DESIGN AND ANALYSIS OF REGULATED CHARGING SYSTEM FOR ELECTRIC VEHICLE

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ABSTRACT

With the increasing potential of the application of electric vehicles, there is another side to be studied which points out towards limited range and long duration charging. Aim behind this paper is to make a charger which is capable to fulfil the gap between the commercial chargers with no features and the ones who have a higher power rating that need more protection and care in terms of domestic level use, and it will be the reference for new designs. The proposed design is having a low power rating. In India a domestic level electric supply is 230V 50Hz. So considering a maximum current we can use for a domestic household purpose, we made a charging system for an E-Rickshaw, E-Bike, E-Cycle and other small Electric Vehicles. For analysing this design two simulation software's are adopted. This system offers various features like monitoring the process of charging, automatic cutting down the supply after the vehicle is fully charged. This makes the system very convenient and reliable for a user as well as vehicle. This system is offering a three different voltage levels that makes it unique and quite competitive with commercial chargers available in market for E-Cycle, E-Rickshaw, E-Bike and other small electric vehicles. According to the simulation results the charging time for a selected battery bank is significantly reduced by a 25%.

Keyword- electric vehicle, charging, commercial charger.

INTRODUCTION

This work gives an insight of EV charging infrastructure which is commercially available in market for mainly 2 and 3 wheelers with their technical specification, also proposed a new design which is an alternative solution for these commercial chargers with some extra features. Lack of public infrastructure for charging Electric vehicles leads to the intent of the user to buy less EV's, because of this number of EV's on the road is affected. The main motive of this work to review the recent literature related to current scenario for charging the EV through various sources and give an alternative solution as a "Domestic level regulated charging system" for EV.

Our previous research paper titled "Review on Design and Analysis of Regulated Charging System for Electric Vehicle." is a completely review of this work which includes the literature of this idea, proposed methodology, modelling of the system in detail. In that the proposed methodology was by using Transformer, Rectification, Filtration, Boost Convertors and the Monitoring System. [13] By following this methodology, we came across some points. They are as follows:

- Transformer causes bulkiness in the system, which leads to obstacle for the portability of the system.
- Transformer is way more expensive for this type of system, where cheap and reliable are the main objectives behind the project.
- After connecting a boost convertor to the Transformer, rectifier and filtration assembly, we found that the output voltage drops. That leads to improper operation of Boost Convertor.
- For resolving the above problem, a feedback circuitry is needed and that increases complexity in circuits.

By considering above points we decided to replace Transformer with the Switch Mode Power Supply (SMPS). The SMPS resolves all above problem with a lesser cost. As SMPS is a main power supplying equipment of the system so the capacity of the system is defined by the ratings of SMPS. [13]

Now in this paper, the new designed is low power rated i.e. 360Watt and will provide three different voltage levels for charging the EV's having the battery bank voltage of 48V, 60V and a variable voltage range in between 1.37V to 38V.To check calculated values of Boost Convertors and proper working of the system two simulation tools are used. They are MATLAB Simulink and Proteus. Reason behind using these two software's is that MATLAB is a heavy software (in terms of PC specification), but MATLAB having a greater advantage that we can set the battery parameters with different SOC's. While in Proteus we designed driver circuit of MOSFET, Monitoring System, Automatic Cut-Off Circuit and Switching arrangement.

PROBLEM STATEMENT

After doing research on IEE and various research sites we found some papers for designing chargers for Electric Vehicles, but after studying we realize that they are designed for higher power ratings. [1][12][14] Though there are some papers available but we couldn't find for a smaller rating that can run on a Domestic power supply. [4][11] In educational institution, or other companies who convert a conventional vehicle into the electric vehicle or building their own EV, they also required a charger to charge their vehicle in developing stage as well as after completing the vehicle. Most of the institutions and companies focus on how they can enhance their EV model, not the charger.

At present stage very few commercial companies like Delta Electronics India, Mass-Tech, Exicom, ABB India, EVQpoint, BrightBlu, Magenta Group, RRT Electro Power (P) make the electric vehicle chargers. Above these only two companies mainly focused on e-Rickshaw, e-bikes and e-Cycles. [10] And now limited number of charging stations are available on road. By reading and analysing the above information we can conclude that there is a need of fulfilment of the gap between the higher power rating chargers and the basic one with no features. This gap can be fulfil by the charger who can charge the EV with a higher charging speed, having some monitoring system, Auto cut OFF feature, compact and easy to use. The proposed design in this paper helps to fulfil that gap.

PROPOSED WORK

The proposed work can be divided into different sections

Methodology

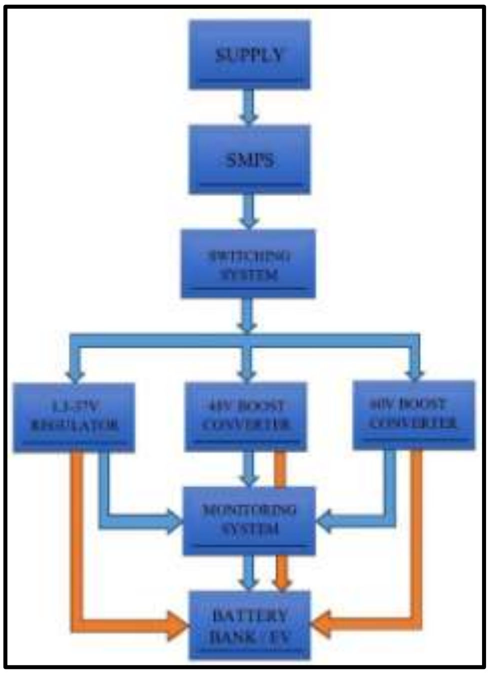


Figure 1: Methodology of the system

Supply

Our aim is to make domestic level charging system, as per Indian standard the domestic level electric supply is 230V with 50Hz frequency. So we design our system in such a way that, it can appropriately work on this supply.

Switch Mode Power Supply (SMPS)

Switch Mode Power Supply (SMPS) gives the stable voltage output and variable current. In this design we used a 12V 30 Amp SMPS, by simulating a design in the simulation tool i.e. MATLAB Simulink, we found that the maximum current taken by a Boost Convertor is 25 Amp. So we decide to took 12V 30 Amp SMPS. Another reason to take SMPS is that it gives the fixed voltage at its output and helps the boost convertor to work properly.

For a higher level power design, you can use higher power rated SMPS. If you don't find the proper one, the another method will be the combination of Transformer, Rectifier, Filters and some feedback circuit to make a fixed output voltage.

Switching System

As an inductor in the boost convertor draws the 3/4th current of the SMPS capacity, there is need to add some protection and switching arrangement to keep one boost circuit ON during the charging. There is a special arrangement is added that if accidently you start the other circuit while the first circuit is in running condition, automatically it cut OFF the supply of the first circuit. Fuses are used for the overload protection.

Convertors

The DC/DC converters are widely used in regulated switch mode DC power supplies. In these converters the average DC output voltage must be controlled to be equated to the desired value although the input voltage is changing. From the energy point of view, output voltage regulation in the DC/DC converter is achieved by constantly adjusting the amount of energy absorbed from the source and that injected into the load, which is in turn controlled by the relative durations of the absorption and injection intervals. These two basic processes of energy absorption and injection constitute a switching cycle. [2]

Table 1: Commercial Chargers Available for Two and Three Wheeler Vehicle

Sr. No	Name of Company	Voltage rating	Current rating
1.	Hero [5]	48V	2.7A
2.	Lzen electronics India[6]	48V, 60V	3.5A & 3A
3.	Powertron [7]	60V	3A
4.	Amptek [8][9]	60V, 48V	2.7A

"Table 1" represents the voltage levels for EV's chargers which are available in commercial market. So the desired values of the voltage are either 48Volt or 60Volt. In this system we used a boost convertor to boost the output of the rectifier to get the desired voltage level. The DC/DC boost converter only needs four external components: Inductor, Electronic switch, Diode and output capacitor. In this design we make two DC-DC convertors i.e. Boost Convertors for a voltage level of 48Volt and 60Volt. As the full charging voltage of this rating of battery bank is 57.6V and 72V respectively. So the boost convertors are designed in such a way that the outputs we receive at the end of convertors are 60Volt and 80Volt which is +2% of desired value.

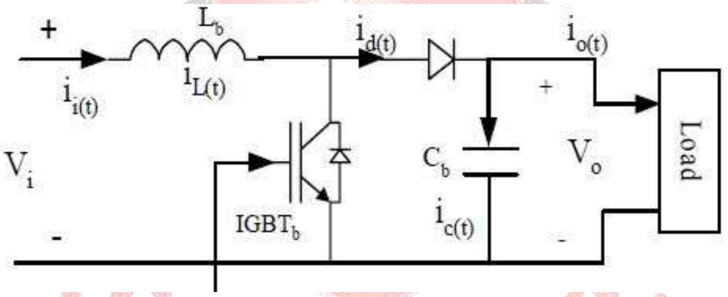


Figure 2: Schematic diagram of Boost Convertor [2]

By using the below equations we can figure out the parameters of Boost Convertor. [3]

$$D(Duty\ Ratio) = 1 - \frac{V_{in(min)} \times \eta}{Vo}$$

$$C(Capacitor) = \frac{I_{(out)max} \times D}{f_s \times \Delta V_{out}}$$

$$L(Inductor) \frac{V_{in} \times (V_{out} - V_{in})}{\Delta I_L \times f_s \times V_{out}}$$

$$\Delta I_L = (0.2\ to\ 0.4) \times I_{(out)max} \times \frac{V_{out}}{V_{in}}$$

A MOSFET is used for a switching purpose and the PWM for switching is generated by a 555 Timer IC. "Fig. 6" indicates the schematic of 555 timer IC to generate PWM. By changing the value of R_1 and R_2 we can vary the duty cycle.

Monitoring System

The monitoring system will monitor the whole charging process of EV i.e. output of boost converter, charging current and the temperature of the system. In "Fig. 1", we can see the output of the Boost Converter as well as the voltage Regulator is fed to the monitoring system, via sensors. These sensors are anything which transfers the real time data of an output of the charging system while the charging process is ON. Ex. Voltage Sensors, Current Sensors, Temperature Sensors etc. The most important thing a monitoring system can do is to show the output parameters on display, to cut down the supply when battery is fully charged and communication between sensors and Arduino. The Monitoring system can be made by using the centralized Microcontroller, Microprocessor, IoT tool or Arduino, but at this rating Arduino will be a better option as a standalone microcontroller and microprocessor are a bit complex to use.

Arduino is a single-board microcontroller. The Arduino which is used in this design is Arduino UNO. The Arduino UNO is a microcontroller board based on Atmel's ATmega328. It has 14 digital input output pins of which 6 can be used as PWM outputs and 6 Analog inputs. With this Arduino UNO board, we are able to perform all the necessary actions. Such as collecting the data from all the sensors, performing the calculation of the data collected by the sensors and displaying the useful output parameters. The arrangement for the same is shown in "Fig. 9".

For a voltage measurement, in this project we used voltage sensor to convert the higher voltage in the range of 0 to 5V, but the maximum input voltage that can be measured by the voltage sensor is 25V. To measure the voltage higher than 25V we have to add a resistor in series with the signal pin of the Arduino. For measurement of current and temperature we prefer ACS712 and LM35 sensors respectively. We use the 16x4 standard alphanumeric LCD display for displaying parameters.

Protection Circuit

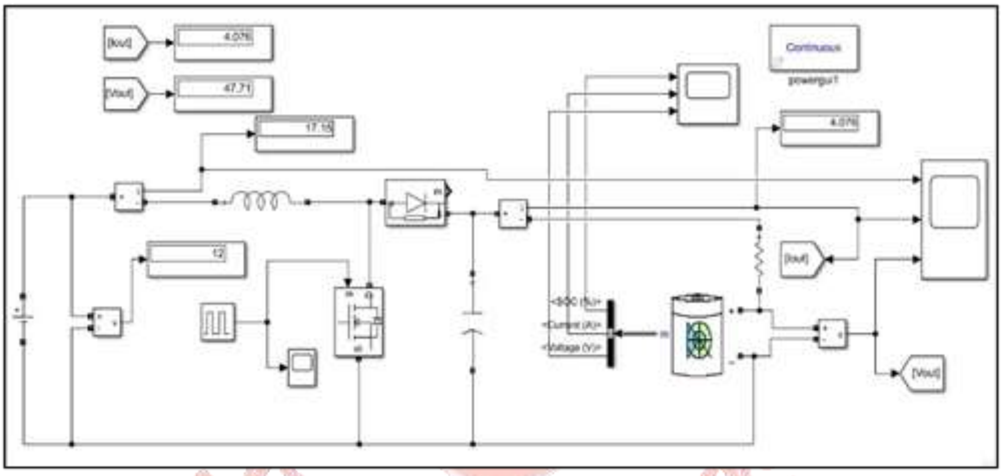
As we used SMPS for rectification and Filtering, capacity of our design is limited by the capacity of SMPS. As single convertor is taking 25Amp form SMPS we select 12V 30Amp SMPS. The need of protection circuit is, if a user accidently switches on the 60V boost while 48Volt boost is running then the total currant in the circuit would be 50Amp and that will damage the SMPS. So this circuit is having an arrangement that at a time single circuit will be in operation. If the other circuit will get start while first circuit is in operation, then this circuit arrangement automatically cut off the supply for first circuit. That saves the SMPS from Overloading. The relay logic is used for this arrangement for switching between two convertors, arrangement for the same is shown in "Fig. 10".

COMPARATIVE ANALYSIS OF MATLAB SIMULINK AND PROTEUS

The working of this design is analysed by using the two software's i.e. MATLAB Simulink (R2019a) and Proteus (8 Professional). As MATLAB is having more advantage like it can allow you to set battery parameters as per your need like selection of type of battery (Lead Acid, Lithium Ion, Nickel Cadmium, Nickel-Metal-Hydride), Temperature effect, Nominal Voltage (V), Rated capacity (Ah), Initial State of Charge (%SOC), Battery response time and some Discharge parameter, so we made Boost Convertor in it and simulate it with the selected battery banks considering it as a load to the Convertors with different SOC. After simulating convertor in MATLAB we observed that it takes too much time to simulate as it is heavy software for our low specification PC's. So we decided to make other circuit arrangements which are more likely control circuit in Proteus. Proteus having advantage that you can select actual component from libraries which are available in market. So we can get the actual results not the ideal ones. The models which are designed in Proteus are mentioned in next point, which are Switching Circuit, Monitoring System, Cut-Off assembly, Protection Circuit. Due to the use of crack version of Proteus some of its features are not working properly, that affect our continuous operation of monitoring system. But by taking a various reading, we can say that while implementing the hardware this problem will get resolved.

SIMULATION MODELS

"Fig. 3" and "Fig. 4" are the MATLAB Simulink models of the 48Volt and 60Volt Boost Converters with battery connected load. In this model MOSFET is operated by pulse generator. The detailed circuit for pulse generator is shown in "Fig. 6" and the switching pattern is shown in "Fig. 7". Switching arrangement, PWM Circuit, Cut-Off arrangement and Boost Convertor without load assembly is simulated in Proteus which is shown in "Fig 5". Voltage regulator is shown in "Fig. 8" which is able to give output voltage of 1.37V to 38V to charge batteries in this range.



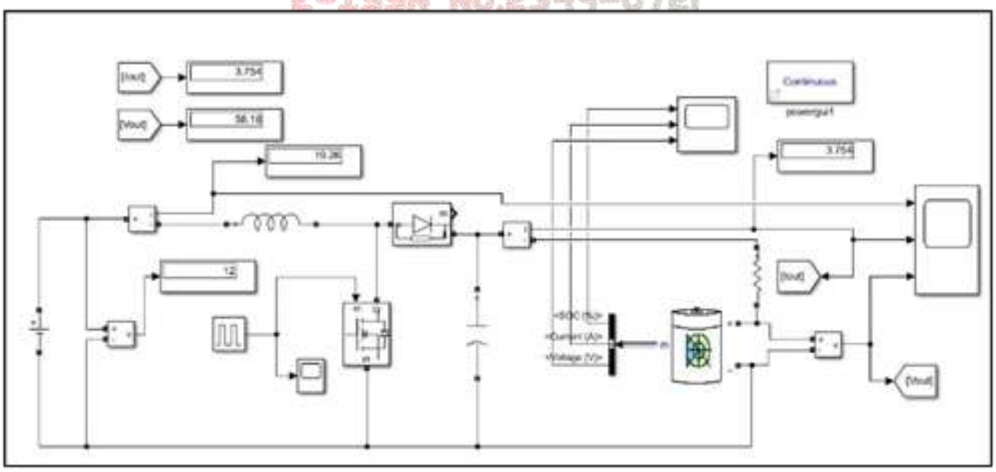


Figure 3: Simulink model for 48V Boost Convertor

Figure 4: Simulink model for 60V Boost Convertor

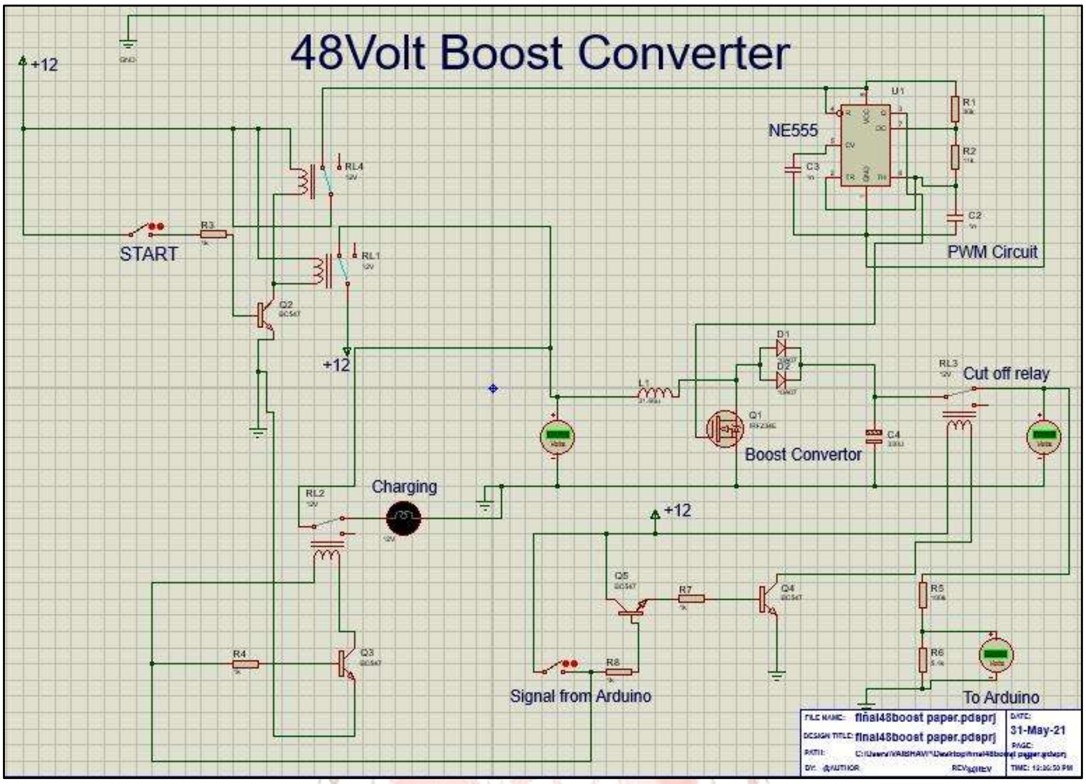


Figure 5: Proteus Model of 48V Boost Convertor

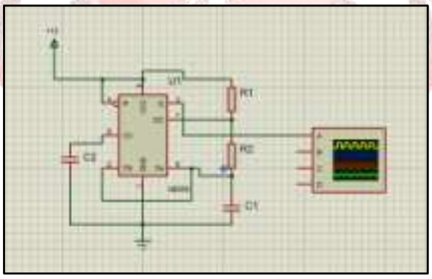


Figure 6: MOSFET Driver circuit/ PWM Generator

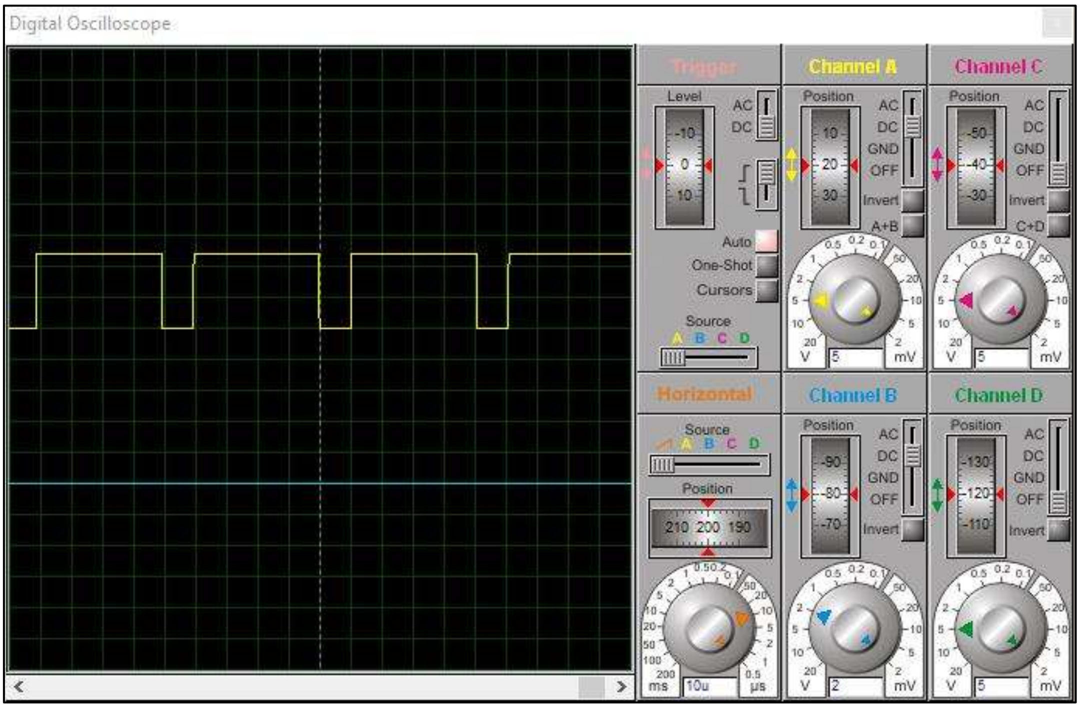


Figure 7: Switching signal for MOSFET

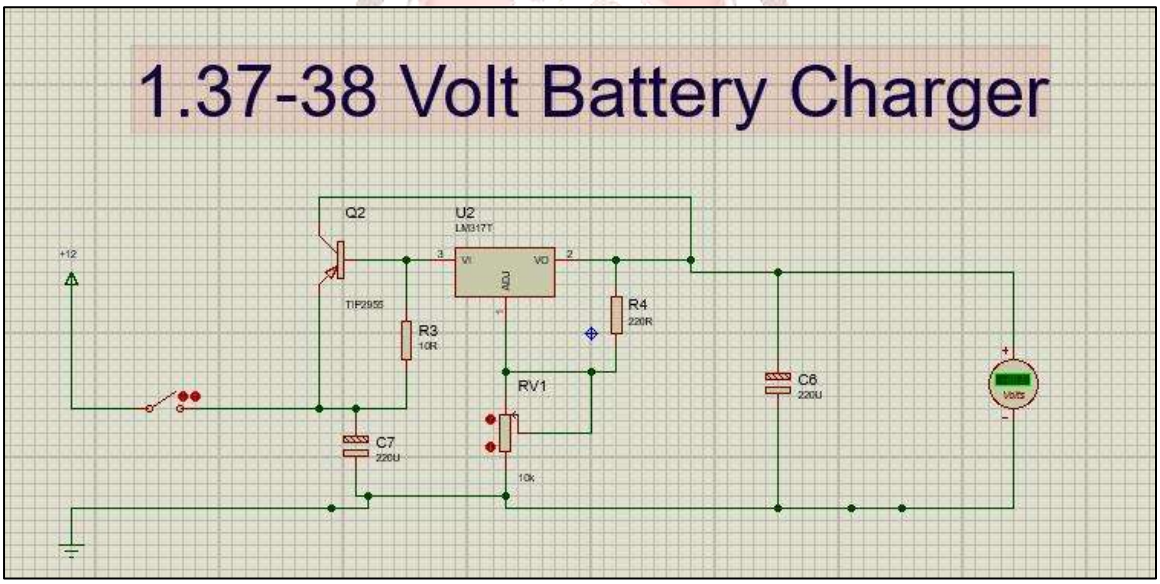


Figure 8: Proteus Model of Voltage regulator

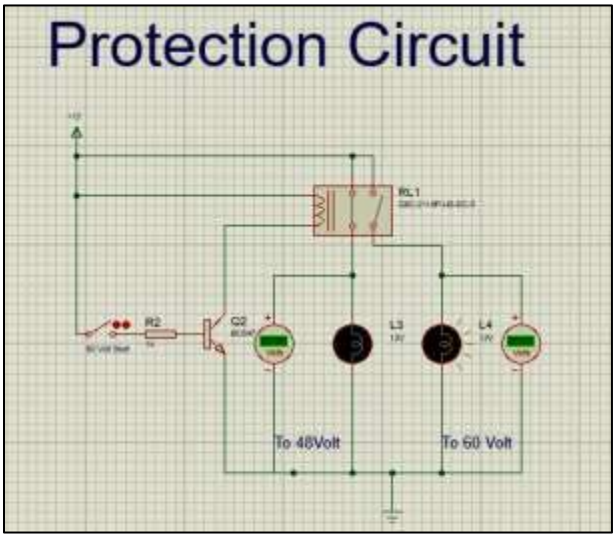


Figure 10: Protection Circuit

RESULTS

The reason behind the selecting this capacity of Battery bank is, as our aim is to make the charging system for two and three wheelers, most of them select the voltage level for their vehicle is 48V and 60V. After analysing simulation models, we can say that the designed system is working properly. Simulation model are giving a satisfactory results and the features mentioned are like Monitoring System, Automatic Cut-Off are working. "Table II" mentioned below is showing the output of Boost Convertor for the battery bank rated for 48V 24Ah and 60V 130Ah lead acid. In "Table II", Boost Convertor's output varies with respective to the battery SOC's. By taking average of these readings we can calculate the charging time for charging the respective battery banks or EV.

Table 2: Observations of Output of Boost Convertor for Different SOC of Batteries

Sr. No.	**(%SOC)**	**48V**		**60V**	
		48V, 24Ah		***60V, 130Ah***	
		Voltage (V)	Current (A)	Voltage (V)	Current (A)
1	30	47.7	4.1	58.18	3.6
2	40	48.56	3.9	59.26	3.4
3	45	48.87	3.9	59.66	3.35
4	50	49.14	3.8	59.99	3.25
5	60	49.58	3.75	60.53	3.2
6	80	50.29	3.6	61.26	3.05
7	85	50.12	3.55	61.41	3.05
8	90	50.68	3.55	61.55	3.05

Formula for calculating the charging time for battery:

$$\text{Charging Time} = \frac{Total\ Ah\ of\ Battery}{Output\ Current\ of\ charger\ in\ Amp}$$

Where,

Output Current of Charger = Average of observed current in amp.

CONCLUSION

All the work concludes that the availability of adequate charging infrastructure is one of the key requirements for adoption of electric vehicle. This paper represents a design of domestic level regulated charging system which include important formulas and easy method which is an alternative solution for commercial chargers available in the markets. All the extra features like monitoring system, switching system, protection assembly and Auto Cut-Off of supply after the battery is fully charged are working properly and giving the reliable output so that the consumer can use it with ease.

According to the simulation results this system or charger can charge any type of battery which has voltage levels of 48Volt and 60Volt and the battery voltages ranging in between 3.7V to 38V. We bought 48V 24Ah battery bank for an electric vehicle purpose. The earlier charger which is used to charge this battery bank taking so much time to charge these batteries. Now this design can charge the 48V battery within a 25% reduced time.

In terms of the future scope of this charger, it is use for base model for further upgradation in chargers, as it works more efficiently with lead acid batteries, doing a fine tuning in the programme of Arduino and knowing about the battery management system this charger can work efficiently for Lithium Ion battery banks also.

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