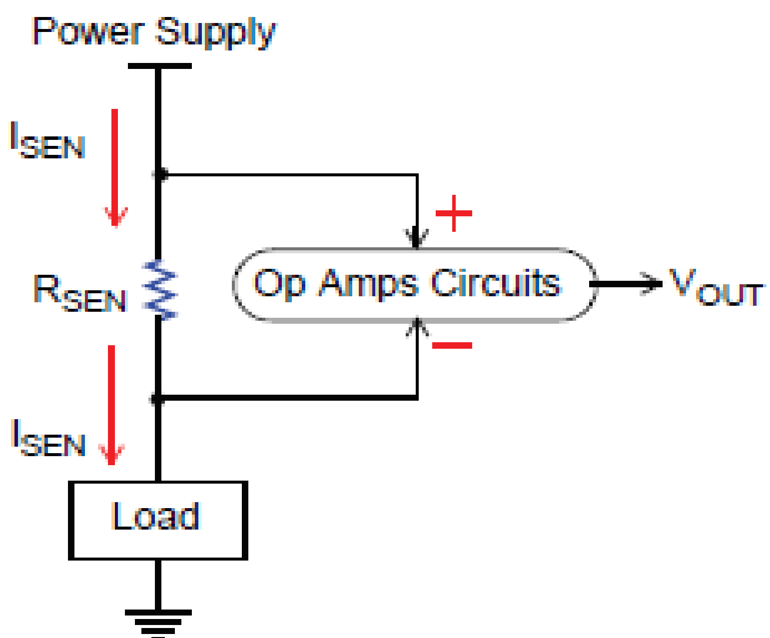


Fig 4.16: Current sensing element.

Advantages of this system which is shown in Figure 4.16 is that it eliminate the ground disturbance. The load can be connected with ground directly. It's another advantage is that it detects the high load current caused by accidental short**.**

4.7 Operation of Temperature sensor

Charging of lead acid battery takes so much time, so the charger becomes hot. For cooling the charger though the cooling fan is available but for safety purposes temperature sensor is used, which monitor the charger temperature. For a certain value of temperature the charger will automatically disconnected.

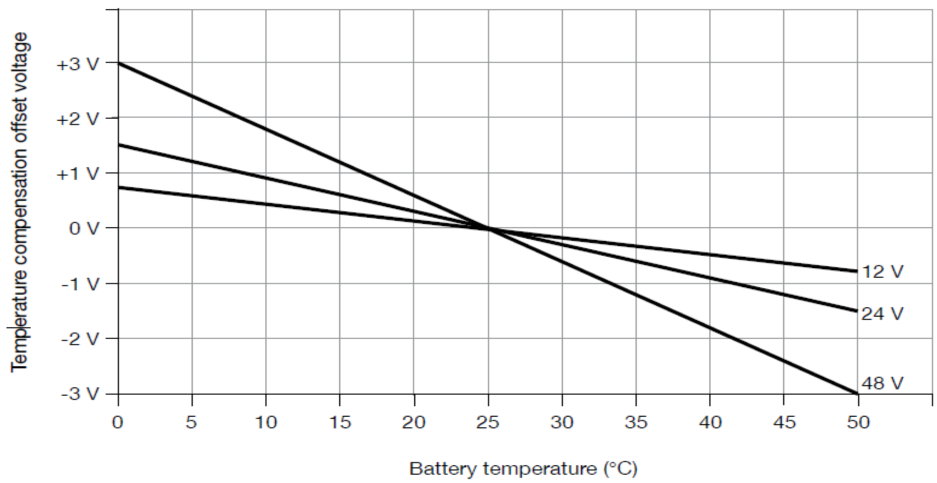


Fig 4.17: Temperature vs voltage graph of battery

So from that it can be understood the importance of temperature sensor, because the provided voltage should be changed on the basis of temperature. In our simulation we used KTY81 (shown in Figure 4.18) temperature sensor, which measure the temperature of the battery and gives signal to micro-controller. The Figure 4.17 shows the curve of battery voltage vs its temperature

Fig 4.18: Temperature sensor

4.8 Operating principal of our system

This charging algorithm shown in Figure 4.19 consists of different stages.

Broadly, it can be explained as follows:

- In our proposed design we consider that the 48V battery is fully discharged. It has a voltage of (10.8*4) 43.2 volt.
- After sensing the voltage level of battery, the voltage divider circuit sends a signal to microcontroller which control the switching circuit.
- After gating the signal, microcontroller will make BJT3 to operate in ON state which will Relay 3 in ON state. As relay 3 is connected with the 3rd top most tap of transformer, it will provide a constant current until voltage reaches a creation value (70% of full charge capacity of battery).
- When the battery is charging then the voltage of battery will increased, but constant current should be maintained. That's why input voltage should be increased. So after few times by sensing the input current it automatically triggered to relay 2 which is connected 2nd topmost tap of the transformer.
- Gradually the voltage of the battery is increasing so after sometime the topmost relay is triggered.
- After that state, when the voltage is about 70% charged, by sensing the voltage of battery the micro-controller keeps topping current stage. In this stage current will be gradually decreased. Since the voltage of battery is increasing and we kept the input voltage in at fixed level (topmost tap), so current will be automatically decreased. In that case the output voltage should be (54.8~55.2) V.
- Since this stage the output current should be gradually decreased. So the Relays connected with different taps is triggered by sensing the voltage of battery. This state known as topping charge state.
- The last stage is Float charging state. At this state the output voltage is about (54.8~55.2V). The float charge in the third stage maintains the battery at full charge. The battery is fully charged when the current drops to a set low level. The float voltage is reduced. Float charge compensates for self-discharge that all batteries exhibit.

- When the battery is fully charged, then the micro-controller makes all the Relay OFF. So, the charger will cut off automatically.
- Temperature Compensation is important for all battery types. The addition of a low-cost battery temperature sensor to charge controller or regulator will protect the batteries from being under or overcharged based on this temperature variation ensuring the longer life of battery bank.

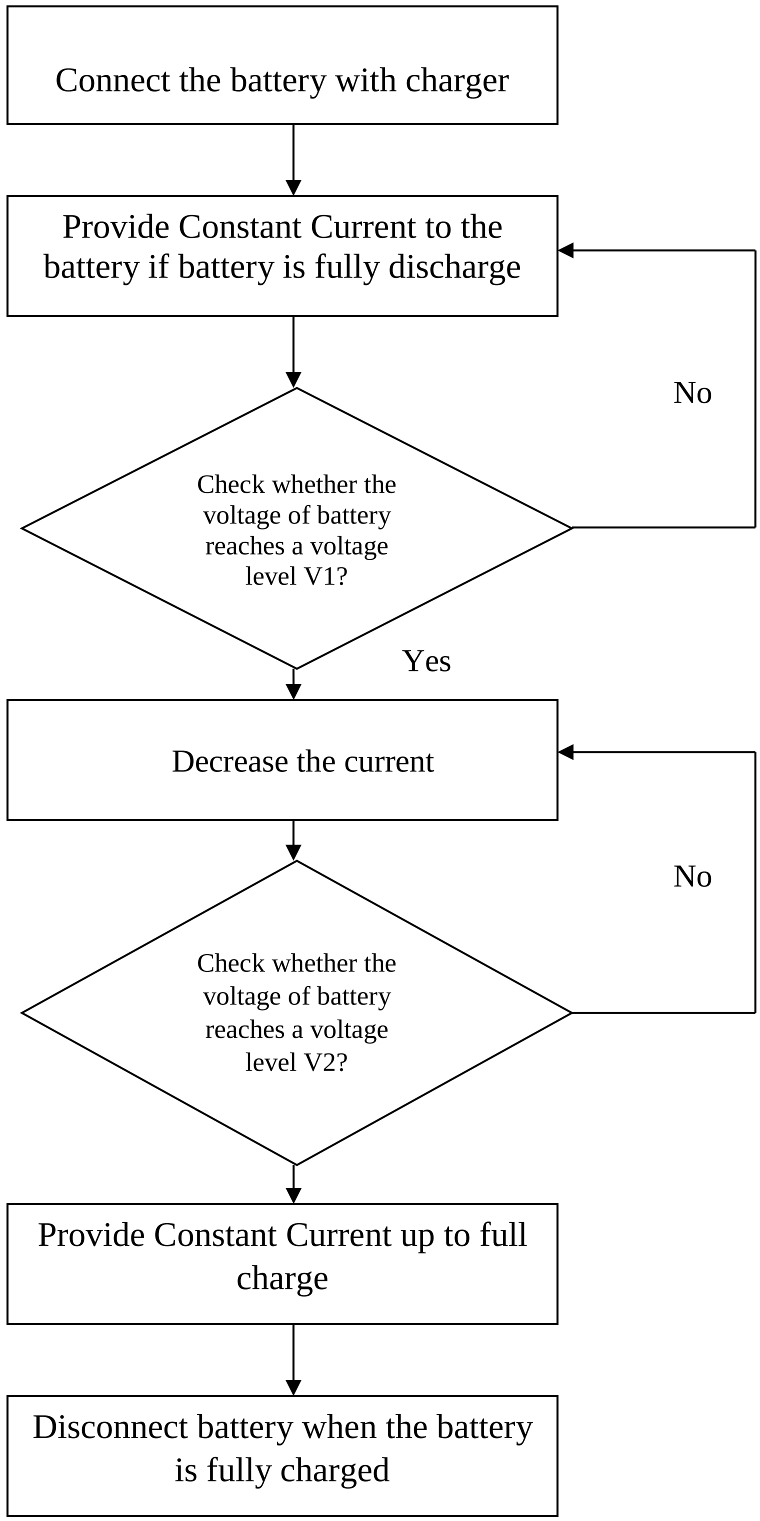


Fig 4.19: Flow chart of charging stage of battery

4.9 Different types of protection for battery charger

Protection system is always an important feature of a charger. Various protection system is given in our proposed design. They are given below:

4.9.1 Short Circuit Protection:

Short circuit at output can cause instant destruction or the charger may survive for a few minutes or it may survive forever - it depends on how it was designed.

4.9.2 Reverse Polarity Protection

Reverse voltage protection circuits prevent damage to power supplies and electronic circuits in the event of a reverse voltage applied at the input or output terminals. Reverse voltage protection is implemented at the input of the power supply or onboard of the custom, multiple output redundant power supplies. This is important in most electronic applications such as laptops, computers, CMOS circuits, etc.

In the proposed system, reverse power polarity is automatically given. Since there are two MOSFET and two Diodes conduct the current. We know that the diode can conduct current in only one direction, so reverse current cannot flow throw this.

4.9.3 Output Overvoltage and Over Current Protection:

It should be present in case of a fault in the charger control circuit. Well-designed electronic circuits are very reliable but components can still occasionally fail on a random basis. In the proposed system the overvoltage and over current protection is given. In previous, we discussed how we can sense the current and voltage. Knowing the current and voltage the micro-controller control the charger. We can switch off the charger by two ways. In first we can switch off relay which is connected with tap changing transformer. Another way is to stop giving pulse to the MOSFET. The second way is easier than first way.

CHAPTER 5

SIMULATION & RESULT

In previous chapter a new model of charge controller has been proposed for lead acid battery of electric rickshaw. In this chapter the simulation result is mentioned. Proteus software has been used to simulate the proposed system. For an ideal charger, it is necessary to maintain constant dc voltage in output. The proposed system successfully fill up this criteria. Another important criteria is power factor correction. To maintain unity power factor, the input current must be sinusoidal. Various protection of charge controller such as Over temperature protection, Short circuit protection, Over voltage protection eve has been simulated in proteus and it is found that the result is satisfactory.

5.1 Graph of Input current

We know that for unity power factor the input current must be sinusoidal. When the proposed circuit has been simulated the graph of input current is like as below in Fig 5.1:

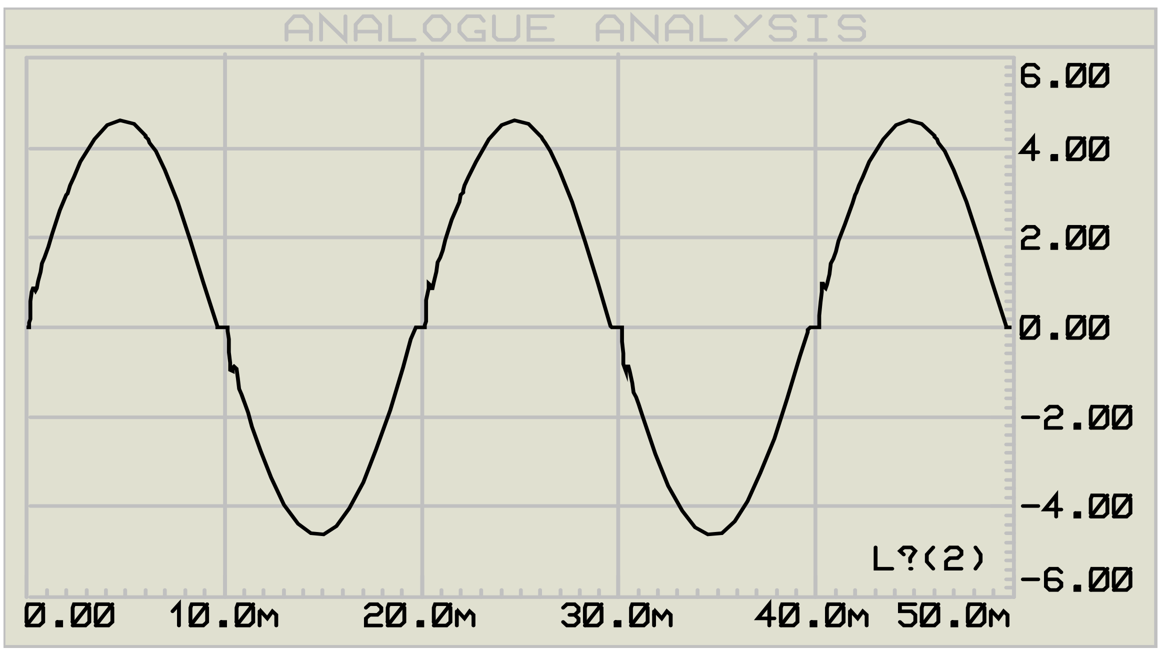


Fig 5.1: Graph of Input Current.

The Figure 5.1 represents the input current of the proposed circuit. The X-axis represents time and Y-axis represents input current. The maximum input current in this proposed circuit is 4.8 ampere. The fig shows that the input current is fully sinusoidal.

5.2 Graph of Input Voltage

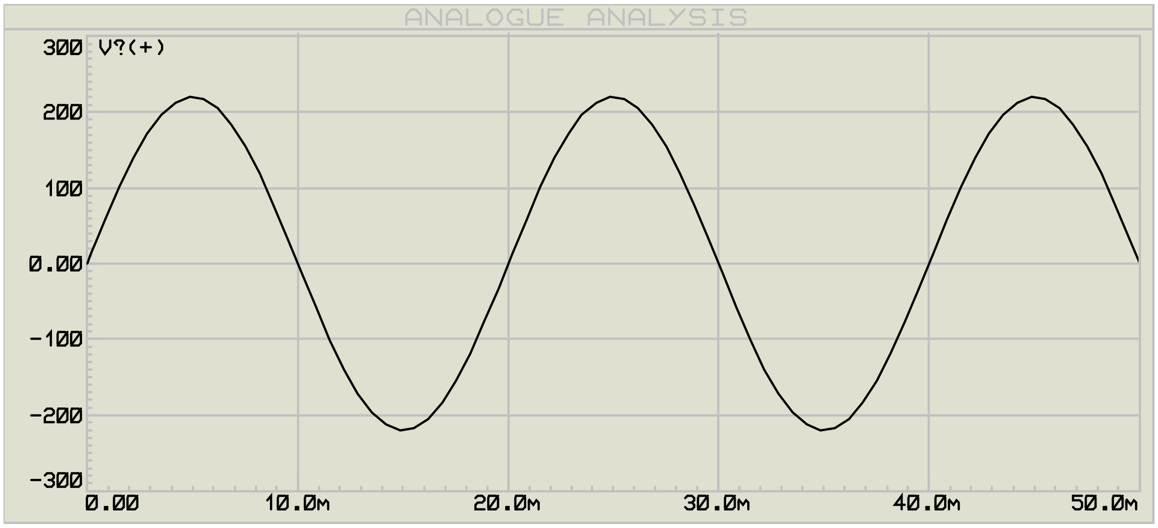


Fig 5.2: Graph of Input Voltage.

Figure 5.2 shows that the supply voltage in battery charger is 220V ac and it is purely sinusoidal.

5.3 Graph of Output Voltage

The output voltage of the charger must be DC. In the proposed system the graph of output voltage is shown in 5.3

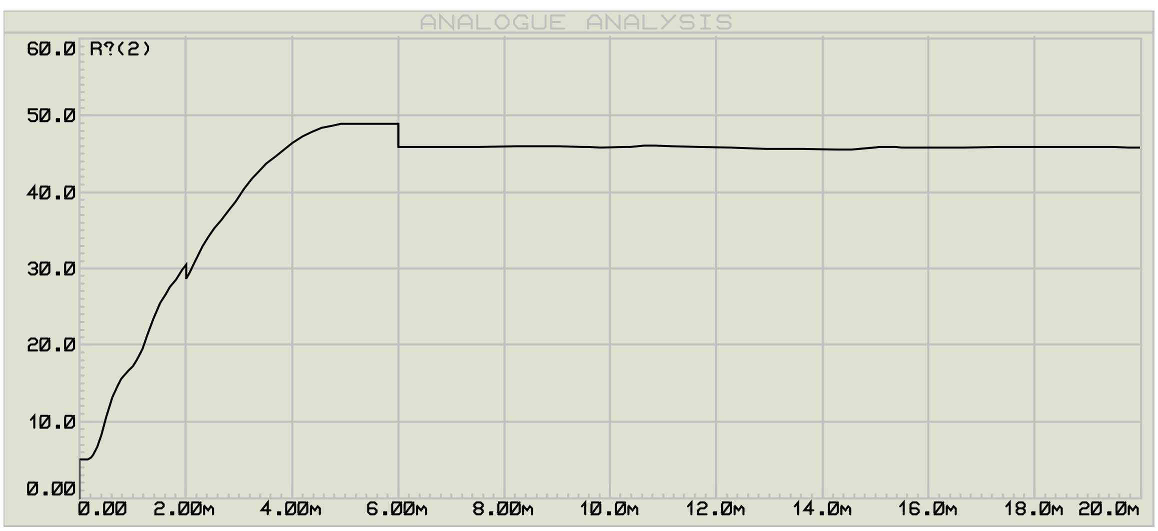


Fig 5.3: Graph of Output Voltage.

Figure 5.3 represents the output voltage of the proposed charger. The X-axis represent time and Y-axis represent the voltage. The maximum output voltage is about 48V for lower tap of tap changing transformer. The output voltage is fully dc.

5.4 Simulation In Proteus:

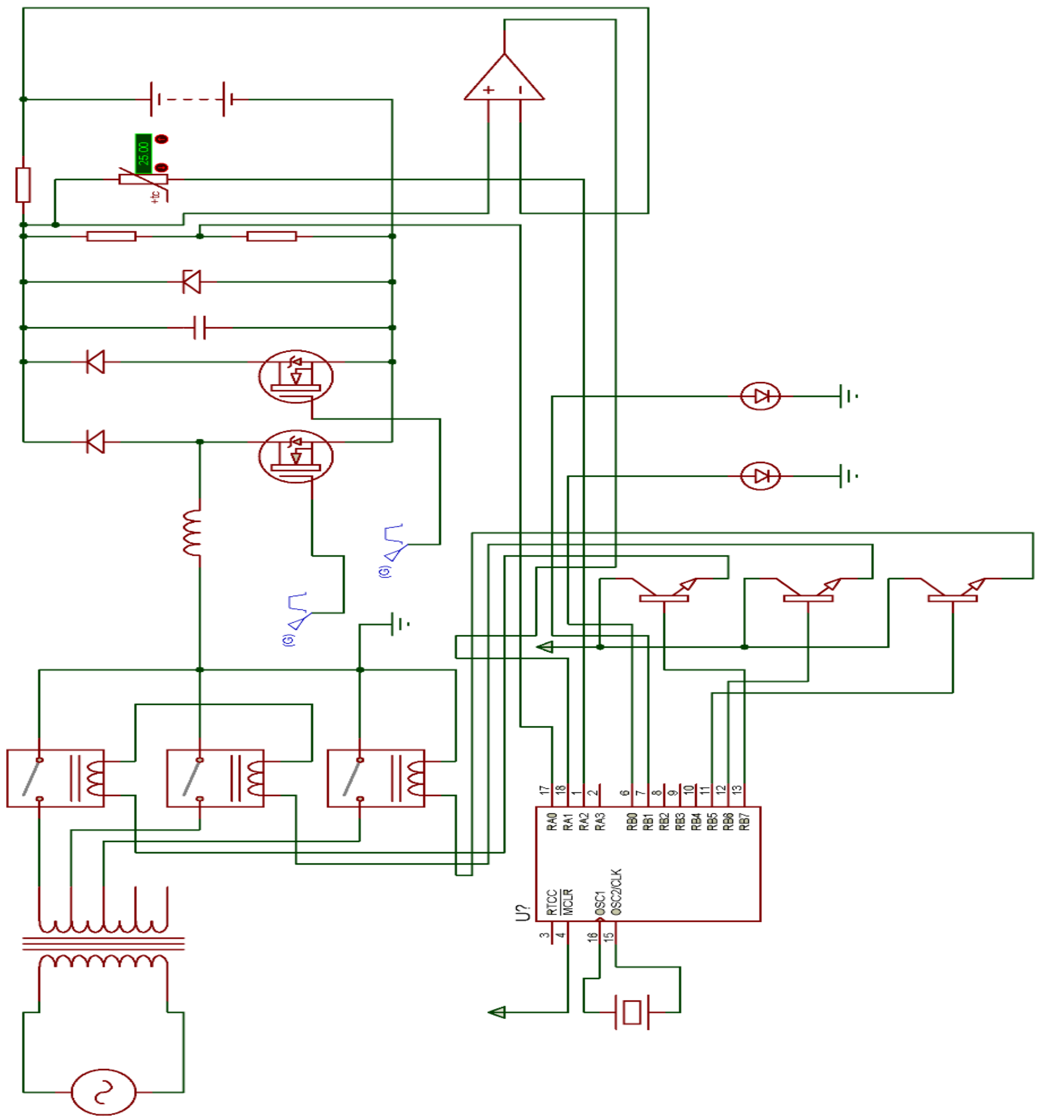


Fig 5.4: Designed circuit in proteus

This Figure 5.4 is the schematic diagram which is designed in proteus. Relays are connected with different tapes of transformer. Every relay is operated by BJT which give power/signal from micro-controller. The Voltage of top-most tap of the transformer is 50 V in this simulation.

5.4.1 Over Temperature Test

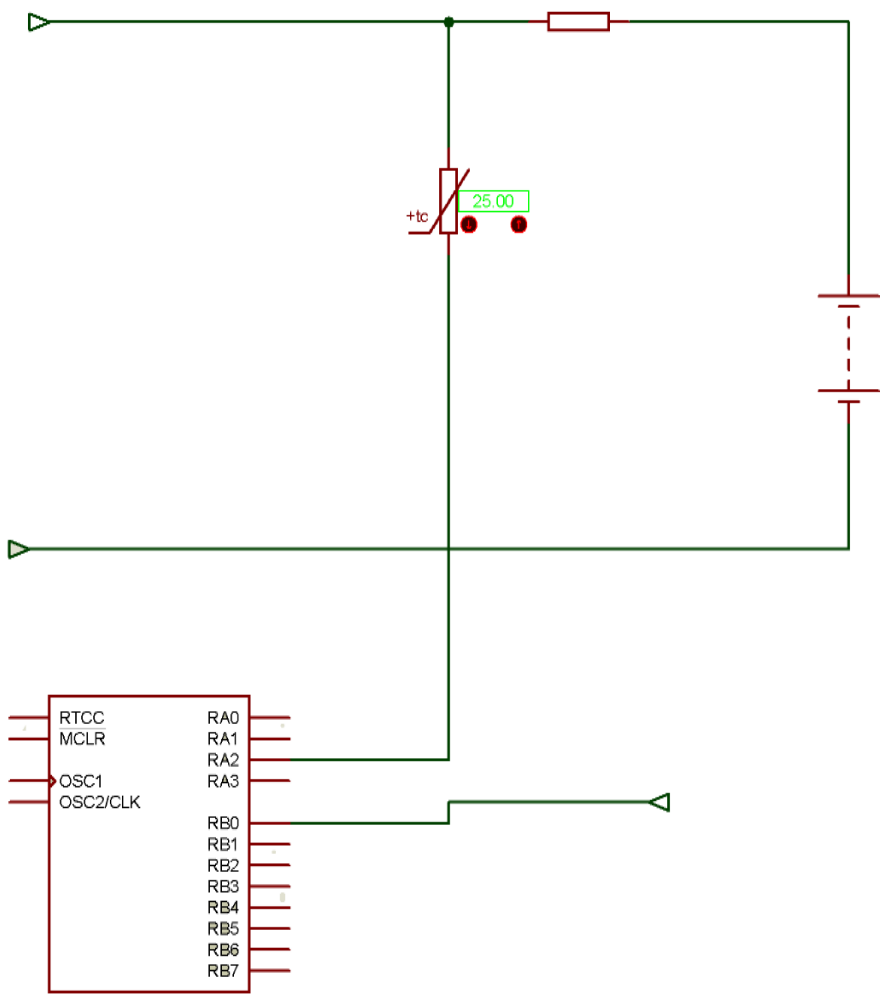


Fig 5.5: Over Temperature Test

The simulation has been accomplished (shown in Figure 5.5) by increasing the temperature by KTY81 (temperature dependent resistance) device. The microcontroller is programmed in such a way that it can sustain unto 50 degree Celsius. After that the charger will automatically disconnect. This feature will protect the battery from overheating.

5.4.2 Over Voltage Test:

The simulation has been done (shown in Figure 5.6) by increasing the voltage. It has been done by variable resistor. The charger will continue to charge until 55 volt appers After that the charger will automatically disconnect.

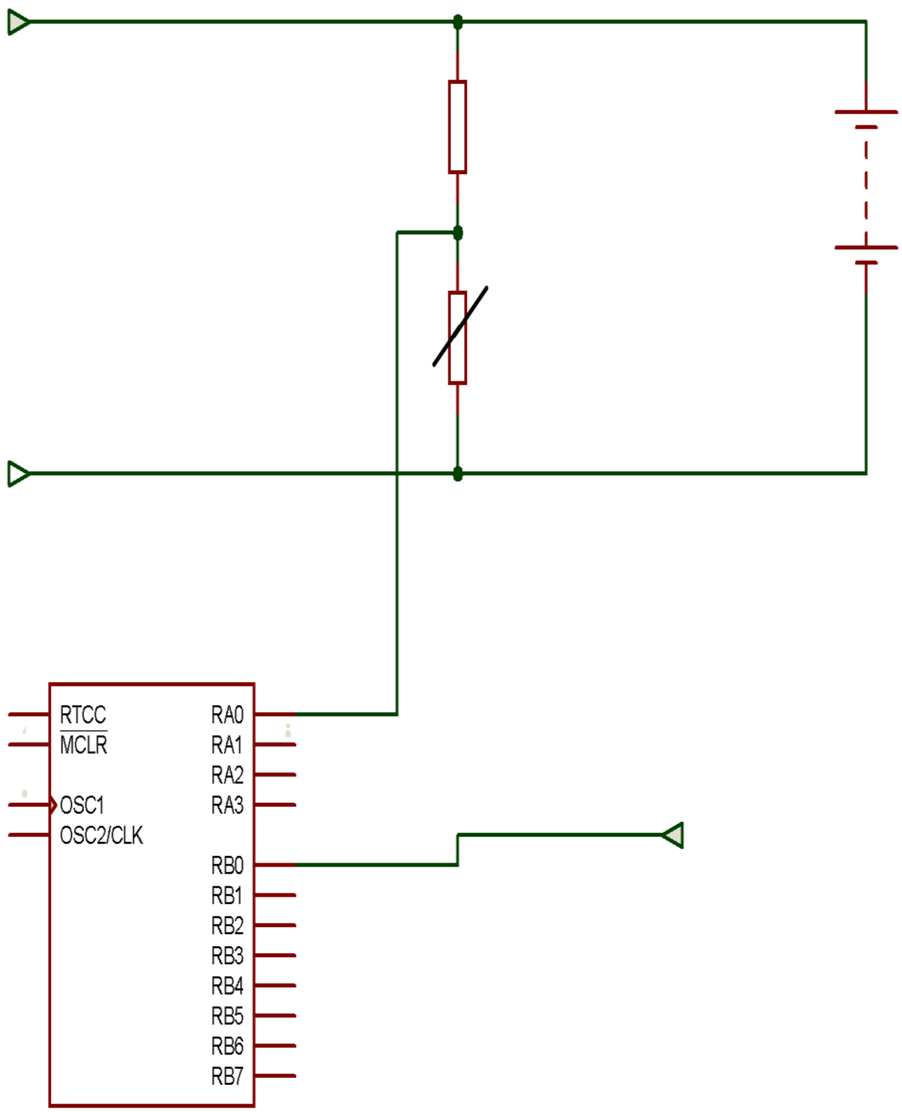


Fig 5.6: Over Voltage Test

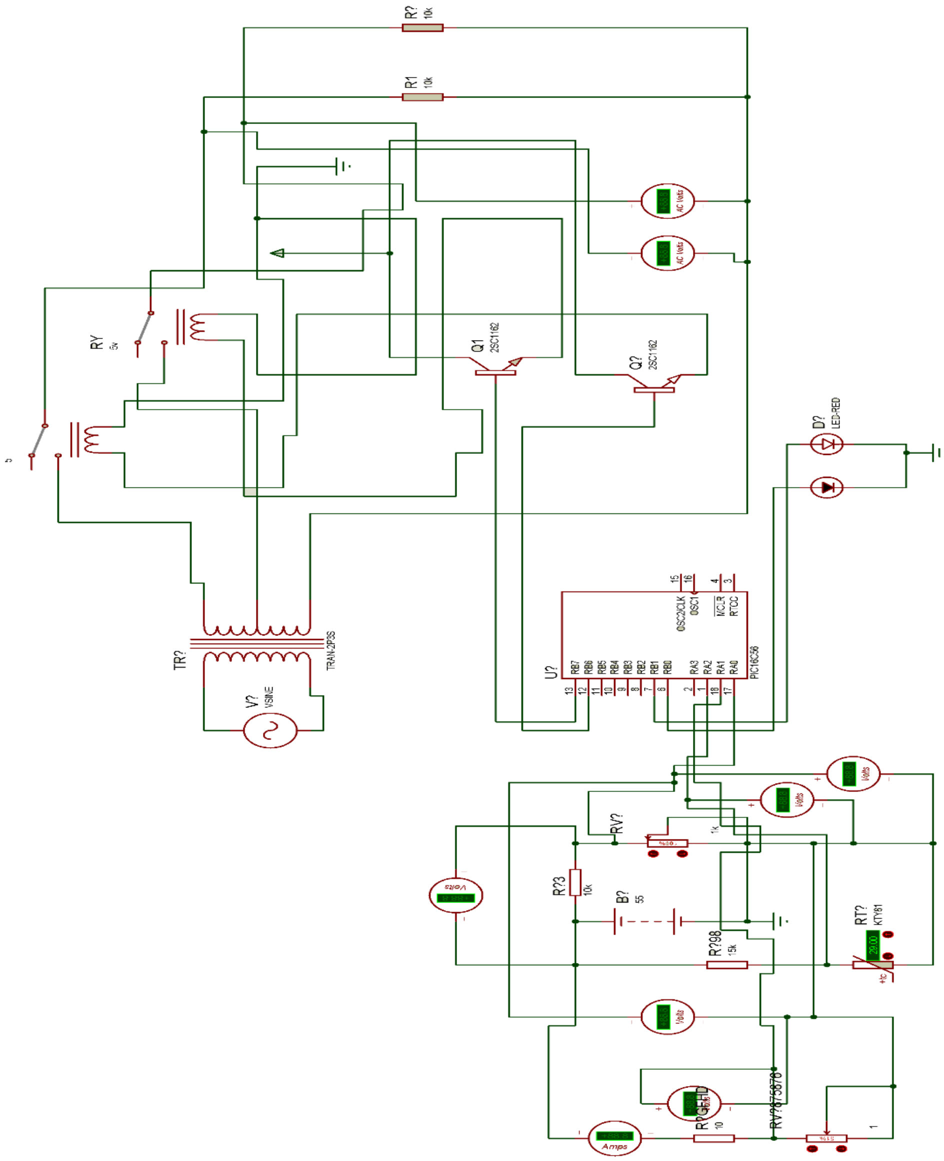


Fig 5.7: Different tests in proteus

Various types of test is taken in proteus software (shown in Figure 5.7). Over temperature,- Over current & over voltage protection has been experimented. Voltage, current and temperature have been manually increased and observed that in which point the charger is disconnected

5.4.3 Abnormal Condition Test

In all these case the output curve is shown as below. In this simulation from 0 second to 5 second the voltage, current and temperature is normal condition. In 5th second an abnormal situation has been made manually by increasing the voltage or current or temperature. Then the charger is failed to carry current. But it doesn't happen that the voltage is dropped suddenly. Because of presence the capacitor, it takes some time to discharge. The output voltage has been observed for normal and abnormal condition. In X-axis of the graph it represent the time and Y-axis it represent the output voltage.

In total procedure simulation is taken in such a way that when voltage limit is crossed a constant voltage 55v the charger will be automatically disconnected. Due to limitation of software only two tap is used. So only two stage of charged is examined. Nominal current of lead acid battery charger is 6 amp. So short circuit current must be (6*1.5)=9 amp. So 8 ampere current is considered as abnormal situation for safety purposes of battery. Above 49 degree temperature there is probability of risk of charger. So 48 degree temperature is considered as abnormal condition.

Two LED are used for visualizing the charging stage. The green LED is ON state when the battery is charging . The red LED indicates that battery is not charging.

Table V: Voltage, Current & Temperature limit in simulation

	Normal condition	Abnormal condition
Voltage:	Less than 50 (stage-1)	Over than 55V
	Between 50~55(stage-2)	
Current:	Up-to 8 amp	More than 8 amp
Temperature:	Less than 48 degree	More than 48 degree

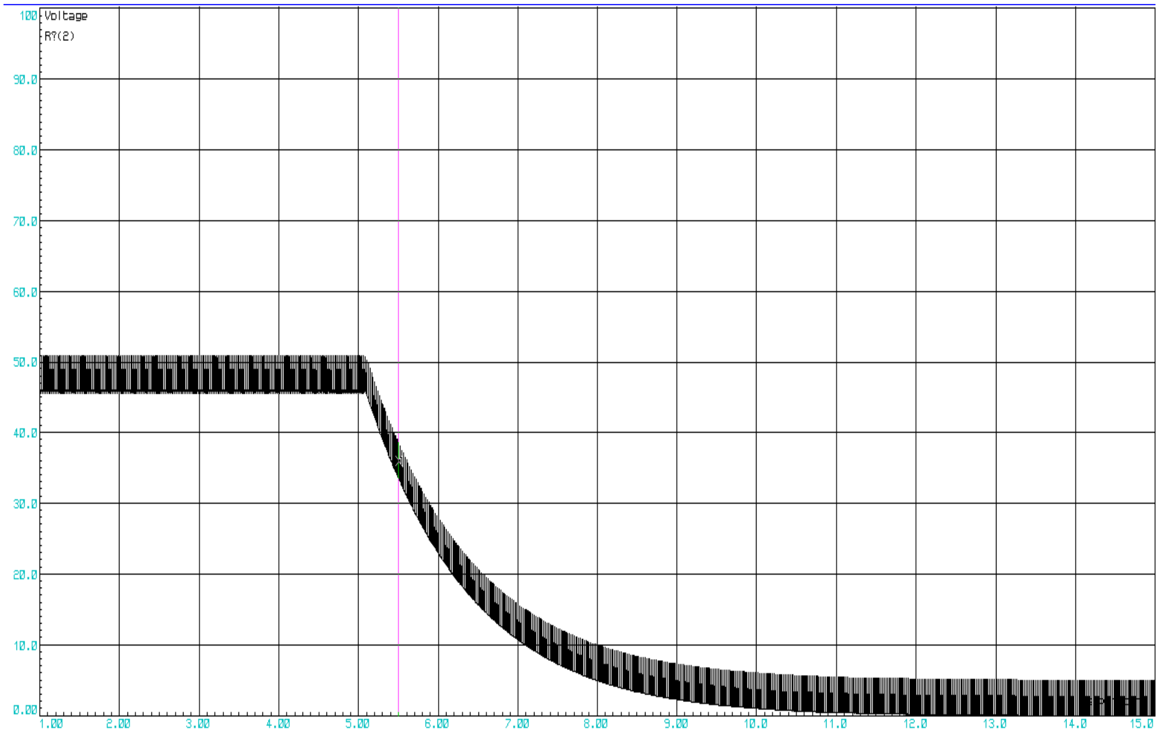


Fig 5.8: Output Voltage at abnormal condition

The Figure 5.8 shows the output voltage curve with respect to time. At the beginning all the condition was normal, so it gives full output voltages. But at 5th second an abnormal condition has been made manually. So the output voltages decreased.

5.4.4 Code for simulation

```
void setup()
{
  Serial.begin(9600);
  pinMode(13,OUTPUT);
  pinMode(12,OUTPUT);
  pinMode(7,OUTPUT);
  pinMode(6,OUTPUT);
  pinMode(A1,INPUT);
  pinMode(A0,INPUT);
  pinMode(A2,INPUT);
  digitalWrite(13,LOW);
  digitalWrite(12,LOW);
  digitalWrite(7,LOW);
  digitalWrite(6,LOW);
}
void loop()
{
  int sensorvalue= analogRead(A0);
  int tempvalue=analogRead(A1);
  int currentvalue=analogRead(A2);
  double temp=tempvalue*(5/1023.0);
  double current=currentvalue*(5/1023.0);
  double voltage= sensorvalue* (4.95/1023.0);
  if (voltage<=.3 && temp<4 && current>=2.5)
  {
    digitalWrite(12,HIGH);
    digitalWrite(13,LOW);
    digitalWrite(6,HIGH);
    digitalWrite(7,LOW);
  }
  if  ( voltage <=2.5 && voltage >=.3 && temp<4 && current>=2.5)
  {
    digitalWrite(12,LOW);
    digitalWrite(13,HIGH);
    digitalWrite(6,HIGH);
    digitalWrite(7,LOW);
  }
  if (voltage>2.5|| temp>4 || current<2.5)
  {
    digitalWrite(12,LOW);
    digitalWrite(13,LOW);
    digitalWrite(7,HIGH);
    digitalWrite(6,LOW);
  }
}
```

CHAPTER 6

CONCLUSION & FUTURE WORK

6.1 Conclusion

This paper deals with a micro-controller based charger for electric rickshaw, which is one of the most used in Bangladesh now-a-days because of need for transportation system especially in rural area. But the available charger have some draw back that we have found in laboratory. The efficiency of those charger is not so good, there are no reverse polarity protection, the current carrying capability is not so good.

In this proposed model a tap changing transformer is used so that the output current is controlled easily. The simulation result says that the input current is about to sinusoidal which is necessary for power factor improvement. Since the input current is not fully sinusoidal so the power factor is near to unity. The output voltage is dc because battery is charged only by dc current.

All features which are needed for an ideal charger are included in proposed system. The short circuit protection, over temperature protection, over voltage protection, over current protection are included in this model. All these protection are simulated by circuit design software and all are worked well.

The advantages of proposed system is that Conduction loss of this circuit is very low because current always flow through only two semiconductor. AC boost inductor contributes to EMI reduction. In previous day Ferro-resonant transformer is used. The ferro-resonant battery charger is inefficient and particularly sensitive to frequency changes. It produces acoustic noise, can interact with SMPS to produce transients and electrical noise on the output, and distort AC power to extremely high levels. Moreover, traditional ferro-resonant battery chargers tend to excessively overcharge the battery banks due to an old formula of change in voltage over change in time.

Since Tap changing transformer is used so we can easily control the current by changing the tap of transformer. Programmability enabling optimum charge profile implementation leading to high battery energy throughput and long service life.

Since we can’t make our device in practical so we can’t measure the efficiency of the proposed designed.

6.2 Future Work

Due to shortage of time, complete implementation was not possible and efficiency of the designed charger could not be measured. Provided sufficient time resources and suitable work environment, implementation is possible. Our model was designed taking under consideration for using on electric rickshaw. But it can be used for auto-rickshaws as well if charging current and some other parameters are altered. Some effective and modified protection systems has been introduced. That is why our proposed design will be more reliable and protective if applied accordingly. Many adaptations and tests remain for the future (such as tests with actual information, usually taking too long, even for days to complete single runs, even days required).

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