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Compensation and Modelling of Hybrid Electric Vehicle Charger and Study the Simulation Results

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ABSTRACT: The Plug-in Hybrid Electric Vehicles are driven by the energy stored in the battery. Electric vehicle supply equipment(EVSE) is connected to Electric vehicle(EV) for charging the battery through conductive charging method. Apartfromchargingitcanalsohelpincreatingtrustworthyequipmentgroundtrackandexchange control data among EV and EVSE. This paper discusses the electrical and physical interface between EV and EVSE to facilitate conductive charging and design of an on-board charger for fast charging of the hybrid electric vehicle. This project aims to design an interfacingsystembetweenEVandEVSEasperautomotiveindustrystandard and a prototype of a 3.45 kwon board charger using Matlab software. By modeling the charger, charging of Li-ion battery can be done which is used for providing propulsion torque and through various stages of charger voltage and current level is controlled and make the desired for charging.

KEYWORDS: Control Pilot Circuit, Electric Vehicle(EV), Electric vehicle supply equipment(EVSE), International Electro-Technical Commission(IEC), International Standard Organization(ISO), PluginhybridElectricvehicle(PHEV), Power factor corrector(PFC).

I. INTRODUCTION

It is necessary that alternating sources for oil reserves that are exhaustible in future need to be found. Due to combustion of oil, it will create environmental pollution problem[4].Most of the vehicles now aday are dependent on internal combustion engine for their operation which is cause of worry because they are responsible for air pollution so, vehicle manufacturers now a day are looking for alternative sources that can reduce pollution. Due to arising problem of pollution plug in hybrid electric vehicles are very essential forthe future [4]. The Hybrid electric vehicle consists of two propulsion sources that are an electrical motor and internal combustion engine. Electrical road vehicle derives all part of their energy from onboard battery[1].On- board chargers are mounted within the vehicles and designed to operate only on the vehicles.

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Road vehicle derives all part of their energy from on board battery[3]. According to automotive industry standard. IEC and ISOstandards provide such protocols that are responsible for the startof charging of battery in the electrical vehicle.IEC protocols are applicable to the EVSE side and ISO it will automatically have interlinked with EVSE and it will inform the driver that vehicle is ready for charging and after charging is done it will automatically notify the driver for bill payment.

II. TERMS FOR CONDUCTIVE AC CHARGING

A. ACLEVEL1CHARGING

A method that permits an EV/PHEV to be coupled to the most common chastised electrical receptacles [2]. The vehicle shall be tailored board charger accomplished of accepting energy from the prevailing single phase alternating current (AC) source network.

B. AC LEVEL 2 CHARGING

A technique that uses devoted ACEV/PHEV supply equipment in any private or public locations. The vehicles hall be fitted with an an on-board charger accomplished of accommodating energy from the single phase alternating current(AC) electric vehicle supply equipment.

C. CHARGER

These are the power converters that are used for charging the battery of the hybrid electric vehicle(HEV). There are two types of chargers that are basically used that are the on-board charger and the off-board charger. These chargers are capable of accepting energy from the existing supply network.

D. CONNECTOR

A conductive device that is connected to the vehicle inlet to establish an electrical connection to the electric vehicle for the purpose of transmitting energy and swapping information. This is part of the coupler

E. CONTROL PILOT

The control pilot circuit will ensure proper operation when EV is connected to EVSE. Control Pilot is the main regular to the conductor and is coupled to the equipment ground over control circuitry the vehicle and accomplishes the following functions[8]:

i. Authenticates that the vehicle is standing and connected.
ii. Allow energization/de-energization of the supply.
iii. Transfers supply equipment currents reading to the vehicle.
iv. Observe the availability of the equipment ground.
v. Create vehicle ventilation necessities.

F. AC SLOW CHARGING PROCESS

Slow charging procedure basically requires phase supply and the desired current rating is approx.(14-15) A.IEC60309connectorsocketshouldbeusedduring this process.

G. AC FAST CHARGING PROCESS

Slow charger procedure basically requires a three-phase supply and the desired current rating is approx.(63-64)A. Due to this IEC 62196connectorsocketduring this process.

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H. ELECTRIC VEHICLE SUPPLY EQUIPMENT(EVSE)

EVSE is considered as an electrical grid that are used for supplying AC supply to Electric vehicle for charging. EVSE act as a charging station it consists of the conductor, plugs, electric vehicle connectors and appliances that are used for delivering power to electric vehicles [5].

H. GENERAL CONDUCTIVE CHARGING

The permission of charging of PHEV battery through EVSE is accomplished through electrical and mechanical parameters. The first process should be started with a rectification process in which AC to DC conversion takes place. Again it should be necessary to control EVSE voltage to a level that provides desired charging rate according to battery charge level property e.g. voltage and other variables above discussed part comes under electrical. Now under mechanical parameters consider physical connection between EV and EVSE which can bed one by the user itself [4].

I. GENERAL CONDUCTIVE CHARGING

The permission of charging of PHEV battery through EVSE is accomplished through electrical and mechanical parameters. The first process should be started with a rectification process in which to DC conversion takes place. Again it should be necessary to control EVSE voltage to a level that provide desired charging rate according to battery charge level property e.g. voltage and another variable the above discussed part comes under electrical. Now under mechanical parameters consider physical connection between EV and EVSE which can be done by the user itself [4].

J. RETAINING DEVICES

A mechanical system which clutches a plug or connector in a place when it is in appropriate contact and avoids accidental dis-connection of the plug or connector

K. SURFACE TEMPERATURE LIMITS

It is necessary to maintain surface temperature limits of EV and EVSE for fault free charging cycle. The surface temperature limits are different for different types of materials for example for metallic and non-metallic parts that are come in direct touch with the user have temperature limit of 45 degrees for metallic part and 56 degrees for non metallic

L. ON-BOARD CHARGER On-board

chargers are mounted within the vehicles and designed to operate only on the vehicles. These chargers are used for charging the battery in EV by converting AC supply in DC.

III. CHARGING CONTROL BY CONTROL PILOT CIRCUIT

The sequence of charging through which EV is charged through EVSE can be explained by control pilot circuit. This circuit will give us detail understanding of how different states of charging takes place

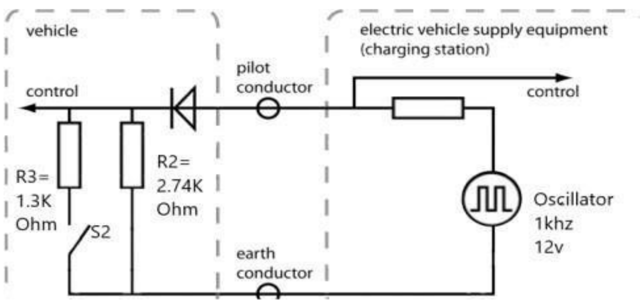

Fig.1. Control pilot circuit

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From Table.1 it is clear that vehicle should operate in seven states and with the help of control pilot circuit working of each state is eexplained. In case of state S1, there is no connection between EV and EVSE so voltage of 12V is appeared along the terminal of EVSE as it was supplied by the oscillator according to figure.1. Similarly, in case of S2 and S3 EV is connected to EVSE but either EV or EVSE is not ready to accept energy this is due to the fact that checking of connection parameters are under process during this interval for flap connection now in this case the terminal voltage of EVSE and EV is 9V as the diode is forward biased and resistance R2 is connected. In state S4 and S5 switch 2 is closed and the vehicle is ready to take energy for charging. For state S6 and S7 EVSE is detached from the vehicle intentionally or unintentionally. Interfacing between EV and EVSE can be done according to IEC 61851 standards and once interfacing is done then ISO 15118 standard should provide such a feature that charging should be done automatically.

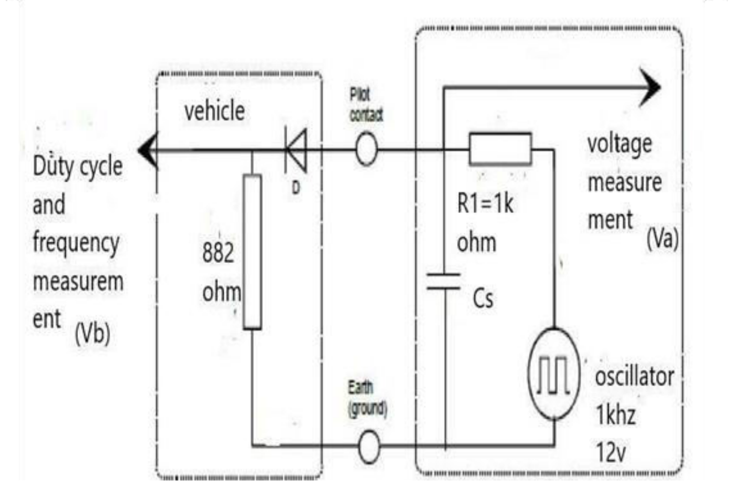

Fig.2. Simplified control pilot circuit

TABLE 1
ELECTRIC VEHICLE SERVICE EQUIPMENT STATES

State designation	V EVSE (DC)	V Vehicle (DC)	EVSE States
S1	12	0	Connection between EV and supply grid not done.
S2	9	9	EV connected to electric grid but grid not ready to supply energy.
S3	9	9	Electric grid ready to supply energy but EV is not ready to take energy.

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S4	6	6	EV coupled and ready to take energy from grid charging ventilation not needed.
S5	3	3	EV coupled and ready to take energy charging ventilation Required.
S6	0	0	EVSE detached from vehicle.
S7	-12	-12	Other EVSE problem

DESIGN OF CHARGER

IV. DESIGN OF POWER FACTOR CORRECTOR

The Fig.3 Shows Block diagram of the on-board charger which is used for charging the propulsion battery of electric vehicle. on- board charger consists of two stages that are power factor corrector(PFC) and DC-DC Converter. Power factor corrector consists of AC-DC rectifier and boost converter [6]. The main purpose of PFC is to improve the power factor so that total harmonic distortion will be reduced and to make current wave form sinusoidal. This can also help in improving the efficiency of the on-board charger and reduces losses during operation of the on-board charger [1]. Fig.4 shows circuit diagram of on-board charger.

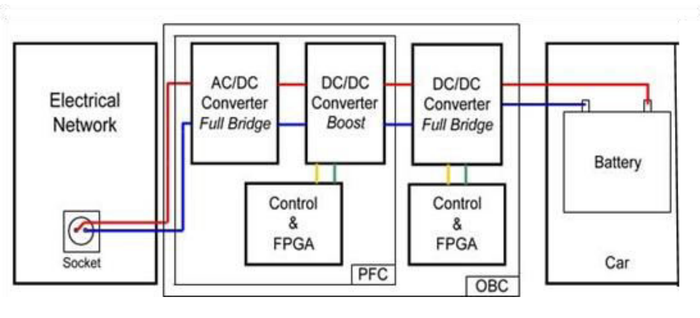

Fig.3. Block diagram of on charger

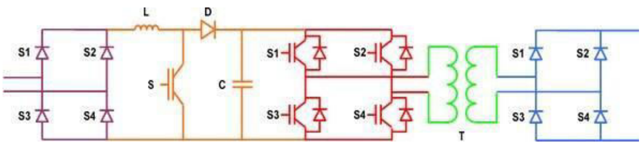

Fig.4. Circuit diagram of on-board charger

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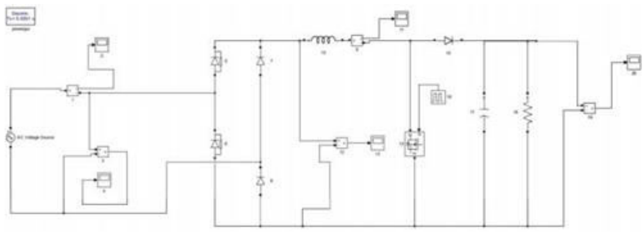
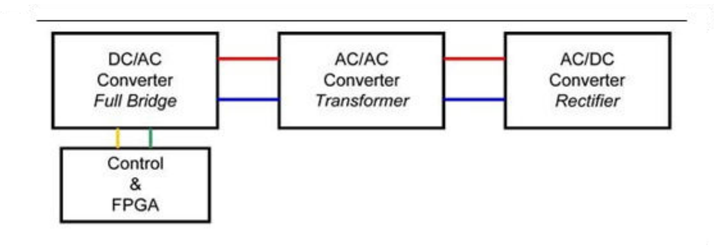


Fig.5. Simulink model of pfc

A. DESIGN OF DC-DC CONVERTER

The Fig.7 Shows the Matlab Simulink model of DC-DC Converter. The design of this converter depends on transmitted power and the requirement of step up or stepdown converter and whether the isolation required or not.it will supply desired value of voltage or current to the battery for charging [4].



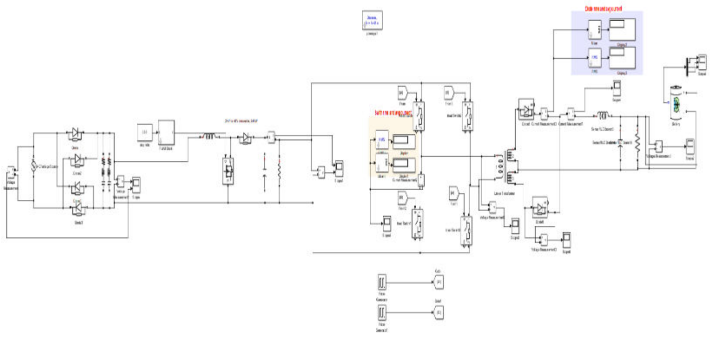


Fig.7.Simulink model of Pfc

Circuit diagram of the on-board charger is shown in fig.4 and its block diagram is shown in figure.3. According to block diagram of the on-board charger, it is clear that the charger consists of two parts first part is power factor corrector and the second part is DC-DC full bridge converter. Simulink model of on-board charger is shown in fig.5 and fig.7. Simulink model of power factor corrector is shown in fig.5 which consists of rectifier bridge for converting ac supply from the grid in to dc and this dc is then supplied to boost converter this arrangement is combined together to form power factor corrector. The main purpose of PFC is to make voltage and current wave form sinusoidal [4]. Simulink model of DC-DC full bridge converter is shown in fig.7 which consists of full bridge inverter, isolation transformer and full bridge rectifier the output of this is transferred to the battery for charging purpose. According to fig.5 and fig.7 the working of the on-board charger is explained and the plotting of waveforms for different parameters can be done. The battery that is used in hybrid electric vehicles are generally Li-ion battery due to their high efficiency and longer life [7].

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A. ELECTRICAL CHARACTERISTICS OF ON- BOARD CHARGER
Input power(Pi) = 3.45 kw
Supply input voltage(Vi) = 230V
Maximum supply voltage(Vm) = 325.22
Frequency =50 Hz
Power factor(PF) = 1 A.
ELECTRICAL CHARACTERISTICS OF POWER FACTOR BRIDGE
Input current (Iin) = Pi /Vi*PF
= 3.45k 230*1
= 15A.
Output bridge voltage = 207V(DC)

B.PFC BOOST CONVERTER CHARACTERISTICS
Output voltage of boost converter(V0) = 450+/-3%
Output current in Boost converter(Io) = 3.45k 450 =7.66A
Inductor(L) = Vout 4*Fswi*¨I
Where ¨I = 20% of peak input current ¨I = 0.2*1.414*15 = 4.3
A L = 450
C = VmIm 4*20k*4.3 2* ¨
Vout*w*Vout = 1.25mH = 2.17mF
Where w= ¥1/LC and Fswi = 20khz

C.DC-DC CONVERTER CHARACTERISTICS
From simulation results it is determined that according to battery, the output voltage of DC-DC full bridge converter varies from 324V to 330 V while the output voltage of boost converter is 450V this can be clearly seen in fig.3 and fig.4. So, output current can vary from 10.7A to 10.5 A. Since, Iout = 3.45k =10.7A 324 and Iout = 3.45k = 10.5 A 330 Iout(max) = 3.45k = 15A

D.TRANSFORMER FOR FULL BRIDGE CONVERTER

Transformation Ratio = 1
Input Voltage = 450V
Input current(max) = 15A
Frequency = 20khz

E. FULL BRIDGE CONVERTER RECTIFIER

Max diode current = 15A
Frequency = 20khz
Battery that is used in the model is Lithium-ion battery whose voltage Vary between 324V to 330V and with the help of simulation, Variation of voltage and current for charging the battery can be determined.

V. SIMULATION RESULT

In the AC conductive charging method of the hybrid Electric vehicle, the states of the vehicle during which charging is possible is determined and it also discusses all those states during which charging is not possible. By simulating different stages of the onboard charger, graphs of different parameters can be plotted and it is helpful in determining the behavior of various stages of the charger and it shows whether theoretically designed parameters are accurate or not.

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A. WAVEFORMS FOR POWER FACTOR CORRECTOR

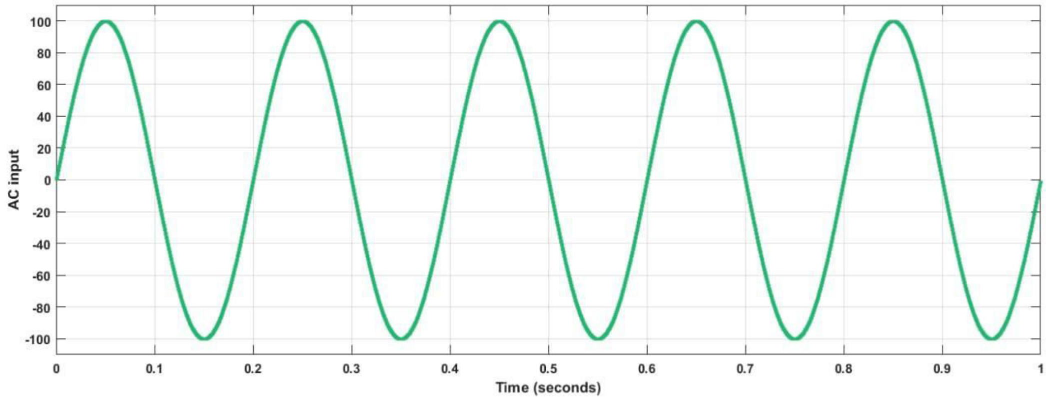

Fig.8Input voltage of PFC with time

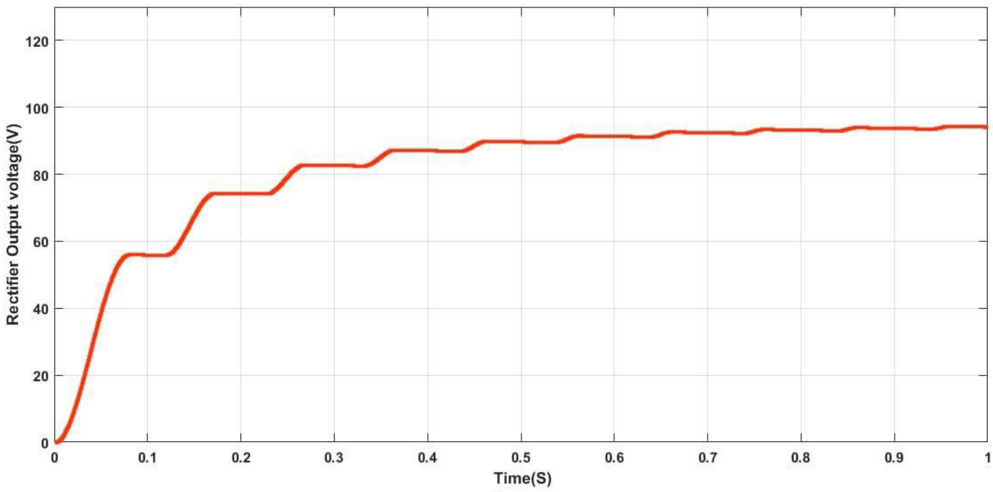

Fig.9. Variation of input current of PFC with time without inrush current solver.

From Fig.9 it is clear that high inrush current is present in the input current waveform this is due to the load capacitance effect this can be solved by using an in-rush current solver in which resistance is connected between the grid and rectifier bridge which can control the input current when current reaches steady state value then resistance is shunted by the breaker [6].

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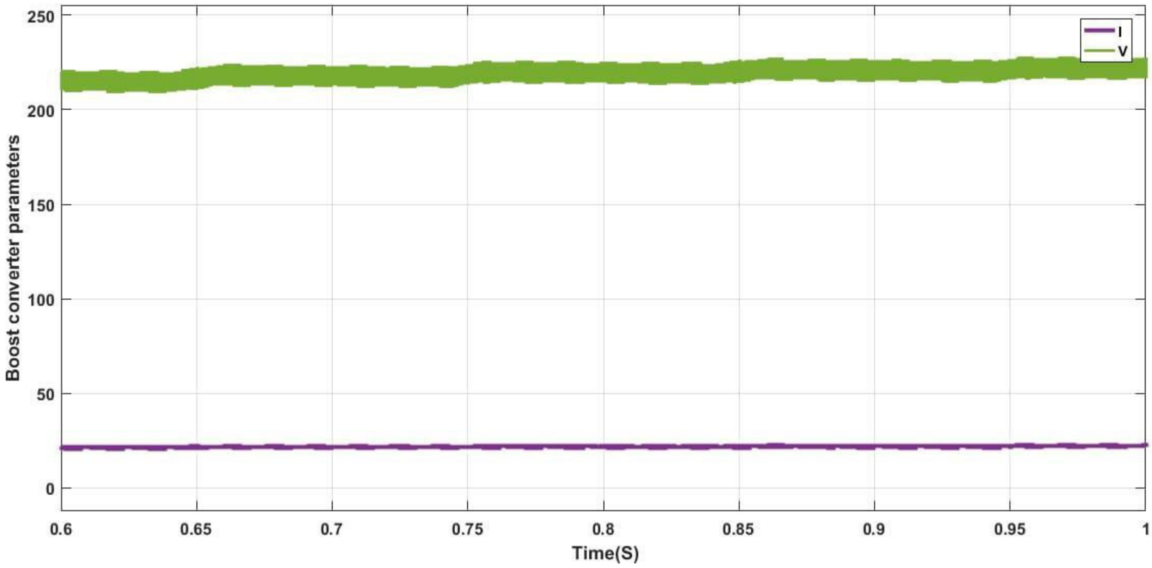

Fig.11. Output voltage of Boost converter

B.WAVEFORMS OF DC-DC CONVERTERS

In case of DC-DC Converters analysis of transformer, inverter and full wave rectifier converter can be done. In this section variation of battery voltage and battery current will be discussed.

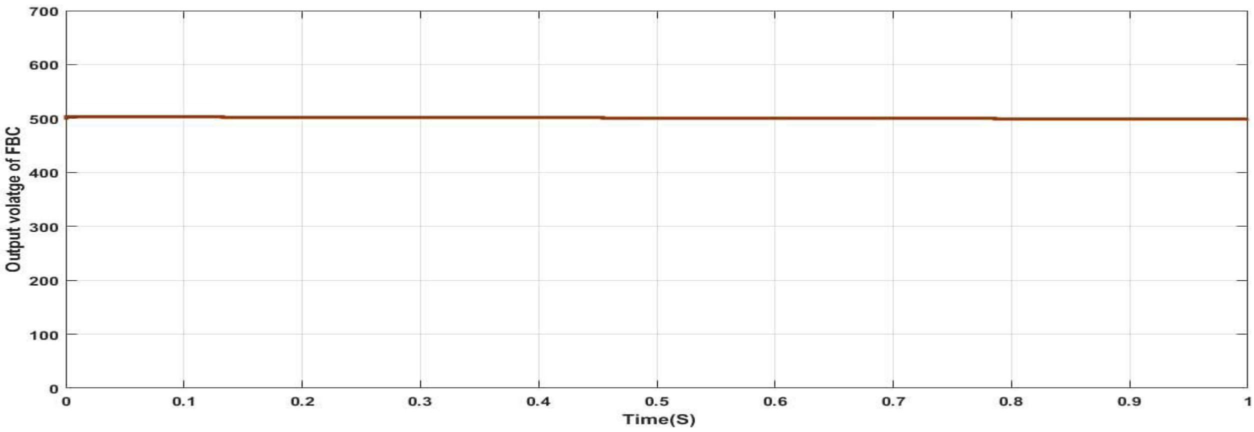

Fig.12. Voltage across transformer primary winding

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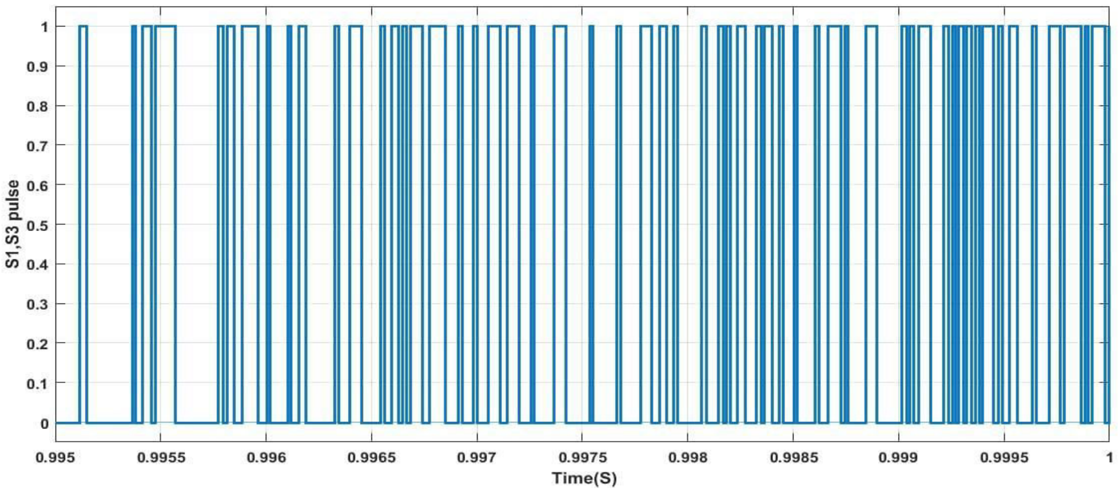

Fig.13. S1,S3 pulses when given to transformer

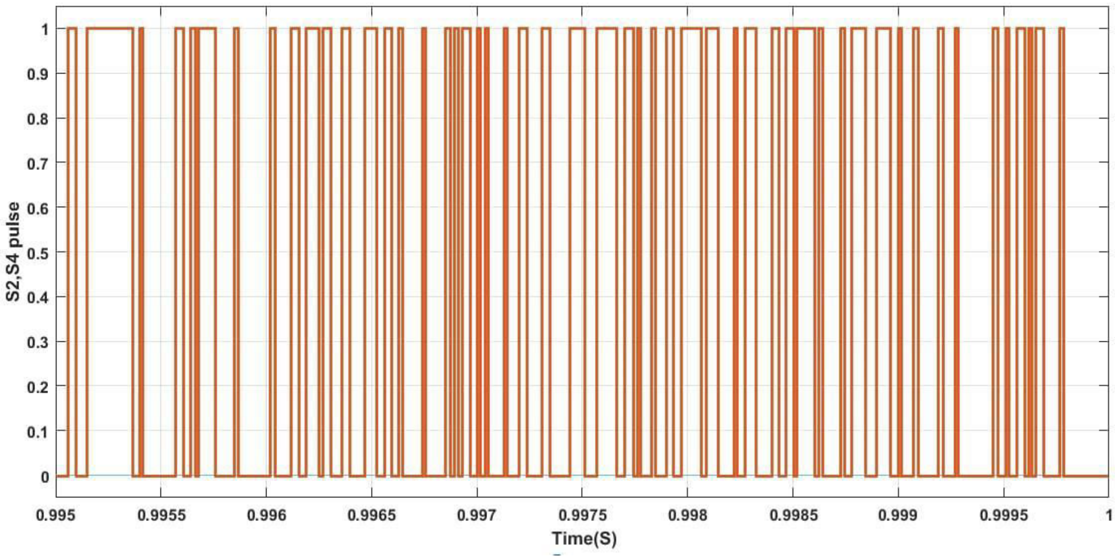

Fig.15. pulses of S2,S4 when given to transformer

Fig.8 shows the sinusoidal input voltage which is applied to input of PFC for converting ac in to dc by using rectifier circuit. In fig.9 spikes of inrush current is observed at the input of PFC which can be avoided by connecting resistance of proper value along with the breaker at the input side of supply which can reduces the spikes of inrush current and sinusoidal wave form of input current is obtained as shown in fig.10.After reducing the inrush current breaker should shunt the resistance.Fig.11 shows the output voltage of boost converter which is approximately 450 volts. In fig.12 and fig.13 variation in primary voltage and primary current of the transformer is shown in which it is observed that frequency is low as 10 HZ this is due to insufficient or low value of inductive reactance which can be improved by selecting proper reactance value. According to fig.14 and fig.15 the voltage and current required for charging Li-ion battery is determined.

VII.CONCLUSION

As the use of electrical vehicles are increasing day by day so their charging system must be robust and reliable so that one can use electric vehicles without any problem. The paper presents conductive AC charging protocols for charging the plug in hybrid electric vehicles. In this paper theory of conductive charging is investigated and complete analysis of the on-board charger is done due to which one should able to verify the valid states for the start of charging and the

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range of maximum current limit is determined by the duty cycle. This paper shows how one can design conductive charging system as per automotive industry Standards.

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