Electrical Vehicles Charging System in Parking Yards

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***Abstract*—This research paper discusses the design and implementation of EV (Electric Vehicle) Charging stations in parking lots. We consider several key factors when implementing this design especially for a country like Pakistan. We also discuss EV's importance to environment in the coming age of technology and how it will benefit our society as a whole. International standards that are going to be used will also be mentioned when implementing the design primarily we will use the SAE (Society of Automotive Engineers) standard for designing our EV Charging System. We have explained in great detail regarding the methodology and working of our system from the Design circuit to the J1772 Plug that will be connected to the EV's Charging module slot. The storage capacity provided due to the batteries enables us to store or supply energy to the electrical vehicle. It is to be noted that this research paper is derived from the works of others whom have been mentioned and credited and thus does not represent the effort of a single individual.**

Keywords—Electrical Vehicle, Charging Station, style, international standards, SAE.

I. Introduction

Climate change is a great concern in our generation as its effect will get worse each year if we keep on track of burning fossil fuels. Any action or inaction taken in this matter will affect the living conditions of generations to come the concern for climate change has sparked an interest in the research and development of Electric Vehicles (EVs), This is further reinforced by the fact that oil prices are increasing especially in the post COVID-19 era. EVs of different kinds are being developed and promoted, such as the battery EV, fuel cell vehicle or plug-in hybrid (electric motor with onboard battery and a traditional internal combustion engine). Technological improvements of EVs are ensuring that this technology will not only tackle any of today's transportation challenges but will also eventually replace the internal combustion engines (ICE) [1-6]. The lower Greenhouse gas emissions due to burning of fossil fuels will reduce as the industry will shift more towards cleaner energy. Lower CO2 emissions from vehicles will drastically impact the air quality of cities like Lahore where according to IQ Air the pollutant-measuring Air Quality Index (AQI) [7-13] record is observed to be of level 296 as of December 2021 which has made Lahore one of the most polluted cities in the world. An infrastructure system needs to be established, connected to the grid that would allow EVs to be charged whether they are at home or at a public location like a mall, office or a parking lot. Therefore, an EV charging system is suggested to be implemented which is a power electronic circuit capable of charging EVs at fast and semi fast rates (depends on the level of the charger) hence with smart grid EV charging systems, and smart building management or parking yard systems in a smart grid-oriented power system is very beneficial as it will contribute greatly in the energy management in the grid **Error! Reference source not found.**. Through our project we want to make people's lives easier when they go to their office or when they visit a public location such as a mall, we want to make sure there is an electric vehicle charging system available there for their EVs to save them from the hassle of going to an EV charging stations which are usually located alongside Petrol/Diesel stations [14-18]. This setup will provide a cost-effective way to charge your EVs relative to the fact that it can be installed in commercial areas and many other institutions.

II. Research on EV Charging Systems

A charged battery is required to drive an EV vehicle in order to charge this battery an EV charging infrastructure is required which can be connected to the electrical power grid system that would provide the necessary energy. Typically for an EV charging station high power is required for fast charging provided by fast charging stations hence these are typically used in large public transportation hub areas such as right next to Petrol and Diesel stations **Error! Reference source not found.**. To provide quick charging at an area such as a parking lot a level 2 or level 3 DC charging system is required which enables us to save time while stopping for a quick bite at a restaurant or when shopping at a mall.

A. Implementation Strategy

Battery prices have been reportedly falling by 19% for every doubling of doubling of battery capacity, in the last three

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decades alone the overall price of a Lithium-ion battery has fallen by 97% **Error! Reference source not found.**. Hence EV prices are much lower than they have ever been in the past, Because of this it is expected that EV prices will not only become comparable to their fuel consuming counterparts but might even become cheaper due to the undergoing development of the new Solid-state batteries that are being worked on by EV manufacturing companies such as TESLA. The International Energy Agency cites that by 2020 up to 20 million electric vehicles will ply the road, a number that is expected to go up to 70 million by 2025.

The increase in production of electric vehicles (EV) in Pakistan is rapidly increasing and people are more willing to understand this technology. This research project will help people whether they are consumers or business owners who are interested in developing as well as installing electrical charging infrastructure. An electric vehicle or EV for short, may use one for even more than one electric motor or traction motors and uses them as prime movers. EV's can be powered through a collector system by electricity whether from a grid system or from any other off-vehicle sources, or perhaps from a self-contained source like a battery, from solar panels or a generic fuel consuming generator in order to change fuel into electricity. EVs can include a wide range of vehicles, some of which are on-road and railway vehicles, ground vehicles and underwater vessels, electric aircraft as well as space crafts that are primarily powered by electricity from solar panels. The topic of EV always brings the question whether the charging time of an EV will be more than the actual operating time of the vehicle. This question has resulted in the development of electric vehicles becoming stagnant, because many people feel that it is unreasonable to wait hours on end when charging an EV. Batteries with a new technology characterized by high energy density and high charging and discharging currents are being used that enable large operation uptime. Not only that but rapid development in this field will lead to charging time being reduced from currently observed 6-12 hours (which are usually observed in most EV vehicles nowadays) assuming no charge is present in the battery beforehand. Hence The purpose of this project (EVs charging system) is to promote EVs in Pakistan but in order to promote EVs there should be EV charging stations and that is why our project is focused on the mainly the Charging station aspect of a EVs. Knowledge of batteries is important when designing an EV charging system which is why we have provided the statistics. Power to the EV charging station in parking lots will be provided by the power from the electrical grid system thus allowing it to be installed in public locations. EV charging setup will provide cost efficient charging of electric vehicles with relative case as it is can be installed in commercial areas or at big institutions. It will provide energy solutions to the problem of fuel dependent vehicles which will reduce both environmental and noise pollution as these vehicles don't have combustion engines [1]. If we want to maximize the benefits that EV's may provide in Pakistan, we require a Research and Development (R&D) facility. The activities pursued by these firms should be indigenous development of technologies for EVs and its ancillary services. Looking past the obvious, R&D has the potential to promote the growth of entrepreneurial activities that have huge potential for increasing exports.

B. SAE J1772 Standard

The J1772 is the standard we have used when designing our system and for choosing a Plug Connector. We had two options, either work on a level 1 or level 2 charger. Most electric vehicles come with a standard level 1 charger on purchase anyway which is an adapter capable of being plugged in a 120V outlet that is easily available at any home, This level 1 charger is convenient to use but takes a lot of time to charge the EV (delivering power output equivalent to 3 to 5 miles worth of EV charge per hour) approximately 24 hours on average for a charge on an empty battery hence given the limited capability of its function we are solely focusing on designing the level 2 variant of the EV charger which will be capable of charging 5-7 times faster as compared to the regular level 1 variants, this level 2 variant will be designed to work with the SAE (Society of Automotive Engineers) J1772 connector which is the standard followed by nearly all level 2 chargers. SAEJ1772 standard, normally know as IEC Type 1 (IEC 62196) or simply J plug, was mandated in 2001 by CARB (California Air Resources Board) to be used from 2006 and onwards into the production of EV's [13] and those specifications and infrastructure be maintained by international society of automotive engineers, hence the name "SAE". Since level 3 variants of this standard deal with dangerously high voltages of above 500V and require very expensive equipment not to mention they can also overload the electrical power system, we will only focus on the DC level 2 charger. In order to optimize the profits generated by operators by optimally placing and sizing fast-charging stations a theory called Nash bargaining theory is utilized. A detailed plan for optimally locating and sizing fast-charging stations on urban roads is presented. This includes factors such as Electric Vehicle and power grid losses when it comes to planning and identifies these components as important factors for estimating siting and also sizing of charging stations.

C. SAE J1772 Connector

To get a perspective a table containing specifications of different levels of chargers we have discussed is given below.

Table 1: Types of EV chargers and their voltage and current ranges

Charger Level	Voltage	Current
Level 1	120 VAC	16A-1.9kv
Level 2	208-240 VAC	80A-20kw

DC Level 1	200-500V DC	80A-40kw
DC Level 2	200-500V DC	200A-100kw

Further-more for a SAE J1772 Standard Connector there are five connection nodes with one of them just providing AC power to the connector and the other being a neutral line for the AC. The purpose of other three nodes deal with controlling the charging and connection state of the connector including the node that detects the pilot signal, duty cycle and proximity of the connector with that of the vehicle's connection point [14]. Figure *1* represents the general structure of a typical J1772 Plug

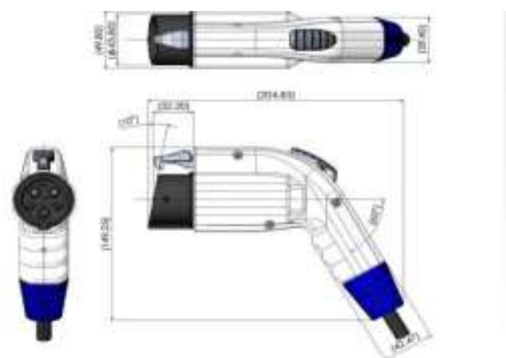

Figure 1: Isometric Drawing of a J1772 Plug (according to SAE J1772 standard).

1) Pilot Signal – Contains signal frequency of 1khz on pilot in order to communicate to the EVSE – EV state
2) Duty Cycle – Through this the EVSE is able to define the maximum current that is available to the EV
3) Proximity – Gives safety to the system when it comes it starting and shutting down the system.
4) It is also important to note that the control pilot is the primary control conductor and is connected to the equipment ground through control circuitry on the vehicle and performs the following functions:
5) Permits energization and de-energization of the supply
6) Checks and verifies whether the EV is present and connected
7) Transmits and supplies equipment current rating to the EV
8) Monitors the presence of the equipment ground
9) Establishes requirements of EV ventilation

III. Methodology

In this part we will discuss in detail how the EV charging system and its different states work.

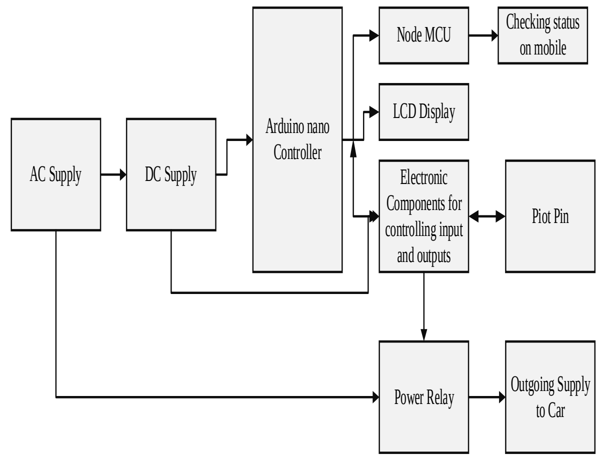

Figure 2: Block Diagram of an EV Charging.

We have considered challenges such as different battery capacities of different EV's thus adjusting our design to only provide power that is required by the system on the EV's end. We will begin by giving a simplified overview explanation of the EV charging system for better understanding as we move forward. Looking at Figure *2* we can see the general network of the entire charging system [15]. AC supply is converted to DC for the sake of providing 5 Volts DC supply to the Arduino Nano Controller via a boost converter. The 5Volts are also used to power any other electronic component that requires 5 Volts DC supply to operate such as the small electronic components that regulate the inputs and outputs. According to our programmed code burned into the Arduino Nano Controller, under ideal conditions the voltage output signal at the Pilot Pin is regulated to be 12 Volts this is true in all cases when the J1772 plug is not connected to any EV, this state is identified as "Not Connected" state and therefore will not activate the power relay that allows AC supply to be supplied to one of the output pins of the J1772 plug. The state of the system is also displayed by the LCD display at all times. When the J1772 plug is connected to the EV then the voltage at the pilot pin changes due to the presence of a resistance of 2.74 kΩ at the vehicles charging circuit. This 2.74kΩ causes the default 12 Volts to drop down to 9 Volts. This information is sent back to the Arduino Nano Controller which identifies this state as "EV Connected" state. After the system recognizes that the EV is indeed connected to the EV charging system the voltages on the pilot pin further drop down to 6 Volts from 9 Volts previously, this is because the EV has detected that the plug is connected and has sent a signal to a relay causing it to close thus allowing the charge to flow into the EV circuit that contains an additional resistance of 1.3kΩ, This 1.3kΩ is parallel to the previous 2.74kΩ resistance thus forming a combined resistance of 882Ω which causes the voltage to drop further down to 6 Volts. Feedback of 6 Volts at the pilot pin goes back to the Arduino Nano Controller and the system now classifies this state as “EV Charge” state. In this charging state a signal is sent by the Arduino Nano Controller to the power relay that closes to allow AC supply to be delivered to one of the output pins of the J1772 plug which provides charging to the EV according to the Duty cycle of the system [16]. In addition to the LCD display showing the current state of the system the Arduino Nano Controller can also be used to send the system and state information to a Node MCU which is connected to the cloud which can then be viewed by the person to check the progress of the EV charge and see the bill calculated according to the total power consumed.

A. *Pilot Pin Signal*

The Pilot pin of a J1772 connector has a 1khz frequency signal with voltage state as +12V to -12V square wave, this voltage helps to define the state of the system. The EV adds resistance pilot to Ground to vary the voltage. The EVSE reads the voltage and changes state accordingly. Different states detected by the pilot pin depend upon the voltage detected via feedback by the microcontroller at that time, this allows the system to act appropriately according to the state of the system. For Example, when the SAE J1772 Connector Is not plugged into the EV then normal voltages of 12V are detected by the Pilot pin this information is sent back to the microcontroller which is programmed to read this state as “Not Connected” and in case where voltages detected are 9V then the state is classified as “Connected State” and vice versa [17]. Table *2* is given showing various voltage states for every scenario that is programmed into the microcontroller.

B. *Duty Cycle Setting*

The Electric vehicle charging system sets the duty cycle according to the pilot pin settings, in this case the Electric vehicle must either accept its original setting or change to the setting of duty cycle. This essentially allows the Charge supplied to the EV to be determined by the EV charging system. Table 3 shows different settings for different values of duty cycles.

Calculations for duty cycles are given below

- 6A - 50A Amps

= Duty cycle x 0.6 Duty cycle

= Current in Amperes / 0.6

- 50A - 80A Amps

= (Duty Cycle - 64) 2.5 Duty cycle

= (Current in Amperes/ 2.5) + 64

C. *Proximity Pin*

The proximity circuit is present in both the J1772 plug and also in the Electric Vehicle’s charging module. Voltage divider circuit is used with resistors in Parallel and series to reach different measured voltages for each state. It senses whether the EV is in close proximity when plugging in. This is done via a clamp like button that changes voltage levels depending upon its own state. This can also be used to only provide output power to the J1772 plug when it is ensured by the system that the plug is indeed in proximity of the EV. This also provides safety in case if plug falls into a puddle of water so there is no shorting of the pins. Table *4* shows different states for the proximity pin.

Table 2: J1772 Pilot Signal Specification.

State	Pilot High	Pilot Low	Frequency	EV Resistance	Description
State 1	+12V	N/A	DC	N/A	Not Connected
State 2	+9V	-12V	1000hz	2.74k	EV Connected
State 3	+6V	-12V	1000hz	882	EV Charge
State 4	+3V	-12V	1000hz	246	EV Charge Vent. Required
State 5	0V	0V	N/A		Error

Table 3: J1772 Duty Cycle Specifications.

Amp	Duty Cycle	Amp	Duty Cycle
6A	10%	40A	66%

12A	20%	48A	80%
18A	30%	65A	90%
24A	40%	75A	94%
30A	50%	80A	96%

Table 4: J1772 Proximity Pin States.

State	Voltage on proximity pin
Not Connected	4.5V
Button Pressed	3V
Connected	1.5V

IV. CIRCUIT DESIGN AND SIMULATIONS

Circuit Design and Simulations are performed on Proteus 8 software. The three states of chargers are also explained using this software for better understanding. Ideal state, connected state, and charging state are all discussed briefly. A usual EV charging system structure having operational needs and requirements involving functional and dimensional requirements for the vehicle inlet and the J1772 Plug (mating connector) are also displayed. There are different states of EV's charger briefly describe given below

A. Ideal State

The control circuit design of our charging system. In the **Error! Reference source not found.**, show the

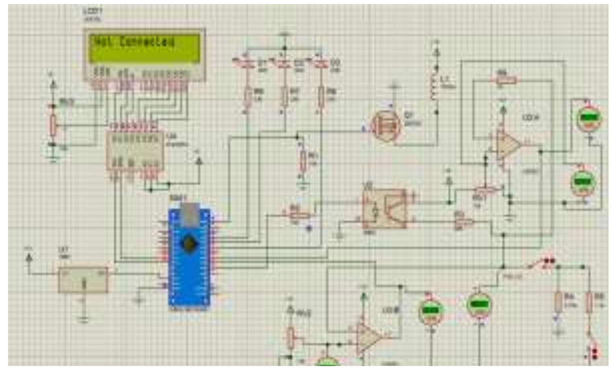

Figure 3: EV Charging System Schematic for Unplugged State.

ideal state (not connected state) that plug is not connected to the EV. Pilot pin having 12 volts in ideal state showing in Figure *4*. This state is then displayed on the LCD by the Arduino Nano Controller as "Not Connected" state. It can easily be observed from the schematic diagram in this case that pilot pin which is represented by a red switch is open indicating that the plug is not connected to anything. The resistors present on the right side of the switch represent the resistances present inside the charging port of the EV which are responsible for changing the voltage levels of the proximity pin thus allowing our system to transition into other states.

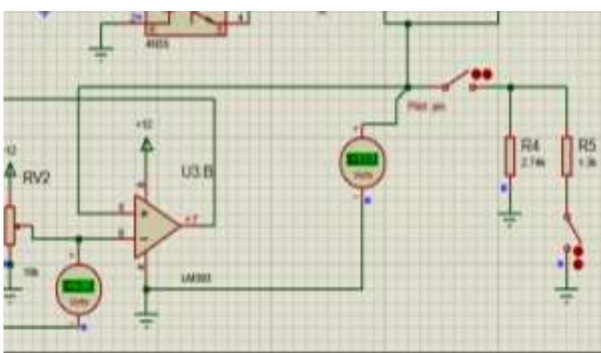

Figure 4: 12 volts showing on Pilot pin.

B. Connected State

When plug is connected to the EV the pilot pin switch can be seen as closed. The voltages drop on pilot pin from 12 to 9 volts due to 2.7k resistance attached in EV controller showing in Figure *5*

C. Charging State

In charging state when plug connected to the EV voltages drops down to 4-6 volts from 9 volts approx. and charge controller detects the voltages and switch the power relay shown in Figure 6. When the EV detects the plug is connected, then it gives the signal to a relay and relay terminal is closed and drop the voltages on pilot pin due to 1.3kΩ resistance attached to a relay shown in Figure 6.

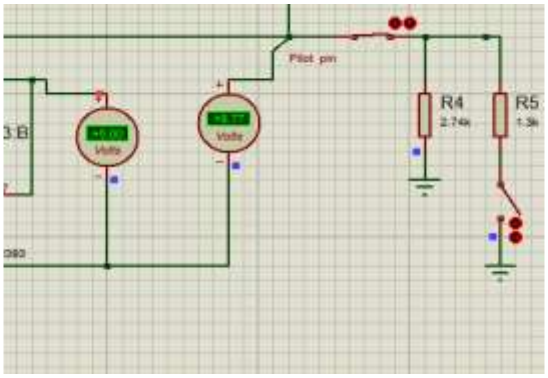

Figure 5: 8.77 volts showing on pilot pin in connected state.

It can be observed from Figure *4* and Figure *5* that the second switch on the EV's charging port end has also been closed finally allowing the voltage change to 4-6 Volts, triggering the signal from Arduino Nano Controller to the power relay allowing the EV to charge.

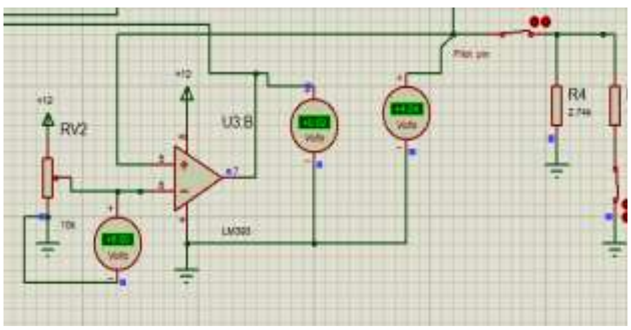

Figure 6: 4.04 volt showing on pilot pin in charging state.

D. Voltage drops on plug connection

We will connect the two resistances for testing the circuit according to the car controlling circuit. When the plug is connected to EV due to 2.7kΩ resistance already installed in the EV drop the voltages to 8-9 volts on pilot pin. If EV requires the charging then the relay is switched and due to 1.3kΩ resistance drop of the voltages occur to 4-6 volts and charge controller detects the voltages and switch the power relay. If EV is not required to charge, then no relay or power switching occurs and the charger doesnot change its state.

V. Hardware implementation

Hardware implementation and results obtained from testing are shown in this section. Hardware depends upon the four main parts Power supply, Controller, Boost converter and Protection relay. It is important to note that the controller circuit, the relay protection circuit and the on separate zero boards for easy identification and sectioning. Pictures of these components are given in this part of the report.

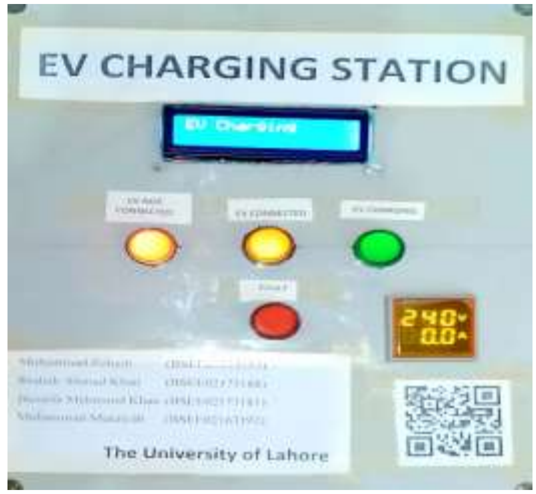

Figure 7: Charging station.

A. Controller

The controller checks the state of the charge either plug connected or not. When the plug is connected to the EV controller detected and check EV's required the charging or not. If EV required the charging, then controller switched the magnetic contactor and supply gives to EV. When EV charged fully then controller cut off the supply. And ESP32 used to monitor the status of EV charging when the plug is connected.

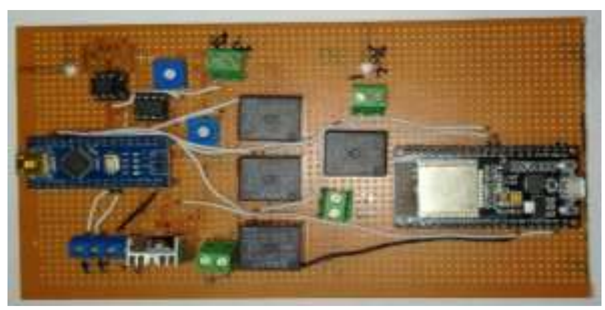

Figure 8:Controller Circuit for the EV charger.

B. Protection Relay

Relay is a protection device which operates automatically when a certain limit of current passes through it. The contacts of these relays close when triggering current flows which completes the circuit inside the relay causing breaker trip coil circuit to be completed, hence tripping separates the faulty part of the circuit from the healthy one. Relay REU 513 is used which is both a Under/Over voltage relay is a secondary relay that is used in conjunction with the voltage transformers of the object to provide protection. Phase to phase voltage wave is monitored b this relay. On detection of fault, the relay activates causing the trip coil circuit to form closing the circuit breaker, can power alarms, send notification, record data etc. Depending on the function and requirement the over-voltage version can be used which includes low-set stage U> and the sub-type which has high-set stage U>>, the under-voltage version having low-set stage U< and another sub-type having high-set stage U<<. can be used. Alternatively, the high-set under-voltage stage can be set to check the positive phase sequence voltage. In addition, the high-set under-voltage stage can be configured to evaluate only one instead of three phase-to-phase voltages. There are separate functions of these relays which work independently of each other and store data. Conventional voltage transformer measurement is done when these relays perform under-voltage and over-voltage sets. An output contact matrix directs starting or tripping waveforms from the protection zones to be routed to the desired output contact.

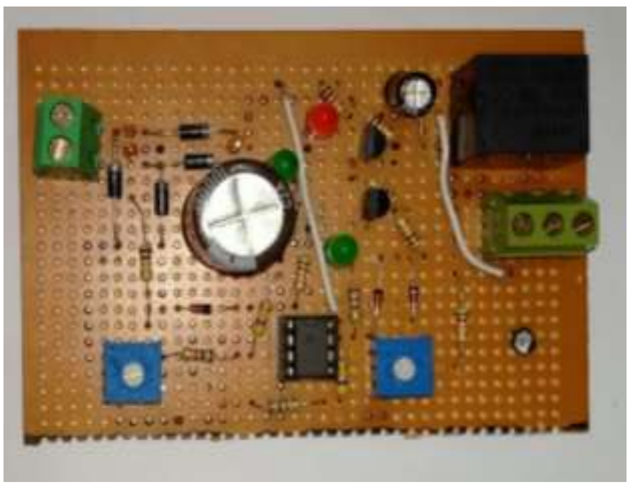

Figure 9: Protection relay circuit.

C. Results

Results obtained from hardware testing are as below

a) Ideal State

When the plug is not connected to the EV and the pilot pin have 12volt DC as shown the resultant simulation in the figure below. This state is the ideal state of EV's charger.

Figure 10: Ideal state oscilloscope waveform.

b) Connected State

When the plug is connected to the EV then square wave of +/- 9volt DC following in the pilot pin as shown the resultant simulation in the figure below. Controller check the EV response if charging is required or not in this state.

Figure 11: Connected state oscilloscope waveform.

c) Charging State

When EV has required the charging then give the charge request to the charger. Charger switched the magnetic contactor and gives to power of EV. In this state the pilot pin +/- 6volt DC response as shown the resultant simulation in the figure below. When the charging is complete then charger goes back in the connected state.

I. CONCLUSION

This research paper discusses the design and implementation of EV (Electric Vehicle) Charging stations in parking lots. We contemplate a couple of key components whilst finishing this association especially for a rustic like Pakistan. We similarly examine EV's importance to surroundings within the oncoming season of advancement and how it'll assist our normal population all matters taken into consideration. This work research and evaluates the short charging establishment and the made technique that could easy out the station gain whilst at this point giving a pursuing cost bring that the gas fee at corner stores. The version copies the fast-charging price for drivers at the station and differences and the residence past due night blaming and for the ice gas (diesel and fuel) at corner stores, for the Portuguese case. Speedy charging stations are one anticipated method for charging an EV in a speedy cooperation and whilst the driving force isn't always at home and has now not appeared at the intention. These stations are fundamental for the EV nonstop rate interplay and intend to act in essentially a similar way to a commercial enterprise gasoline corporation station.

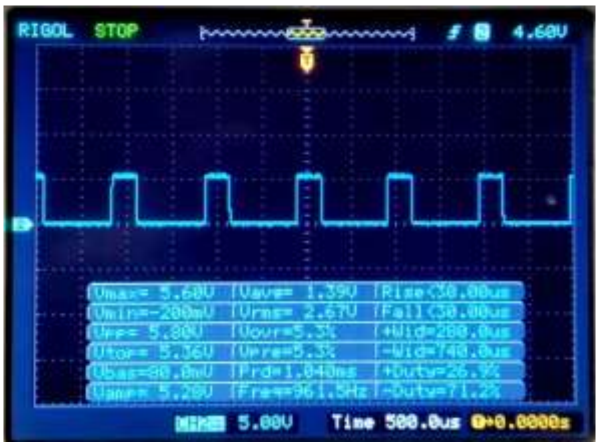

Figure 12: Charging state oscilloscope waveform.

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