International Journal For Technological Research In Engineering
Volume 7, Issue 7, March-2020 *ISSN (Online): 2347 - 4718*

SIMULATION OF CONVERTER CONTROLLED ELECTRICAL VEHICLE CHARGING SYSTEM

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Abstract: Limited fossil fuels focused the entire world for developing new Renewable energy sources for electricity generation. The use of vehicles based on petrol and diesel fuels are also focused to develop electrical vehicles. The only challenge for Electrical Vehicle (EV) is to develop charging system with fast rate of charging. This paper proposes an innovative integrated bidirectional converter with a single-stage on-board charger to reduce the number of switches, size, and weight of the power electronic interfaces. The multifunctional electronics devices interfacing provides reliable and efficient charging system for EV. In majority of EVs, a bidirectional dc/dc converter is deployed between the battery and propulsion machine inverter. This converter is responsible to boost the battery voltage and efficiently control the delivered or absorbed power during cruising and acceleration or regenerative braking, respectively. In this conventional structure, the bidirectional dc/dc converter is only operated during propulsion and an individual ac/dc converter is utilized to charge the battery.

Keywords: EV, HEV, Power Charging, electrical vehicle to Grid,etc.

I. INTRODUCTION

Presently, developing new types of energy conversion and storage systems is becoming evident because of increasing human population and thus greater reliance on energy-based devices for survival. Due to the rapid increase in the world population and economic expansion geometrically, this is bringing about rapidly diminishing fossil fuels and the continuously growing environmental concerns as greenhouse gas emissions. Furthermore with the technological advancements in this modern era, more electronic devices are being used to replace manpower thus leading to a further increase in energy consumption.

The necessity for a better fuel economy and further reduction in greenhouse gas emissions is pushing automotive industry to go through a comprehensive restructuring to electrify the vehicles and introduce plug-in hybrid electric vehicles (PHEVs) and electric vehicles, cumulatively called plug-in Electric vehicle (PEVs). The electrical powertrain of current and upcoming PEVs is composed of an energy storage system connected to propulsion machine through an inverter. In addition, an add-on battery charger is inevitable part of vehicle powertrain. In majority of PEVs, a bidirectional dc/dc converter is deployed between the battery and propulsion machine inverter. This converter is responsible to boost the battery voltage and efficiently control the delivered or absorbed power during cruising and acceleration or regenerative braking, respectively. In this conventional structure, the bidirectional dc/dc converter is only operated during propulsion and an individual ac/dc converter is utilized to charge the battery. Regardless of the converter topologies, this architecture consists of two individual power electronic converters for two independent operation modes. An efficient solution to make the system more compact, lighter, and cost efficient would be integrating the add-on charger unit with the bidirectional dc/dc converter, which is used during cruising and acceleration. The basic power electronic interfaces rendering volume and weight of electric and plug-in hybrid electric vehicles are an inverter, an on-board charger, and a bidirectional dc/dc converter.

The aim of this paper is to design and evaluate a charging algorithm that will prioritize EVs and fill some faster than others. This approach can be utilized by private businesses to categorize and lower the fees for charging, making EVs more attractive economically. The scenario considered for this paper is an office building parking lot that is shaded by solar photovoltaic (PV) panels. This paper discussed Time-multiplexing method, a strategy to charge EVs from solar energy.

This method proved to be successful by simulation and experiment in charging EVs different amount of energy based on priority. Further investigation of this method can be carried to reduce the charging cycle time, and study the effect of constant switching on the battery lifetime.

II. PROBLEM IDENTIFICATION AND OBJECTIVES

The overall electric powertrain with a single integrated power electronic converter is illustrated in Fig. 1. In this structure, the charger and the bidirectional dc/dc converter share the same power stage as charging and propelling do not happen at the same time. As a result, overall cost, weight, and volume of the power electronic converter can be reduced effectively through reducing the number of switches, sensors, and large volume energy storage elements such as inductors.

In this regard, this paper proposes a new integrated single-stage charger topology for PEVs, which can also be used in retrofit conversion of an HEV to a PHEV. The proposed converter uses minimum circuit components offering a further cost-effective solution in comparison to the other integrated charger topologies presented in the literature review. With the boost charging capability, it enables operating with wide single-phase charging voltage ranges including 120/220/240 VAC, considering the battery voltage is between 300–400 V, which is the case in Chevy Volt. In addition, it is capable of stepping up and stepping down the voltage in both power flow directions during cruising and acceleration, as well as regenerative braking.

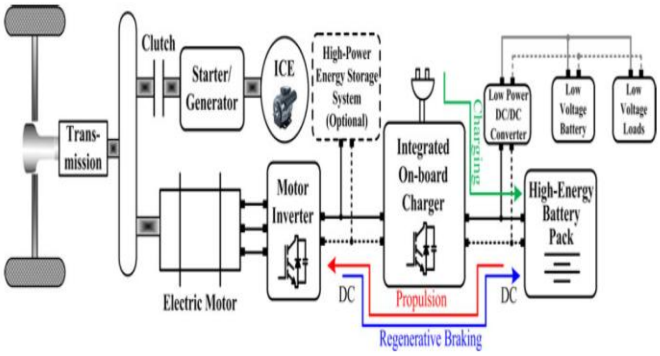

Fig. 1. System level structure of a parallel powertrain PHEV with on-board integrated battery charger

This paper is organized as follows:-

- The advantages and motivation of using an integrated charger and a bidirectional dc/dc converter in the powertrain.
- The proposed integrated topology is introduced and operation modes are explained in detail.
- The proposed converter is compared with other possible basic single-stage charger topologies.
- In addition, detailed analyses on size reduction, loss, and reliability are presented in this section.
- The overall control scheme developed for controlling each essential operation mode is explained in detail.

III. OVERVIEW OF HYBRID ELECTRICAL VEHICLE

A hybrid electric vehicle (HEV) uses both an internal combustion (IC) engine and an electric motor in the powertrain, and also uses a bank of batteries to recapture and store energy from braking. This combination of an electric motor and an IC engine is more efficient from a system viewpoint than a conventional powertrain. There are many different configurations of hybrid electric systems, including series, parallel, and power-split platforms. All PHEVs in this study have a parallel hybrid configuration with a pre-transmission motor location and a continuously variable transmission (CVT). This configuration is shown in Figure 2.

The addition of HEV technology to a vehicle design improves efficiency primarily by four ways. First, the addition of the electric system allows the IC engine to operate in a more efficient range a greater amount of time. Typically, IC engines are more efficient at a higher load near wide open throttle. In a conventional vehicle, power requirements at cruising and idling are so low that the engine is forced to run at a lower than optimum loading. However, with a hybrid configuration, the IC engine can run at the most efficient load most of the time, using the excess power to charge the batteries. If the batteries are charged, the electric motor can provide the small amount of power required to propel the vehicle while the engine remains off.

Second, having the power of an electric motor at hand, it makes it possible to downsize the engine. Electric motors have higher torque at low rpm range while I.C engines typically have high torque at high rpm range. This makes using an electric motor combined with an engine during acceleration, a time when the highest torque is needed, more efficient that using a larger equivalent torque I.C engine. Also, having a smaller engine reduces the engine braking load, leaving more energy available to be recovered by regenerative braking. Thirdly, having an electric motor allows the I.C engine to completely shutoff instead of idling. The electric motor can simultaneously start the car moving and start the engine. Not having the engine idling while sitting at a traffic light significantly increases fuel economy in city driving.

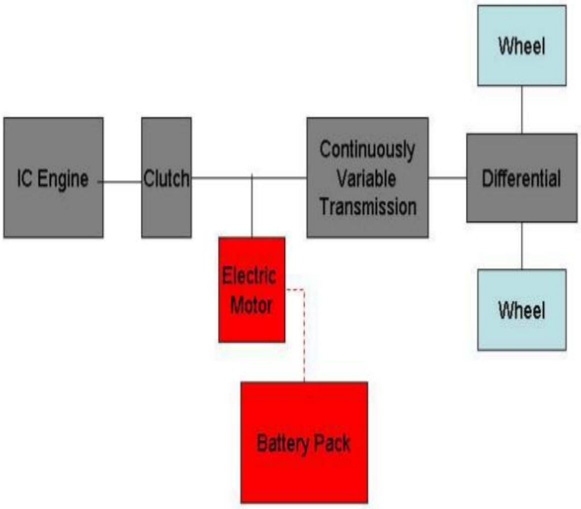

Figure 2. PHEV Parallel Pre-Transmission Configuration with CVT

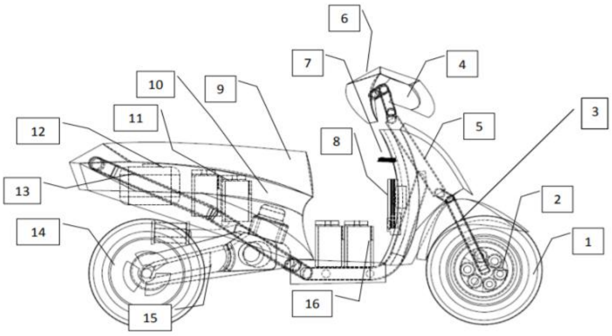

Fig 3. Wire Frame Model Side View

Battery Pack: - The battery pack is the main electrical energy storage device. It is typically made up of a number of modules, connected in series with an open circuit voltage in the range of 100 to 300 volts, with the best designs at the higher end of this range. Each module is made of a number of cells. Battery packs can be come in many different chemistries, but the most common are Nickel Metal Hydride (NiMH), Lead Acid (Pb Acid), and Lithium Ion (Li Ion).

These are the chemistries considered in this study. Each chemical battery type has its own power, energy, and voltage characteristics. The battery pack's energy capacity is given in amp-hours and its state of charge (SOC) is defined as:

$$SOC = \frac{(C_{\max} - C_{\text{used}})}{C_{\max}} \qquad \text{…………. (3.1)}$$

Where $C_{\max}$ is the nominal rated C/3 capacity of the pack in A-h and Cused is the capacity of the pack in A-h that has been used since the pack was fully charged. C/3 is the capacity rating where the entire charge of the pack is discharged in 3 hours. The safe operating SOC range varies with different battery chemistries but is forced to stay over the constant range of 0.2 to 1 for this study. For most battery chemistries, the battery pack starts to be damaged at a SOC less than 0.2.

Electric Motor: - The electric motor, often referred to as simply the motor, converts' electrical energy from the battery pack to mechanical power into the CVT. The electric motor can also be used in reverse as a generator, converting mechanical energy from braking into electrical energy to be used to charge the battery pack. There are two main types of electric motors used in HEVs. The first is permanent magnet motors, using a permanent magnet to create the magnetic field needed to produce power. The second is an induction motor, which uses current to create the magnetic field. This study investigates only permanent magnet motors, the more common of the two in HEV applications.

Power Electronics: - Since the battery pack is basically a constant voltage device, a motor controller is needed to vary the current so that the motor produces the necessary torque. The power electronics are typically designed to the specific characteristics of the electric motor and are typically comprised of a microprocessor, power switching semiconductors, and a thermal management system.

IV. PROPOSED TOPOLOGY AND OPERATION MODES

The proposed integrated interface, shown in Fig.4, is essentially non-isolated. However, it can be isolated from the grid using an LF transformer placed either on board or off board, if needed.

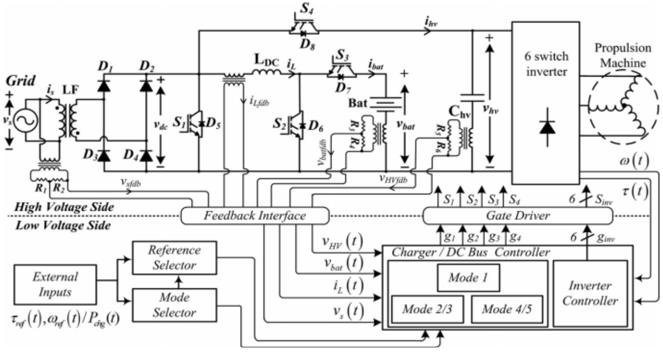

Fig. 4. Proposed integrated topology

TABLE I- OPERATION MODES AND SWITCHING SEQUENCE OF THE PROPOSED CONVERTER

Operation Mode	Energy Flow	Mode	#	S_1	S_2	S_3	S_4	D_5	D_6	D_7	D_8
Propulsion	$V_{bat} \to V_{dc}$	BOOST	1	PWM	OFF	ON	OFF	-	-	-	PWM'
	$V_{bat} \to V_{dc}$	BUCK	2	OFF	OFF	PWM	OFF	-	PWM'	-	ON
Regenerative Braking	$V_{dc} \to V_{bat}$	BOOST	3	OFF	PWM	OFF	ON	-	-	PWM'	-
	$V_{dc} \to V_{bat}$	BUCK	4	OFF	OFF	OFF	PWM	PWM'	-	ON	-
Charging	$V_{grid} \to V_{bat}$	BOOST	5	OFF	PWM	OFF	OFF	-	-	PWM'	-

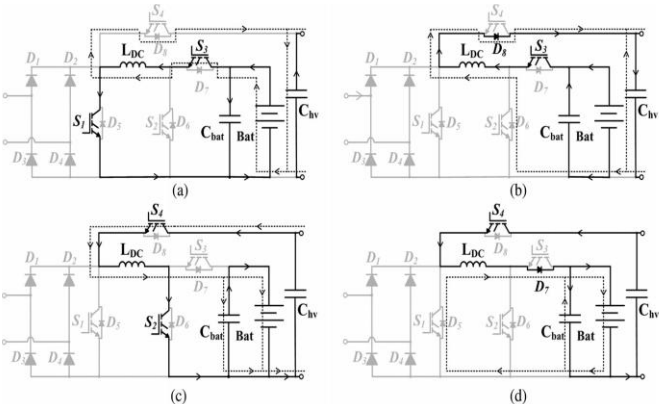

Fig. 5 Operation modes of the converter: (a) boost operation during propulsion, (b) buck operation during propulsion, (c) boost operation during regenerative braking, (d) buck operation during regenerative braking

Basically, the circuit consists of four active switches with body diodes, one inductor and one diode bridge. In charging mode, it operates as a power factor correction (PFC) boost rectifier. Considering that the battery voltage varies between 300 and 400V, the charger can operate universally from single-phase 120/220/240 VAC. Moreover, the propulsion machine controller can be used to control the charging stage. With the feedback acquired by the voltage sensor placed on the grid side of the passive rectifier, charger controller can also be integrated with the motor controller. The proposed integrated topology has basically three modes of operation namely charging, propulsion, and regenerative braking. During propulsion and regenerative braking operations, both stepping-up and stepping-down capabilities are possible, allowing more flexible control, capability of efficiently capturing regenerative braking energy, as well as flexibility of choosing wide ranges for battery nominal voltage. The states of the switches in each mode are summarized in Table I, where PWM' represents the complementary signal of PWM.

A. Mode 1: Boost Mode during Propulsion

In this mode, integrated converter will boost the battery voltage to the dc bus voltage. The conduction paths according to the state of the boost switch *S*1 are shown in Fig. 5(a). In this operation, *S*1 is used as the main boost switch and *S*3 is turned ON. When *S*1 is turned ON, the inductor stores energy and meanwhile capacitor supplies energy to motor through an inverter. When *S*1 is turned OFF, inductor transfers the stored energy to motor by generating a voltage high enough to force *D*8 to conduct and charges the high voltage bus capacitor Chv.

B. Mode 2: Buck Mode during Propulsion

In buck mode [see Fig. 5(b)], only $S3$ is pulse width modulated and the other switches are always in OFF state. When $S3$ is turned ON, the input voltage source supplies energy to the inductor and to the load whereas, when $S3$ is turned OFF, D6 is forward biased and energy is transferred to the load. During propulsion, the energy flow is from battery to inverter in both buck and boost modes.

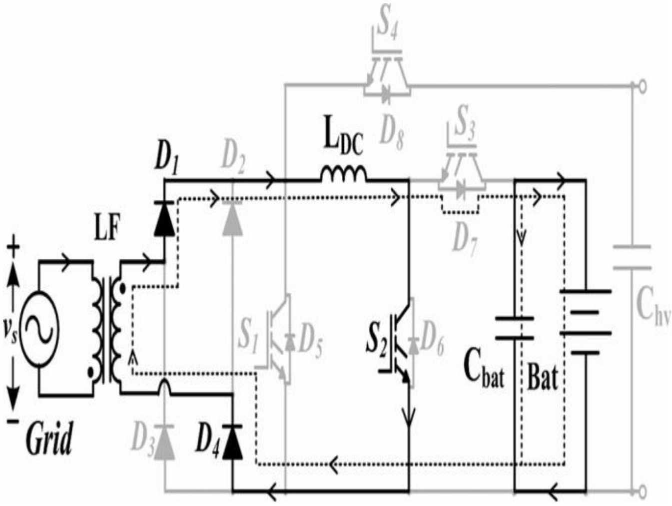

Fig. 6. Current flow during charging

C. Mode 3: Boost Mode during Regenerative Braking

Boosting capability during regenerative braking operation provides additional advantage, through capability of capturing the power during low speeds. In fact, in urban traffic, where vehicles are driven in low speeds, the generated voltage across the terminals of the propulsion machine is lower and if the interface converter does not have boosting capability during regenerative braking, this energy will be lost. With boosting capability in reverse direction (from machine to battery), this energy can be recovered. The buck and boost operating modes during regenerative braking are similar to the ones during propulsion but in reverse direction. The conduction intervals are shown in Fig. 5(c). In this mode, $S4$ is always ON, and $S2$ is pulse width modulated and the rest of switches are in OFF state.

D. Mode 4: Buck Mode during Regenerative Braking

The buck operation is an essential mode as the highest braking energy emerges at high speeds inducing high voltage across the propulsion machine terminals. The operation of the circuit in this mode is shown in Fig. 5(d). The high voltage at the output of the inverter is stepped down by switching $S4$. In the conduction period of $S4$, inductor stores energy with a terminal voltage of $Vi - Vo$ and energy is transferred from high voltage dc bus to battery through $D7$. During freewheeling operation, inductor transfers its energy to battery, where capacitor discharges over the battery as well.

E. Mode 5: Charging Operation

The integrated on-board charger operates as an ac/dc boost rectifier with PFC capability. The operation of the circuit in charging mode is shown in Fig. 6.When $S2$ is ON, the inductor is short circuited and stores a certain amount of energy based on applied input voltage. Meanwhile, the capacitor connected in parallel to battery supplies energy to the load. Only diodes $D1$ and$D4$ are conducting in this mode. Diodes$D2$ and$D3$ will conduct depending on the grid voltage polarity. During the time when $S2$ is turned OFF, $D7$ is forced to conduct and the inductor current decreases under the influence of Vgrid − Vbat. At the same time, the capacitor in parallel with battery is charged as well.

V. SIMULATION AND RESULT DISCUSSION

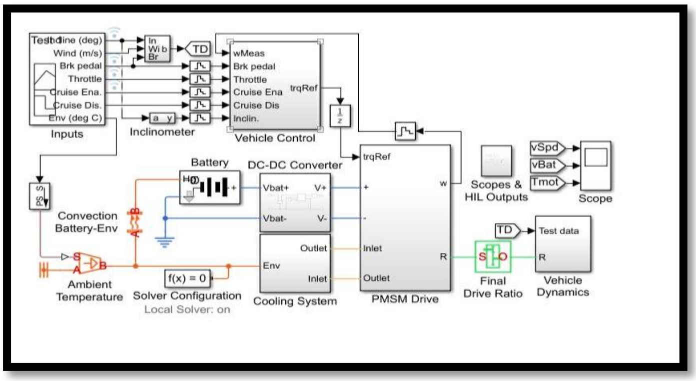

Fig.7 Electrical Vehicle Charging System

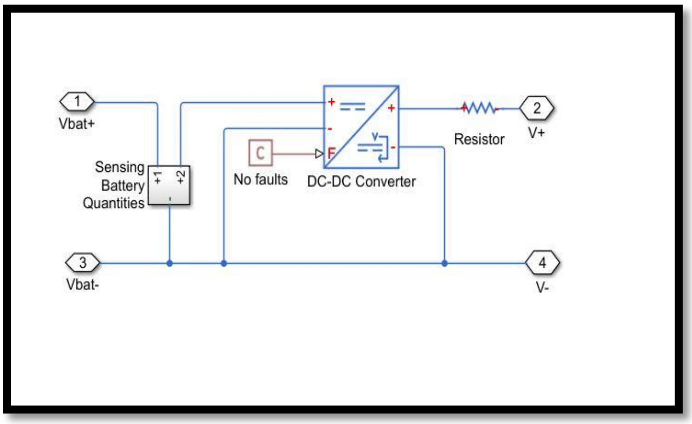

Fig 8- DC-DC Converter for Proposed System

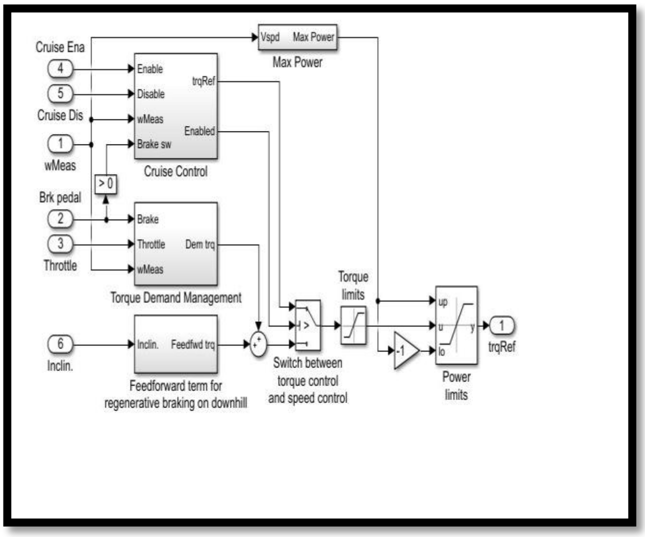

Fig.9- Vehicle Control Subsystem

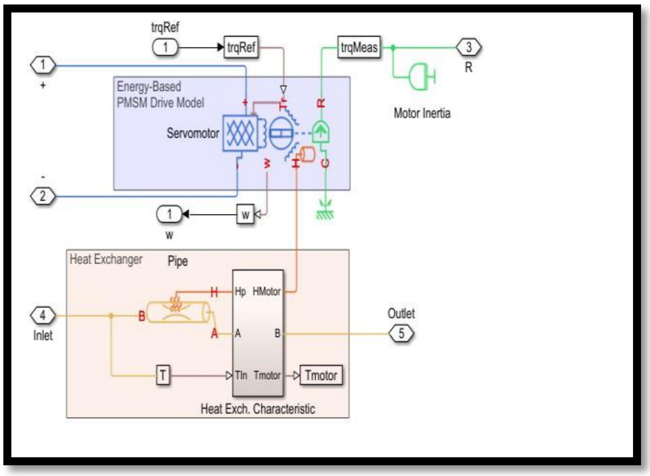

Fig.10-PMSM Drive Subsystem

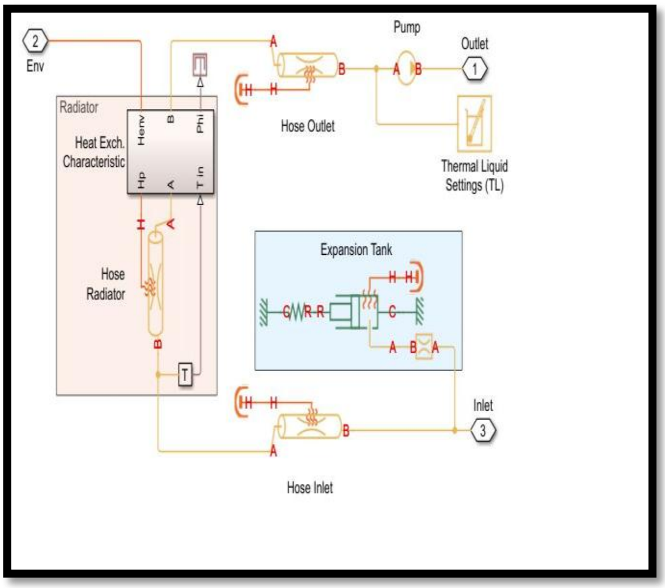

Fig.11- Colling Subsystem

Simulation Results

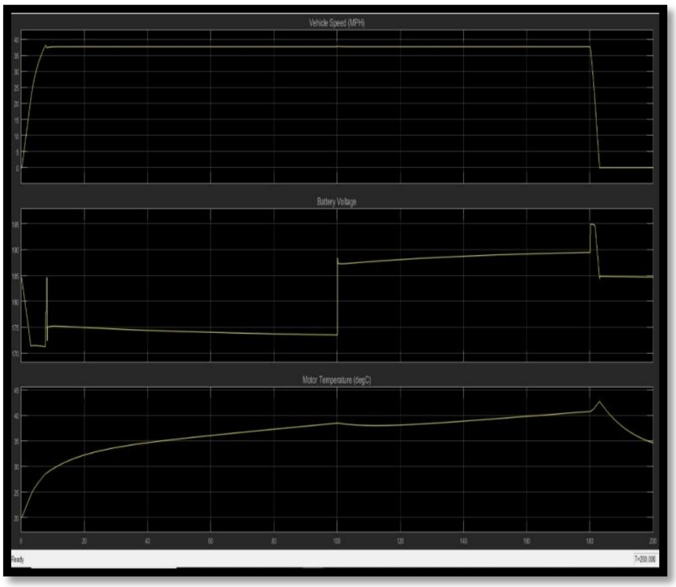

Fig.12 Electrical Vehicle output system

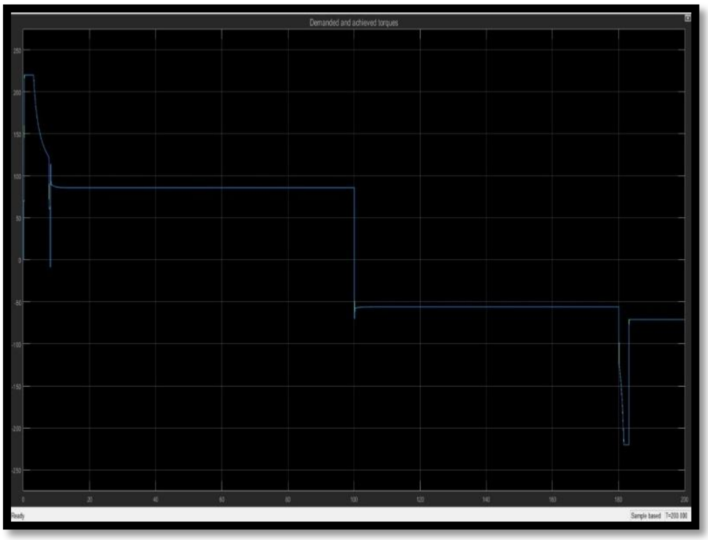

Fig.13 Torque Variation after controlling

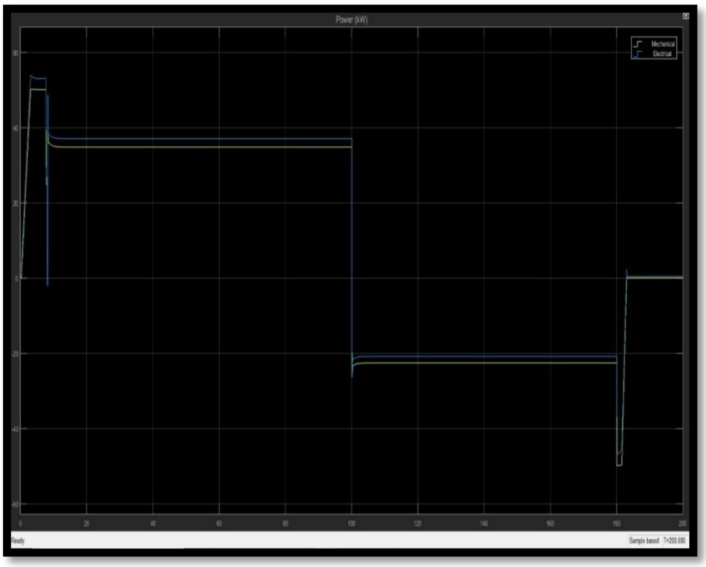

Fig.14- Mechanical and Electrical Power Variation

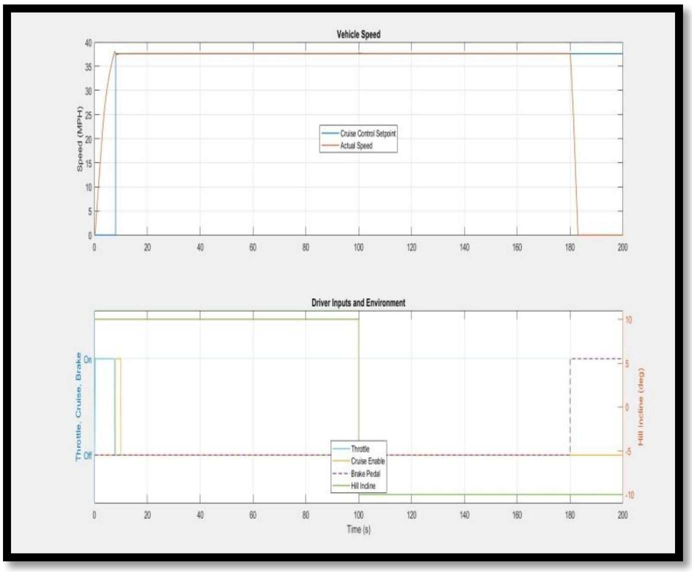

Fig.15- Vehicle Parameters

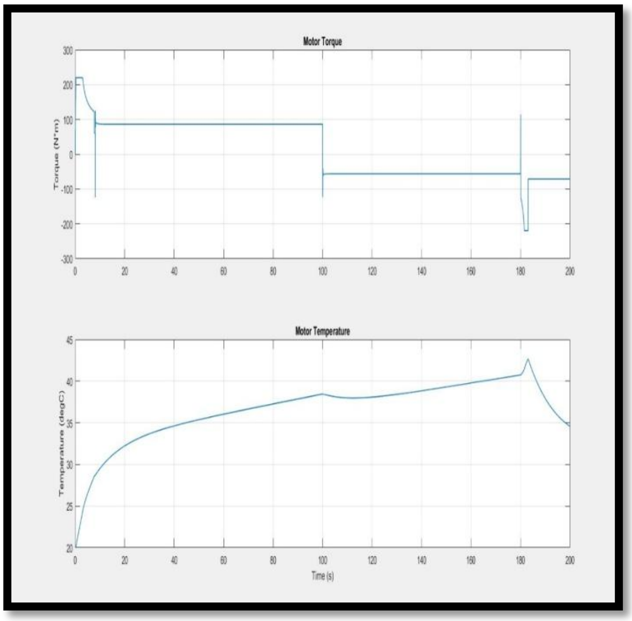

Fig.16- Motor parameters

Simulation of Proposed system

Simulation tests are carried out for charging, propulsion boost, and regenerative braking buck modes at various power levels. The screenshot of the current and voltage waveforms during charging with 1.8 kW power is shown in Fig. 5.19. The input (grid) and output voltages are measured through the voltage sensor, which outputs 6 mV per each Volts. The input voltage is 150VAC and the output voltage is kept constant at 250VDC. The input (grid) current is also measured through the current sensor.

When the switch is turned ON, the inductor current (battery side) increases with a constant slope. The dc bus current is continuous and smooth because of the output filters. Small voltage spikes are observed on the dc-link voltage. These happen in the instances of switching due to the reverse recovery losses, which slightly reduces the efficiency as previously discussed in the additional loss analysis. This can be overcome through active soft-switching techniques such as zero-voltage-zero-current switching and using faster switches to reduce the switching losses, particularly the reverse recovery losses.

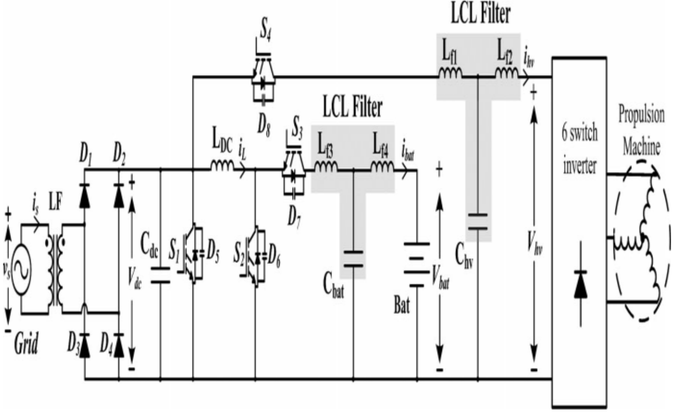

Fig.17. Schematic of the converter with deployed *LCL* filters.

Case-I PFC boost rectifier Operating mode

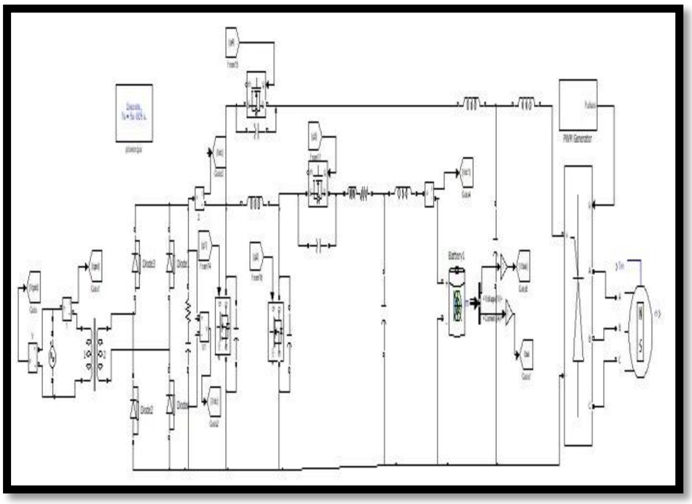

Fig 18- Main Proposed system

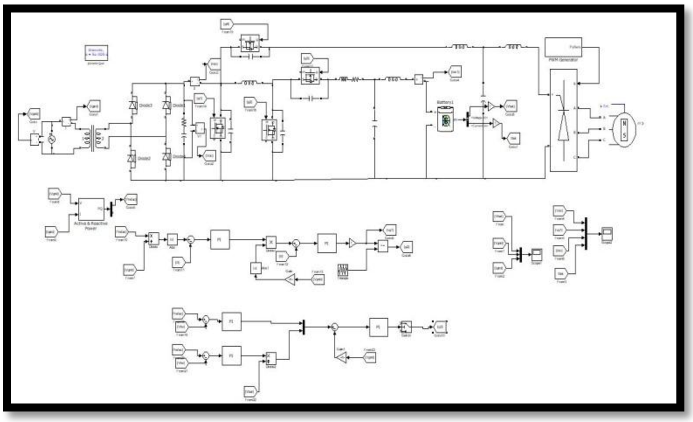

Fig.19 Whole Test model using Matlab

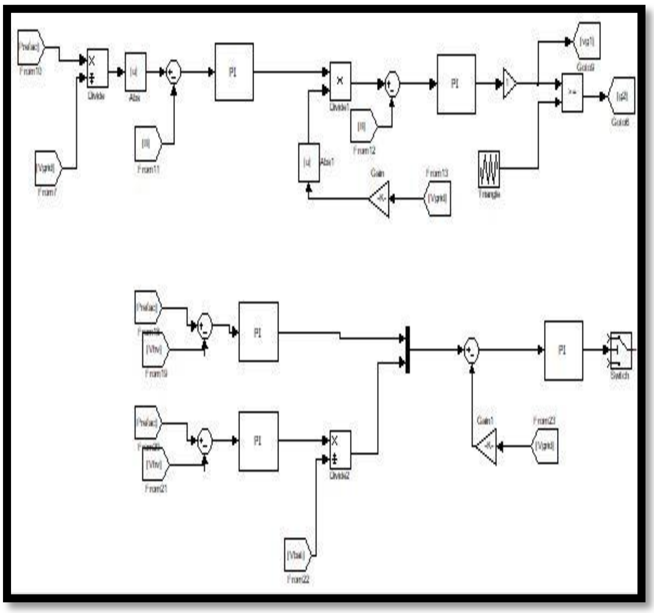

Fig.20- Controlling subsystem

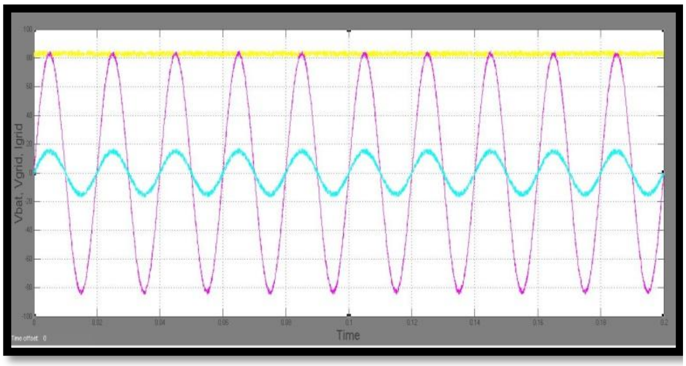

Fig.21- Battery voltage-Vbat, Vgrid and I grid (Grid Voltage and current)

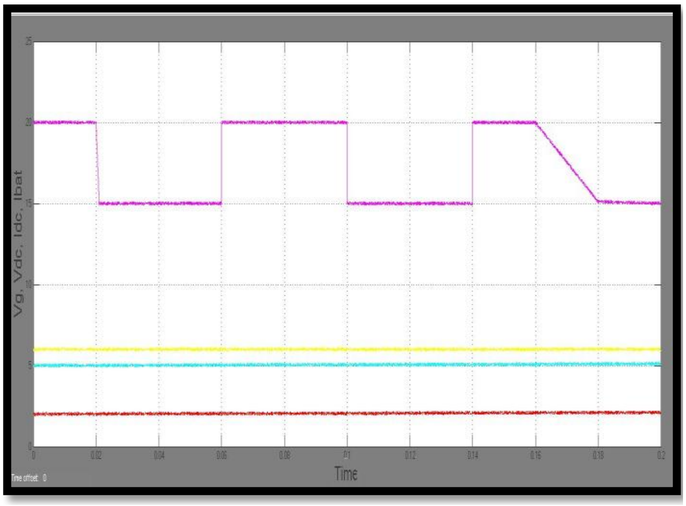

Fig.22- gate signal, battery side current, dc bus voltage and dc bus current

Case- II semi active dual PFC boost rectifier operating mode

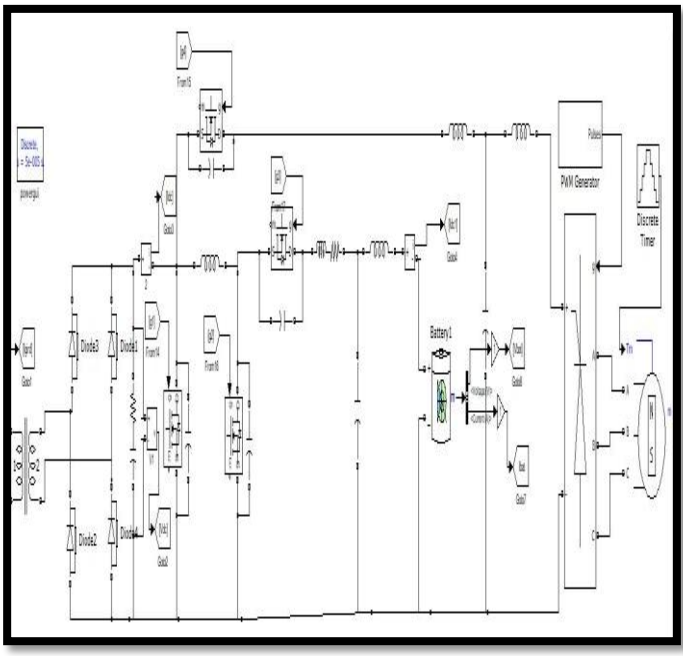

Fig.23- Case-II of semi active dual PFC boost rectifier operating mode

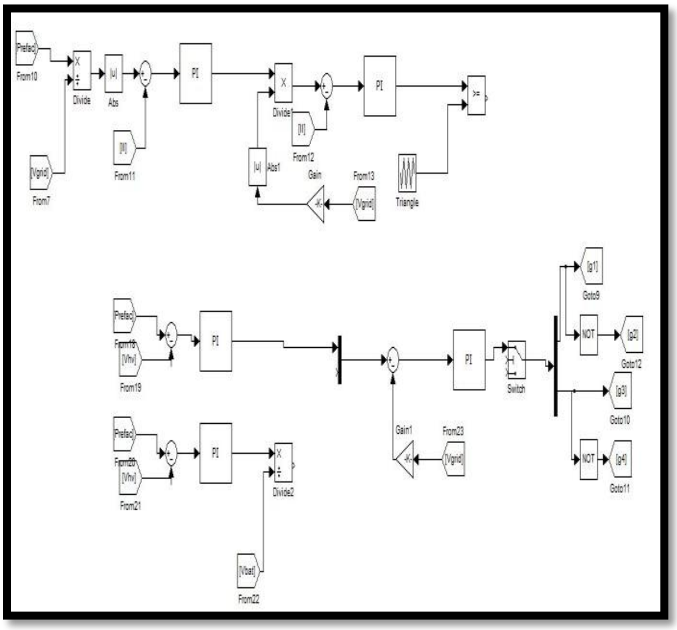

Fig.24- Controlling subsystem of case-II

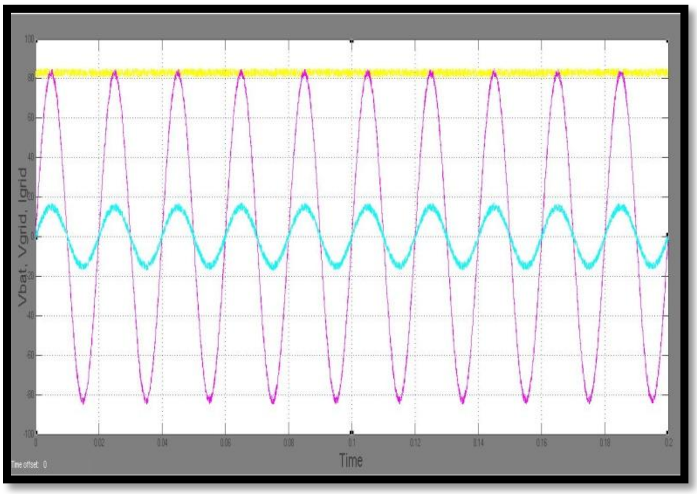

Fig.25- Battery voltage-Vbat, Vgrid and I grid (Grid Voltage and current) for case study-2

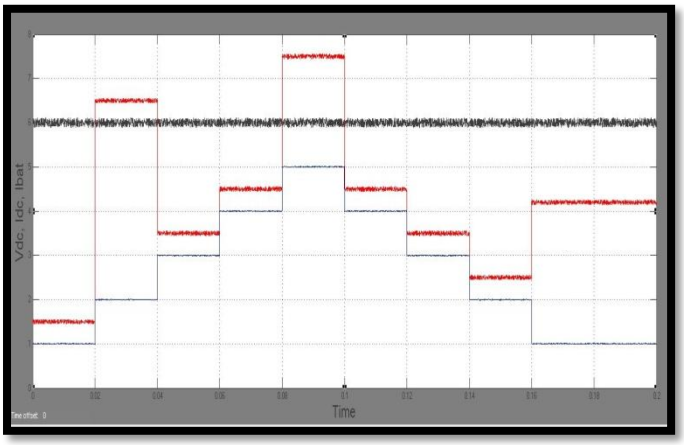

Fig.26- battery side current, dc bus voltage and dc bus current

Case-III inverting buck/boost PFC rectifier operating mode

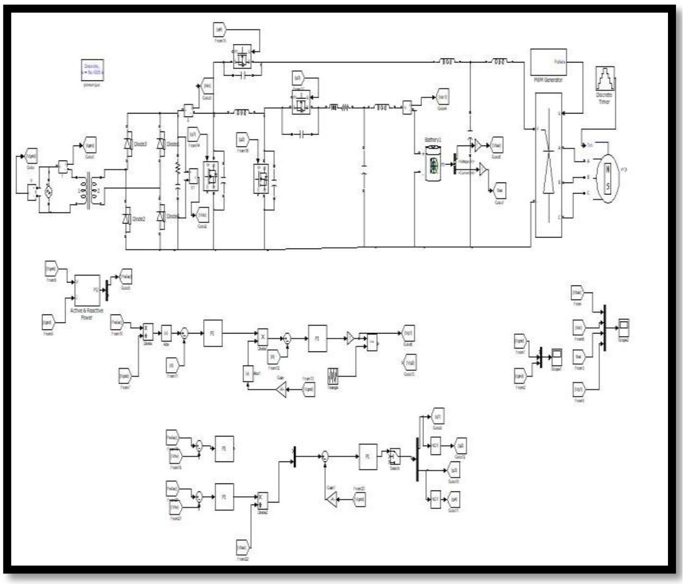

Fig.27- Matlab model of inverting buck/boost PFC rectifier operating mode

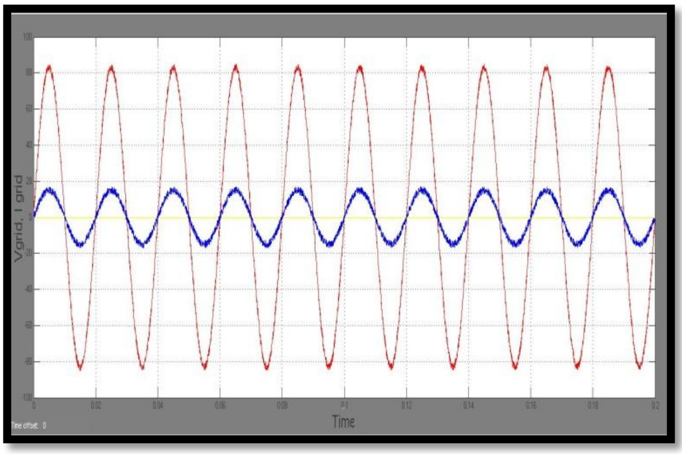

Fig.28- Grid voltage and current

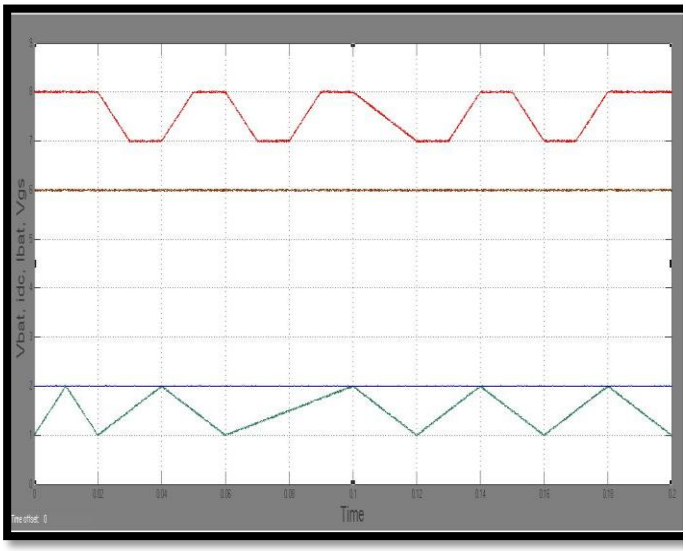

Fig.29- Battery voltage and Current (Vbat, Ibat), dc bus current (Idc), gate signals

Case-IV positive buck/boost PFC rectifier operating mode

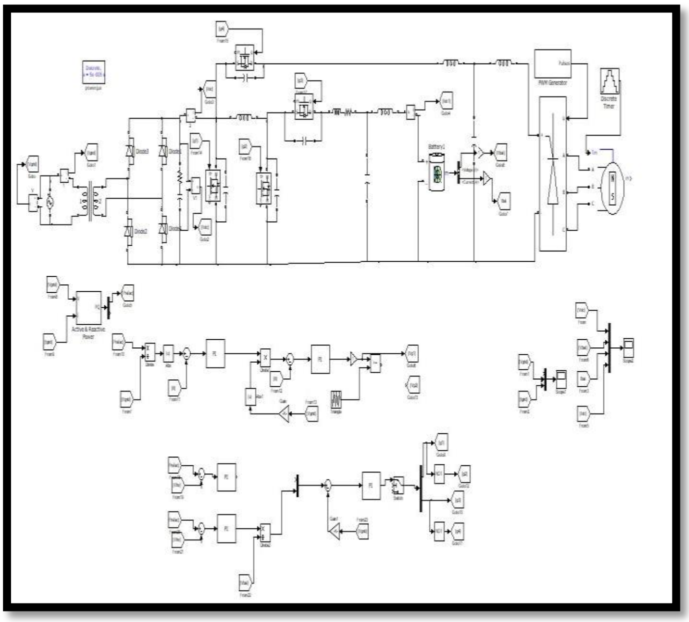

Fig.30 Matlab model of positive buck/boost PFC rectifier operating mode

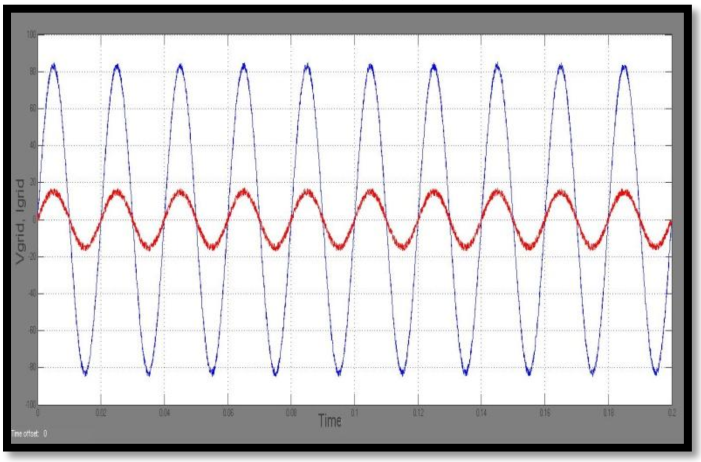

Fig.31- Grid voltage and Current

Fig.32- Vbat, Ibat and Vdc, Idc

VI. CONCLUSION

This paper discussed about importance of Electrical Vehicle and its implementation. The software part of E.V modelling is done with Matlab Simulink. This method proved to be successful by simulation and experiment in charging EVs different amount of energy based on priority. Further investigation of this method can be carried to reduce the charging cycle time, and study the effect of constant switching on the battery lifetime. The EV charger through elimination of an inductor core, which is presented in conventional structure with two individual power electronic converters for PFC. In addition, all essential operation modes during propulsion are achieved using four switches and a diode bridge. The functionality and performance of the proposed integrated topology have been verified with simulation results. The Matlab simulation is successfully done for all operating modes and for modelling of EV system. The simulation results are effectively showing the EV charging control through proposed control strategy.

REFERENCES

[1] Serkan Dusmez and Alireza Khaligh “A Compact and Integrated Multifunctional Power Electronic Interface for Plug-in Electric Vehicles”. IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 28, NO. 12, DECEMBER 2013.
[2] Benjamin Frieske, Matthias Kloetzke, Florian Mauser, “Trends in Vehicle Concept and Key Technology Development for Hybrid and Battery Electric Vehicles”, IEEE EVS27 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium.
[3] Rayad Kubaisi, Frank Gauterin, and Martin Giessler “A Method to Analyze Driver Influence on the Energy Consumption and Power Needs of Electric Vehicles”, 978-1-4799-6075-0/14/$31.00 ©2014 IEEE.
[4] Gerfried Jungmeier, Jennifer B. Dunn, Amgad Elgowainy, Enver Doruk Özdemir, Simone Ehrenberger, Hans Jörg Althaus, Rolf Widmer, “Key issues In Life cycle Assessment of Electrical Vehicles-Findings in the International Energy Agency (IEA) on Hybrid and Electrical Vehicle”, IEEE EVS27 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium.
[5] Chunhua Liu, K. T. Chau, Diyun Wu and Shuang Gao, “Opportunities and Challenges of Vehicle-to-Home, Vehicle-to-Vehicle, and Vehicle-to-Grid Technologies”, 0018-9219/$31.00 _2013 IEEE.
[6] Mohamed YAICH, Mohamed Radhouan HACHICHA and Moez GHARIANI, “Modeling and Simulation of Electric and Hybrid Vehicles for Recreational Vehicle”, 16th international conference on Sciences and Techniques of Automatic control & computer engineering - STA'2015, Monastir, Tunisia, December 21-23, 2015, 978-1-4673-9234-1/15/$31.00 ©2015 IEEE.
[7] X.D. Xue, K.W.E. Cheng, Raghu Raman S, Jones Chan, J. Mei, and C. D. Xu “Performance Prediction of Light Electric Vehicles Powered by Body-Integrated Super-Capacitors”. 978-1-5090-0814-8/16/$31.00 ©2016 IEEE.
[8] Soheil Mohagheghi Fard, Avesta Goodarzi, Amir Khajepour Ebrahim and Esmailzadeh “Design and Control of a Narrow Electric Vehicle”, 0-7803-7657-9/02/$17.00 02002 IEEE.
[9] Araz Saleki, Saman Rezazade, Mahmudreza Changizian “Analysis and Simulation of Hybrid Electric Vehicles for Sedan Vehicle”, 25th Iranian Conference on Electrical Engineering (ICEE2017), 978-1-5090-5963-8/17/$31.00 ©2017 IEEE.
[10] Dakshina M. Bellur and Marian K. Kazimierczuk “DC-DC CONVERTERS FOR ELECTRIC VEmCLE APPLICATIQNS”, 978-1-4244-0446-91071$25.00 @2007 IEEE.