ON-BOARD AND OFF-BOARD ELECTRIC VEHICLE CHARGING STATION

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Abstract—**The selection of charger for electric vehicles is a major task. It is important to select an appropriate rating of electric charger based on the load to be carried. The charger circuit consists of diode bridge rectifier, Buck DC-DC converter (chopper), single phase DC-AC inverter and transformer. The design and operation of all the components are discussed. Single phase DC-AC inverter is modelled and analyzed with different modulation techniques. From the comparison, the Simple PWM (SPWM) is chosen for our network. A simulation of charger circuit is carried out in MATLAB/SIMULINK and a model is built considering the simulation results. In this project we designing and developing 48V, 20A output on-Board charger, 72V & 48V, 40A output Off-Board charger along with battery safety by limiting current when battery temperature goes beyond the ambient temperature.**

Keywords—

I. INTRODUCTION

Due to the increase in the cost of fuels and pollution there has been a need for an alternative (electric vehicles) to conventional Internal Combustion engine powered vehicles. As electric vehicles are environment friendly, they are considered as Green Transportation. In an electric vehicle various components like motor, battery, charger, and controllers are used. While designing an electric vehicle the first and foremost component to be selected is an electric charger, it is because the Internal Combustion engines of conventional vehicles are replaced by an Electric Motor in an electric vehicle which requires power to run. Charging of an electric vehicles can be done in two ways i.e., ON Board and OFF Board charger.

ON BOARD CHARGER: The ON board charger,which is built in vehicle, handles this by converting the AC power into DC energy so that it can be stored in the battery.

OFF BOARD CHARGER: The OFF board charger which is outside the vehicle, supply a DC to the vehicle battery.

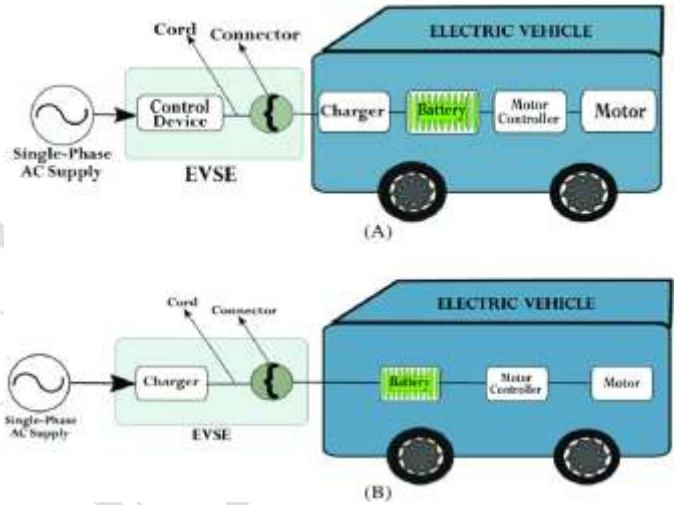

Fig. 1 (A) On board charger (B) OFF board Charger

II. CIRCUIT DIAGRAM WITH CALCULATIONS

A. RECTIFIER

Rectifier is an electrical circuit which converts Alternating current to Direct current. A Diode bridge rectifier is an arrangement of 4 or more diodes in a bridge circuit configuration which provides the same output polarity for either input polarity. Capacitor is used as filter in the circuit to remove the ripple

CALCULATION

Let Vin(ac) =230V, Idc =20A

Vm= Vin(ac)* √2=325.26V

Vo(dc)=2* Vm/ π=207V

So RL =Vo(dc)/I(dc)

RL=207V/20A =10.35ohm

Let Ripple factor, r = 0.01 or 1% and

Vo(dc) = 207V , Idc =20A

Ripple factor, r = 1 / (4√3fRLC)

Therefore C = 1/ (4√3fRLr)

Take C= 0.027F

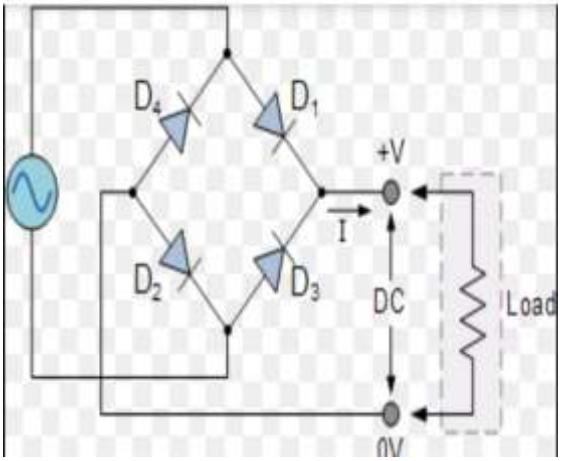

Fig.2 Rectifier circuit

B. DC-AC CONVERTER

DC-AC converter is also known as an inverter. It is an electronic device that changes direct current to alternating current. There are various classification of inverter techniques, this project involves single phase inverter with Simple Pulse Width Modulation (SPWM) technique.

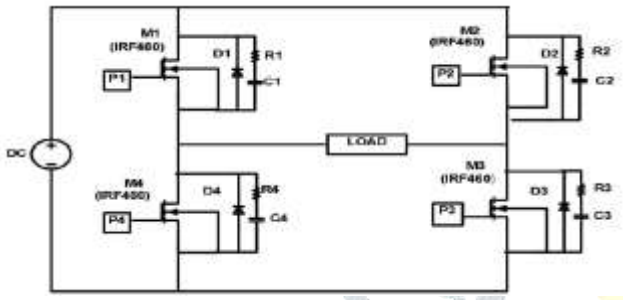

Fig. 3 DC-AC CONVERTER

CALCULATION

Input voltage=48V , R=50Ω

Pluse generator 1

Time period=50%

Switching frequency is 25kHz , so period=4*10-5s

Phase difference will be zero

Pluse generator 2

Time period=50%

Switching frequency is 25kHz , so period=4*10-5s

Phase difference will be 2*10-5s for 180° phase shift.

C. DC-DC CONVERTER

A DC-to-DC converter is an electronic circuit that converts a source of direct current (DC) from one voltage level to another. It is also known as buck-boost converter. We are using Buck converter. It has the benefit of low ripple content in input and output voltage, reduced peak current value and high ripple frequency. This leads to high efficiency and high reliability. As the converter operates at high frequency, the size and losses of the magnetic components can be reduced.

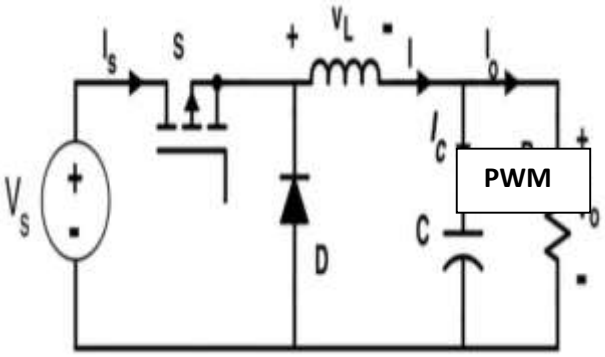

Fig. 4 DC-DC CONVERTER

CALCULATION

Vin=230V,Vout=72V,IL=20A,Fsw=25kHz

D=Vout/Vin =0.313

Iripple=0.3*I load = 6A

Inductor = (Vin–Vout)(D/Fsw)/Iripple

=(230-72)(0.313/25k)/6

=329.6µH

Capacitor min = Iout*D(1-D)*1000/Fsw*Vpmax

Vpmax = 1% of input voltage

= 2.3V

Cmin= 20*0/313(1-0.313)*1000/25k*2.3

=74.7mF

Cout=(1-D)/ ((△Vcout/Vout) 8L(nFsw) 2)

= 333.49µF

D. TRANSFORMER

A transformer is a static device that transfers electrical energy from one electrical circuit to another through mutual (electromagnetic induction) and without change in frequency.

We are using Isolating Transformer also called as 1:1 transformer, which is used to isolate the vehicle from the main circuit.

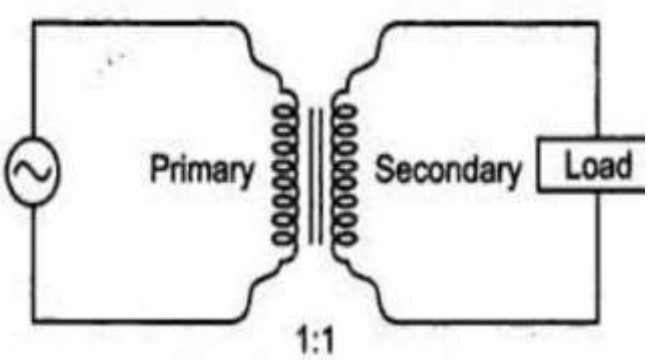

Fig.4 Isolation transformer

CALCULATION

For 48V,20A

VA=48*20=960VA~=1000VA

For 1KVA, Turns per volts=1.6 Therefore, No. of turns=1.6*48=76.8~=77 turns on both primary and secondary windings as we designing 1-1 transformer.

III. SIMULATION WITH RESULTS

A. SOFTWARE USED: MATLAB – SIMULINK

The MATLAB version of 6.1 and above can be used for the simulation. Simulink is a MATLAB-based graphical programming environment for modeling, simulating and analyzing multi-domain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multi-domain simulation and model-based design.

B. COMPLETE CIRCUIT CONSTRUCTED FOR THE SIMULATION

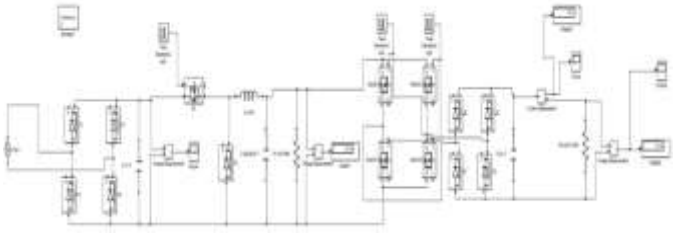

Fig.5 Simulation

We have constructed the complete circuit diagram of the electric vehicle charging station in the MATLAB-Simulink software for the simulation of the same and obtained the final output voltage and output current for the load to be given as per our calculations.

We will take AC 230v input and rectify it to 230v DC which will be provided to the buck converter which will step down to 72v DC, in inverter circuit we will be using two PWM to provide the alternating pulse and provide us 72v AC, here we are converting in to AC because of isolation purpose which will isolate battery from charging station with the help of isolation transformer (1 to 1 transformer). As we need DC voltage for charging the battery rectification will be done according to the calculation and finally we will have 48v and 20A output Charger.

C. SIMULATION RESULTS

The Simulation results obtained are as follows:

Voltage: 47.5V

Current:19.52A

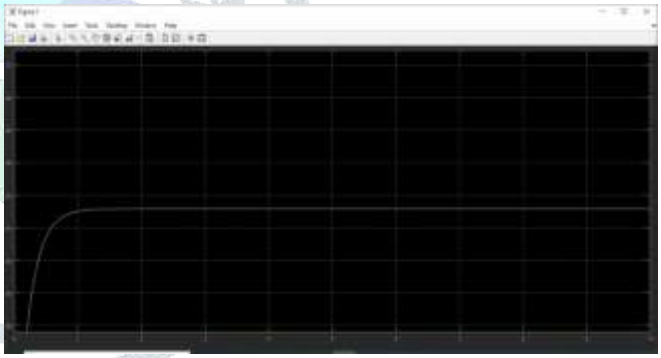

Fig.6 Voltage graph

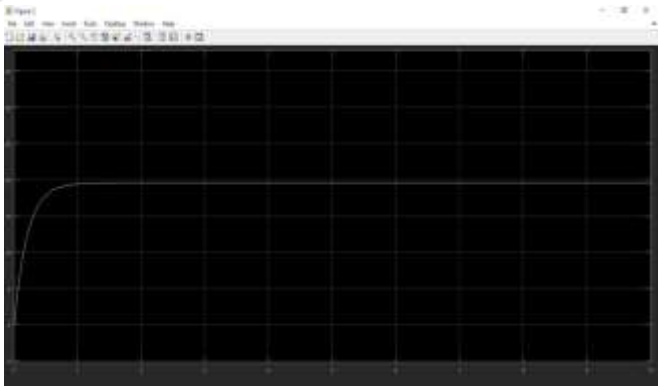

Fig.7 Current graph

IV. COMPONENTS USED

A. MOSFET

A MOSFET is voltage controlled field effect transistor. It has "Metal Oxide" at gate terminal which is insulated electrically from the main semiconductor p-channel or n-channel by a very thin layer of insulating material usually silicon dioxide, commonly known as glass. This thin insulated metal gate electrode can be thought of as a plate of a capacitor. The isolation of a controlling Gate makes input resistance of a MOSFET very high in the range of Mega-ohms (MΩ) region thereby making it almost infinite. As the Gate electrode is separated from the main current carrying channel "Zero current flows into the gate terminal" and just like the JFET, the MOSFET also acts as a voltage controlled resistor where the current flowing through the main channel between the Drain and Source is directly proportional to the input voltage. The MOSFETs has very high input resistance that can easily accumulate large amounts of static charge resulting in the MOSFET becoming easily damaged unless the MOFETs are carefully handled or safely protected.

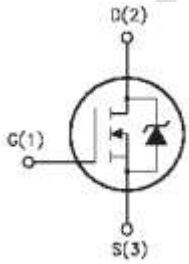

Fig .8 Internal schematic Diagram of MOSFET

1) Types of MOSFET

Different types of MOSFETs are available in market.

- N-Channel Depletion.
- N-Channel Enhancement.
- P-Channel Depletion.
- P-Channel Enhancement

2) MOSFETS USED IN OUR PROJECT

The MOSFETs used in our project are n-channel enhancement type of model series. Enhancement type of MOSFETs are MOSFETs that are normally off devices. When you connect an enhancement type of MOSFETs, no current flows from drain to source when no voltage is applied to its gate. This is why it is called a normally off devices. The current flow without gate voltage. We used model of MOSFET IRF 460 in our project for the chopper circuit and the inverter circuit

3) FEATURES

i. Continuous Drain Current: 21A
ii. Maximum Power Dissipation: 300W
iii. Linear Derating Factor: 2.4 W/°C
iv. Pulsed Drain Current: 84A
v. Gate-to-Source Voltage: ± 20V
vi. Drain-to-Source Breakdown Voltage: 500V
vii. Avalanche Current: 21A
viii. Min Gate Threshold Voltage: 2.0V
ix. Max Gate Threshold Voltage: 4.0V
x. Min Operating Temperature: -55°C
xi. Max Operating Temperature: 150°C

B. DIODE

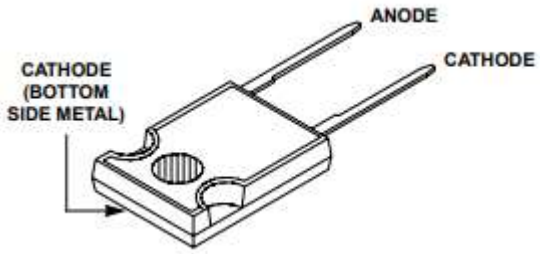

Fig .8 Schematic Diagram of diode

A diode is a static device that allows the flow of current only in one direction and avoids the flow of current in the opposite direction. The most commonly used diodes in current circuit design are the semi-conductor diodes, even though additional featured diode technologies are present in the market. When a diode is positioned in a simple battery light circuit, then the diode will either permit or restrict flow of current through the light, all this depend on the polarization of the volts applied. There are different types of diodes but their fundamental role is identical. The most commonly used diode is silicon diode; it is placed in a glass cylinder.

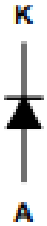

Fig.9 Pin diagram of diode

1) DIODE USED IN OUR PROJECT

The diode used in our project is named as diode model number of RHRG3060. The diode model RHRG3060 are hyper fast diodes with soft recovery characteristics. They occupy half of the recovery time of the ultrafast diodes and are of silicon nitride passivated ion-implanted epitaxial planar construction. These diodes are especially used as freewheeling, clipping, clamping diodes and rectification process in a variety of switching power supplies and other power switching applications. Their low stored charge and super-fast soft recovery lowers ringing and electrical noise in many of the power switching circuits, thus decreasing power loss in the switching circuits.

2) APPLICATIONS

i. Switching Power Supplies.
ii. Power Switching Circuits.
iii. Rectification.
iv. Clipping and clamping circuits.

3) FEATURES

i. Hyper fast with Soft Recovery : <40ns
ii. Peak Repetitive Reverse Voltage: 600V
iii. Working Peak Reverse Voltage: 600V
iv. Average Rectified Forward Current: 30A
v. Repetitive Peak Surge Current: 70A
vi. No repetitive Peak Surge Current: 325A
vii. Maximum Power Dissipation: 125W
viii. Avalanche Energy: 20mJ
ix. Min operating temperature: -65°C
x. Max Operating Temperature: 175°C

C. PULSE TRANSFORMER

A pulse transformer is a transformer that is enhanced to produce electrical pulses with high velocity, as well as stable amplitude. These are regularly employed while transmitting digital information as well as in transistors, mainly in gate drive circuits.

Fig.10 Pulse-transformer

A pulse transformer is also called as trigger transformer, gate drive transformer, gate transformer, signal transformer (or) wideband transformer in some applications, a. The main function of the Pulse transformer is to transmit voltage pulses between windings and the load. These transformers are used for galvanic isolation (signal transmission), low-power control circuits, & the major components used in the high-power Switch Mode Power Supply (SMPS). By using this transformer, amplitude in the voltage pulses can be changed; the polarity of the pulse can be inverted, coupling different stages in the pulse amplifier and an isolation transformer. The construction of a toroidal shaped pulse transformer is shown as shown below. The main objective of this transformer is to produce a pulse for semiconductor devices as well as provides electrical isolation.

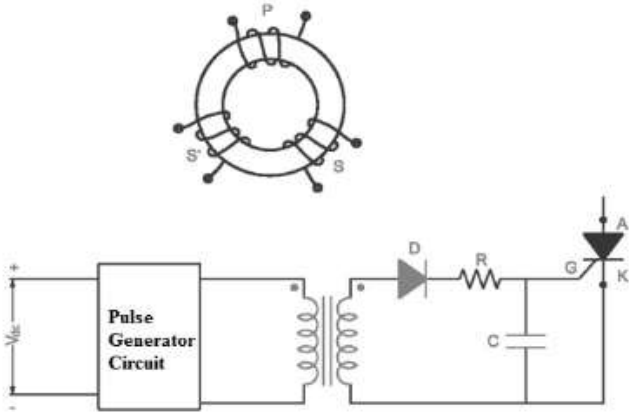

Fig.11 Pulse-transformer construction

1) ADVANTAGES

i. Small size
ii. Less cost
iii. Operates at high frequency
iv. Isolation voltage is high

2) DISADVANTAGES

i. At low frequency, both the primary and secondary waveforms are different from each other.

ii. Saturation current of the core can be reduced because of DC through the primary winding.

3) APPLICATIONS

i. The uses of this transformer include the following.

ii. Signal pulse-transformers are used in telecommunication, digital circuits

iii. Power pulse-transformers are used to isolate power circuits from the control circuit.

iv. High voltage pulse-transformers are used in radar application & pulsed power applications.

v. Power electronics

vi. Radars

vii. Digital electronics

viii. Communication

D. OPTOCOUPLERS

Optocouplers provides electrical isolation between an input source and an output load. There are four types of optocouplers, each one having an infra-red LED source but with different photo-sensitive devices. The four types of optocouplers are named as: Photo-transistor, Photo-Darlington, Photo-SCR and Photo-triac .

Fig.12 Optocoupler

1) DESIGN OF OPTOCOUPLER

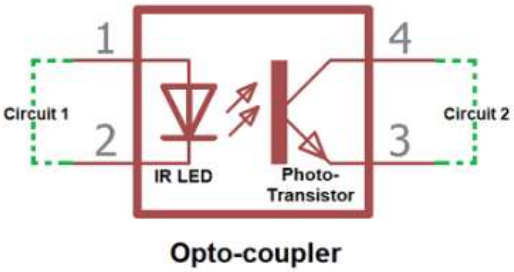

Fig.13 Design of Optocoupler

A photo-transistor device is as shown above. Current from the source signal flows through the input LED which produces an infra-red light whose intensity is proportional to the electrical signal.

This emitted light falls upon the base of the photo-transistor, resulting in switching ON and conducting in a similar way to a normal bipolar transistor.

The base connection of the photo-transistor can be left open (unconnected) for maximum sensitivity to the LEDs infra-red light energy or connected to ground via a suitable external high value resistor is used to control the switching resulting it more stable and resistant to false triggering by external electrical noise or voltage transients.

When the current passes through the LED is stopped, the infra-red emitted light is cut-off, causing the photo-transistor to cease conducting. The photo-transistor can be used for switching current in the output circuit. The spectral response of the LED and the photo-sensitive device are closely matched being isolated by a transparent medium such as glass, plastic or air. Since there is no direct electrical connection between the input and output of an optocoupler, electrical isolation up to 9kV is achieved.

2) APPLICATION

i. Microprocessor input/output switching.

ii. DC and AC power control.

iii. PC communications.

iv. Signal isolation.

v. Power supply regulation.

E. HEAT SINK

A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing efficient regulation of the device's temperature. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature.

Fig.14 Heat sink

V. FUTURE SCOPE AND CONCLUSION

As there is synchronization between the electric motor and ICE propulsions, less petrol consumption can be seen with less charging cycle of batteries (long life per charge).If one vehicle can save about an average of 30% of petrol fuel, then an average of about 40%-60% of national fuel can be conserved by using this type of vehicle. Also electric bill can also be saved, as the batteries last long per charge. An idea of charging the batteries through ICE can also be implemented here. In this project we have designed 960W power output charger as a result we have obtained the same i.e.,48V 20A.Weight, space issues, and cost constraints are the main reasons to limit power for on-board chargers, in charging circuit transformer weight is high for that reason we have eliminated the transformer. But in future we will try to replace pulse transformer with any other isolation device.

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