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Boost Converter Based Power Electronics Interfaced Electric Vehicles

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Abstract:

Power electronics interfaces play an increasingly important role in the future clean vehicle technology. This paper proposes a novel integrated power electronics interface (IPEI) for battery electric vehicles (BEVs) in order to optimize the performance of the powertrain. The proposed IPEI is responsible for the power-flow management for each operating mode. In this paper, an IPEI is proposed and designed to realize the integration of the dc/dc converter, on-board battery charger, and dc/ac inverter together in the BEV powertrain with high performance. The proposed concept can improve the system efficiency and reliability, can reduce the current and voltage ripples, and can reduce the size of the passive and active components in the BEV drivetrains compared to other topologies. In addition, low electromagnetic interference and low stress in the power switching devices are expected. For further extension we are modeling a design with boost converter topology for better efficiency. The proposed topology and its control strategy are designed and analyzed by using MATLAB/Simulink. The simulation results related to this research are presented and discussed.

I.INTRODUCTION:

DUE to rising concerns about environmental issues, such as climate change and urban pollution, as well as energy issues, automobile manufacturers are being forced to shift their attention toward clean vehicle technologies. Recently, battery electric vehicles (BEVs) can be an alternative to the internal combustion engine vehicles due to advances in battery technologies, power electronics interfaces (PEIs), and control strategies. In general, the BEVs are powered by electric batteries, which need to be recharged with electricity from the grid. A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. The switch is typically a MOSFET, IGBT, or BJT.

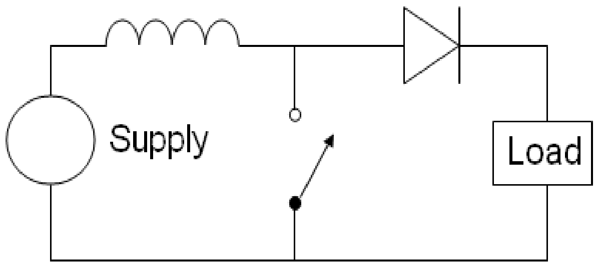

Figure 1:basic boost converter circuit

Furthermore, the BEVs can provide an ideal solution to reduce the environmental impact of transports and reduce energy dependence because they have low energy consumption and zero local emissions. In other words, BEVs are zero-emission vehicles. However, the BEVs still have some challenges, which need to be solved. These challenges are limited driving range, long charging time, battery lifetime, power electronics performance, and high initial cost. Fig. 1 illustrates the schematic diagramof the BEV powertrain.

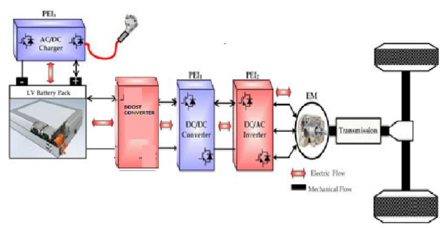

Figure 2: schematic diagram of the battery electric vehicles

In the literature, limited research work on integrated power electronics interface (IPEI) has been reported to interface a low-voltage (LV) energy source (such as fuel cells,

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battery systems, and super capacitors) to electric motor (EM) in electric vehicle (EV) and plug-in hybrid electric vehicle (PHEV)powertrains. In and the authors proposed the Z-source inverter (ZSI) for EV applications. ZSI is considered as an emerging topology for dc/ac converters, due to its boosting capability, and it saves component cost by utilizing a single conversion stage.

However, the major drawbacks of the ZSI are that it has a complex control and high current and voltage stresses. Furthermore, it has a limited boost ratio and less reliability compared to the other topologies. Owing to these disadvantages, the ZSI is still under investigation and developing. On the other hand, there are a number of research efforts on developing the PEIs that can be used in vehicular applications.

II.SUPER CAPACITORS

Capacitors store electric charge. Because the charge is stored physically, with no chemical or phase changes taking place, the process is highly reversible and the discharge-charge cycle can be repeated over and over again, virtually without limit. Electrochemical capacitors (ECs), variously referred to by manufacturers in promotional literature as Super capacitors also called ultra capacitors and electric double layer capacitors (EDLC) are capacitors with capacitance values greater than any other capacitor type available today.

Capacitance values reaching up to 400 Farads in a single standard case size are available. Super capacitors have the highest capacitive density available today with densities so high that these capacitors can be used to applications normally reserved for batteries. Super capacitors are not as volumetrically efficient and are more expensive than batteries but they do have other advantages over batteries making the preferred choice in applications requiring a large amount of energy storage to be stored and delivered in bursts repeatedly.

The most significant advantage super capacitors have over batteries is their ability to be charged and discharged continuously without degrading like batteries do. This is why batteries and super capacitors are used in conjunction with each other. The super capacitors will supply power to the system when there are surges or energy bursts since super capacitors can be charged and discharged quickly while the batteries can supply the bulk energy since they can store and deliver larger amount energy over a longer slower period of time.

1. Super capacitor construction:

What makes' super capacitors different from other capacitors types are the electrodes used in these ca00000capacitors. Super capacitors are based on a carbon (nano tube) technology. The carbon technology used in these capacitors creates a very large surface area with an extremely small separation distance. Capacitors consist of 2 metal electrodes separated by a dielectric material. The dielectric not only separates the electrodes but also has electrical properties that affect the performance of a capacitor. Super capacitors do not have a traditional dielectric material like ceramic, polymer films or aluminum oxide to separate the electrodes but instead have a physical barrier made from activated carbon that when an electrical charge is applied to the material a double electric field is generated which acts like a dielectric. The thickness of the electric double layer is as thin as a molecule. The surface area of the activated carbon layer is extremely large yielding several thousands of square meters per gram. This large surface area allows for the absorption of a large amount of ions.

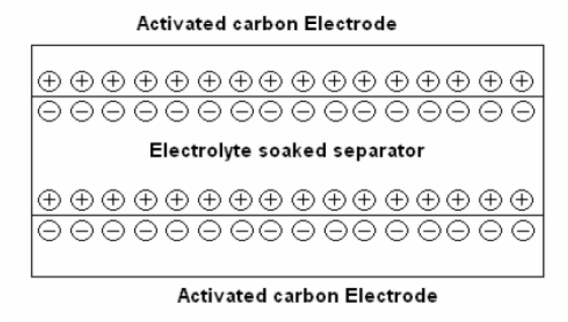

Figure 3 basic super capacitor structure

The double layers formed on the activated carbon surfaces can be illustrated as a series of parallel RC circuits. As shown below the capacitor is made up of a series of RC circuits where R1, R2 …Rn are the internal resistances and C1, C2..., Cn are the electrostatic capacitances of the activated carbons.

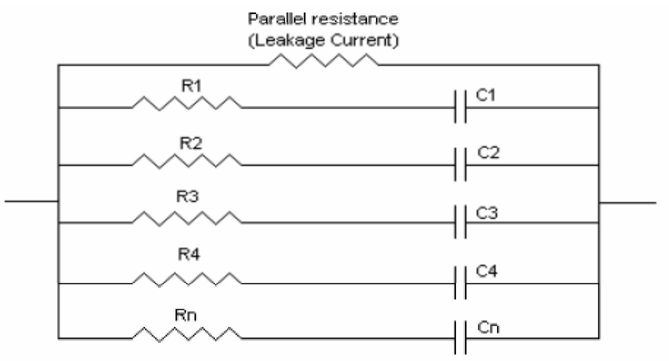

Figure 4: double layer of activated carbon

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When voltage is applied current flows through each of the RC circuits. The amount of time required to charge the capacitor is dependent on the CxR values of each RC circuit. Obviously the larger the CxR the longer it will take to charge the capacitor. The amount of current needed to charge the capacitor is determined by the following equation:

$$In= (V/Rn) \exp(-t/ (Cn*Rn))$$

Super capacitor is a double layer capacitor; the energy is stored by charge transfer at the boundary between electrode and electrolyte. The amount of stored energy is function of the available electrode and electrolyte surface, the size of the ions, and the level of the electrolyte decomposition voltage. Super capacitors are constituted of two electrodes, a separator and an electrolyte. The two electrodes, made of activated carbon provide a high surface area part, defining so energy density of the component. On the electrodes, current collectors with a high conducting part assure the interface between the electrodes and the connections of the super capacitor. The two electrodes are separated by a membrane, which allows the mobility of charged ions and forbids no electronic contact. The electrolyte supplies and conducts the ions from one electrode to the other.

2 equivalent circuits:

Super capacitors can be illustrated similarly to conventional film, ceramic or aluminum electrolytic capacitors

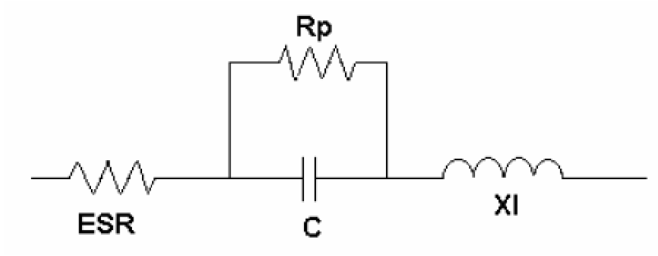

Figure 5: equivalent circuit of super capacitor

This equivalent circuit is only a simplified or first order model of a super capacitor. In actuality super capacitors exhibit a non ideal behavior due to the porous materials used to make the electrodes. This causes super capacitors to exhibit behavior more closely to transmission lines than capacitors. Below is a more accurate illustration of the equivalent circuit for a super capacitor.

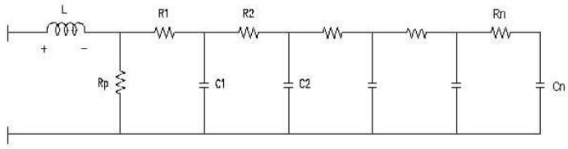

Figure 6: equivalent circuit of super capacitor

3 how to measure the capacitance:

There are a couple of ways used to measure the capacitance of super capacitors.

1. Charge method
2. Charging and discharging method.

A. charge method:

Measurement is performed using a charge method using the following formula.
C=t/R
t= .632Vo where Vo is the applied voltage.

B. Charging and discharging method:

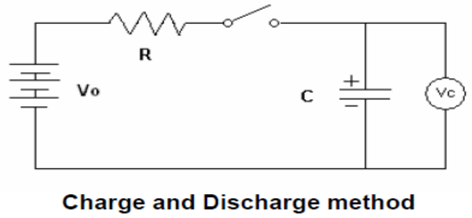

Figure 7: charging and discharging method

This method is similar to the charging method except the capacitance is calculated during the discharge cycle instead of the charging cycle. Discharge time for constant current discharge
t= Cx (V0-V1)/I
Discharge time for constant resistance discharge
t= CRln (V1/V0)
Where t= discharge time, V0= initial voltage, V1= ending voltage, I= current.

4 capacitance:

Super capacitors have such large capacitance values that standard measuring equipment cannot be used to measure the capacity of these capacitors.
Capacitance is measured per the following method:

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1. Charge capacitor for 30 minutes at rated voltage.
2. Discharge capacitor through a constant current load.
3. Discharge rate to be 1mA/F.
4. Measure voltage drop between V1 to V2.
5. Measure time for capacitor to discharge from V1 to V2.

III.BOOST CONVERTER:

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. Power can also come from DC sources such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion.

A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P = VI or P = UI in Europe) must be conserved, the output current is lower than the source current.A boost converter may also be referred to as a 'Joule thief'. This term is usually used only with very low power battery applications, and is aimed at the ability of a boost converter to 'steal' the remaining energy in a battery. This energy would otherwise be wasted since a normal load wouldn't be able to handle the battery's low voltage.*

- This energy would otherwise remain untapped because in most low-frequency applications, currents will not flow through a load without a significant difference of potential between the two poles of the source (voltage.)

1. block diagram:

The basic building blocks of a boost converter circuit are shown in Fig.The voltage source provides the input DC voltage to the switch control, and to the magnetic field storage element. The switch control directs the action of the switching element, while the output rectifier and filter deliver an acceptable DC voltage to the output.

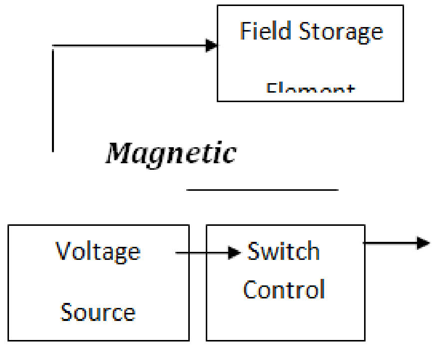

Figure 8: block diagram of boost converter

2 o.perating principle:

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy (somewhat like a resistor), when being discharged, it acts as an energy source (somewhat like a battery). The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages.

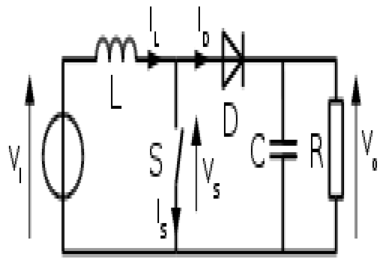

Figure 9:boost converter schematic

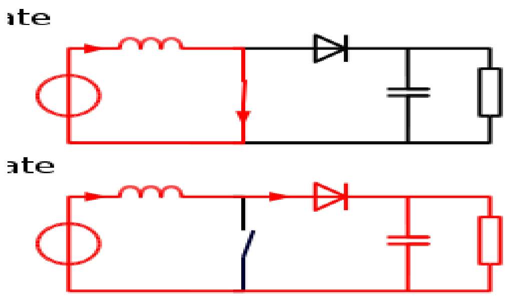

Figure 10: the two configurations of a boost converter, depending on the state of the switch S.

The basic principle of a Boost converter consists of 2 distinct states (see figure):

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• In The On-State, The Switch S (See Figure) Is Closed, Resulting In An Increase In The Inductor Current;
• In The Off-State, The Switch Is Open And The Only Path Offered To Inductor Current Is Through The Fly Back Diode D, The Capacitor C And The Load R. This Result In Transferring The Energy Accumulated During The On-State Into The Capacitor.

A. Continuous Mode:

When A Boost Converter Operates In Continuous Mode, The Current Through The Inductor (Il) Never Falls To Zero. Figure Shows The Typical Waveforms Of Currents And Voltages In A Converter Operating In This Mode. The Output Voltage Can Be Calculated As Follows, In The Case Of An Ideal Converter (I.E. Using Components With An Ideal Behavior) Operating In Steady Conditions:

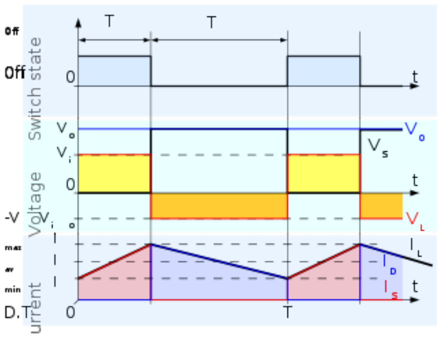

Figure 11: Waveforms Of Current And Voltage In A Boost Converter Operating In Continuous Mode.

During the On-state, the switch S is closed, which makes the input voltage (Vi) appear across the inductor, which causes a change in current (IL) flowing through the inductor during a time period (t) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{L_{On}} = \frac{1}{L}\int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

D is the duty cycle. It represents the fraction of the commutation period T during which the switch is on. Therefore D ranges between 0 (S is never on) and 1 (S is always on). During the Off-state, the switch S is open, so the inductor current flows through the load. If we consider zero voltage drop in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of IL is:

$$V_i - V_o = L\frac{dI_L}{dt}$$

Therefore, the variation of I_L during the Off-period is:

$$\Delta I_{L_{Off}} = \int_0^{(1-D)T} \frac{(V_i - V_o)\,dt}{L} = \frac{(V_i - V_o)(1-D)T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2} L I_L^2$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = 0$$

Substituting $\Delta I_{L_{On}}$ and $\Delta I_{L_{Off}}$ by their expressions yields:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1-D)T}{L} =$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

Which in turns reveals the duty cycle to be?

$$D = 1 - \frac{V_i}{V_o}$$

From the above expression it can be seen that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

b. Discontinuous mode:

In some cases, the amount of energy required by the load is small enough to be transferred in a time smaller than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle (see waveforms in figure). Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows

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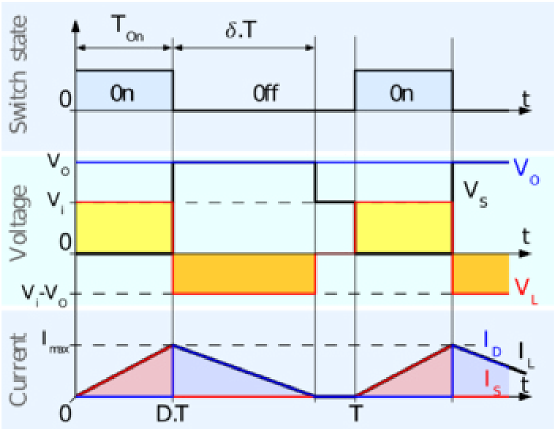

Figure 12: waveforms of current and voltage in a boost converter operating in discontinuous mode.

As the inductor current at the beginning of the cycle is zero, its maximum value $I_{L_{Max}}$ (at t = DT) is

$$I_{L_{Max}} = \frac{V_i DT}{L}$$

During the off-period, I_L falls to zero after δT:

$$I_{L_{Max}} + \frac{(V_i - V_o)\,\delta T}{L} = 0$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_o - V_i}$$

The load current I_o is equal to the average diode current (I_D). As can be seen on figure 4, the diode current is equal to the inductor current during the off-state. Therefore the output current can be written as:

$$I_o = \bar{I_D} = \frac{I_{L_{max}}}{2}\delta$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_o = \frac{V_i DT}{2L} \cdot \frac{V_i D}{V_o - V_i} = \frac{V_i^2 D^2 T}{2L\,(V_o - V_i)}$$

Therefore, the output voltage gain can be written as flow:

$$\frac{V_o}{V_i} = 1 + \frac{V_i D^2 T}{2L I_o}$$

Compared to the expression of the output voltage for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage gain not only depends on the duty cycle, but also on the inductor value, the input voltage, the switching frequency, and the output current.

3.Applications:

Battery powered systems often stack cells in series to achieve higher voltage. However, sufficient stacking of cells is not possible in many high voltage applications due to lack of space. Boost converters can increase the voltage and reduce the number of cells. Two battery-powered applications that use boost converters are hybrid electric vehicles (HEV) and lighting systems.The NHW20 model Toyota Prius HEV uses a 500 V motor. Without a boost converter, the Prius would need nearly 417 cells to power the motor. However, a Prius actually uses only 168 cells and boosts the battery voltage from 202 V to 500 V. Boost converters also power devices at smaller scale applications, such as portable lighting systems. A white LED typically requires 3.3 V to emit light, and a boost converter can step up the voltage from a single 1.5 V alkaline cell to power the lamp. Boost converters can also produce higher voltages to operate cold cathode fluorescent tubes (CCFL) in devices such as LCD backlights and some flashlights.

IV.ELECTRIC VEHICLE:

An electric vehicle (EV), also referred to as an electric drive vehicle, uses one or more electric motors for propulsion. Electric vehicles include electric cars, electric trains, electric lorries, electric aero-planes, electric boats, electric motorcycles and scooters and electric spacecraft. Electric vehicles first came into existence in the mid-19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. The internal combustion engine (ICE) is the dominant propulsion method for motor vehicles but electric power has remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.During the last few decades, increased concern over the environmental impact of the petroleum-based transportation infrastructure, along with the spectre of peak oil, has led to renewed interest in an electric transportation infrastructure. Electric vehicles differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, wireless energy transfer such as inductive charging, or a direct connection through an electrical cable.

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1.vehicle types
Hybrid electric vehicle

A hybrid electric vehicle combines a conventional (usually fossil fuel-powered) power train with some form of electric propulsion. Common examples include hybrid electric cars such as the Toyota Prius.

on- and off-road electric vehicles

Electric vehicles are on the road in many functions, including electric cars, electric trolleybuses, electric bicycles, electric motorcycles and scooters, neighborhood electric vehicles, golf carts, milk floats, and forklifts. Off-road vehicles include electrified all-terrain vehicles and tractors.

airborne electric vehicles

Since the beginning of the era of aviation, electric power for aircraft has received a great deal of experimentation. Currently flying electric aircraft include manned and unmanned aerial vehicles.

2.advantages of electric vehicles environmental

Due to efficiency of electric engines as compared to combustion engines, even when the electricity used to charge electric vehicles comes a CO2 emitting source, such as a coal or gas fired powered plant, the net CO2 production from an electric car is typically one half to one third of that from a comparable combustion vehicle.Electric vehicles release almost no air pollutants at the place where they are operated. In addition, it is generally easier to build pollution control systems into centralized power stations than retrofit enormous numbers of cars.

Mechanical

Electric motors are mechanically very simple.Electric motors often achieve 90% energy conversion efficiency over the full range of speeds and power output and can be precisely controlled. They can also be combined with regenerative braking systems that have the ability to convert movement energy back into stored electricity. This can be used to reduce the wear on brake systems (and consequent brake pad dust) and reduce the total energy requirement of a trip. Regenerative braking is especially effective for start-and-stop city use.They can be finely controlled and provide high torque from rest, unlike internal combustion engines, and do not need multiple gears to match power curves. This removes the need for gearboxes and torque converters.

Energy resilience:

Electricity is a form of energy that remains within the country or region where it was produced and can be multi-sourced. As a result it gives the greatest degree of energy resilience.

Energy efficiency:

Electric vehicle 'tank-to-wheels' efficiency is about a factor of 3 higher than internal combustion engine vehicles. It does not consume energy when it is not moving, unlike internal combustion engines where they continue running even during idling. However, looking at the well-to-wheel efficiency of electric vehicles, their emissions are comparable to an efficient gasoline or diesel in most countries because electricity generation relies on fossil fuels.

V.AC MOTOR THEORY
1.construction, working, principle of operation

Ac motors are widely used to drive machinery for a wide variety of applications. To understand how these motors operate, a knowledge of the basic theory of operation of AC motors is necessary. The principle of operation for all AC motors relies on the interaction of a revolving magneticfield created in the stator by AC current, with an opposing magnetic field either induced on therotor or provided by a separate DC current source. The resulting interaction produces usabletorque, which can be coupled to desired loads throughout the facility in a convenient manner.Prior to the discussion of specific types of AC motors, some common terms and principles mustbe introduced.

Rotating field:

Before discussing how a rotating magnetic field will cause a motor rotor to turn, we must firstfind out how a rotating magnetic field is produced. . Figure 1 illustrates a three-phase stator towhich a three-phase

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AC current is supplied.The windings are connected in wye. The two windings in each phase are wound in the samedirection. At any instant in time, the magnetic field generated by one particular phase willdepend on the current through that phase. If the current through that phase is zero, the resultingmagnetic field is zero. If the current is at a maximum value, the resulting field is at a maximumvalue. Since the currents in the three windings are 120° out of phase, the magnetic fieldsproduced will also be 120° out of phase. The three magnetic fields will combine to produce onefield, which will act upon the rotor. In an AC induction motor, a magnetic field is induced inthe rotor opposite in polarity of the magnetic field in the stator.

2.types of ac motors
classification based on principle of operation
Synchronous motors.

1. Plain
2. Super

Asynchronous motors.
I. Induction Motors:
(a) Squirrel Cage
(b) Slip-Ring (external resistance).

Commutator Motors:
(a) Series
(b) Compensated
(c) Shunt
(d) Repulsion
(e) Repulsion-start induction
(f) Repulsion induction

classification based on type ofcurrent
1. Single Phase
2. Three Phase

Classification based on speed of operation
1. Constant Speed.
2. Variable Speed.
3. Adjustable Speed.

Classification based on structural features
1. Open
2. Enclosed
3. Semi-enclosed
4. Ventilated
5. Pipe-ventilated
6. Riveted frame-eye etc.

3 advantages
•Simple Design
•Low Cost
•Reliable Operation
•Easily Found Replacements
•Variety of Mounting Styles
•Many Different Environmental Enclosures

VI.SIMULATION RESULTS:

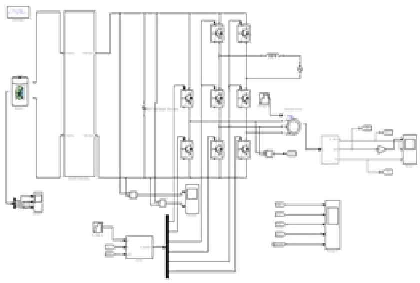

Figure 13: final simulation circuit of power electronic interfaced battery electric vehicle

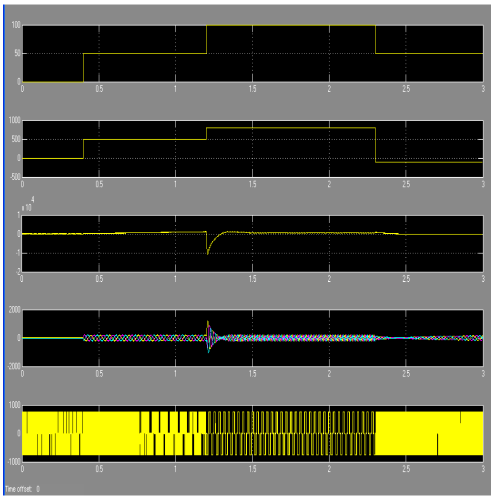

Figure 14: simulated output wave forms

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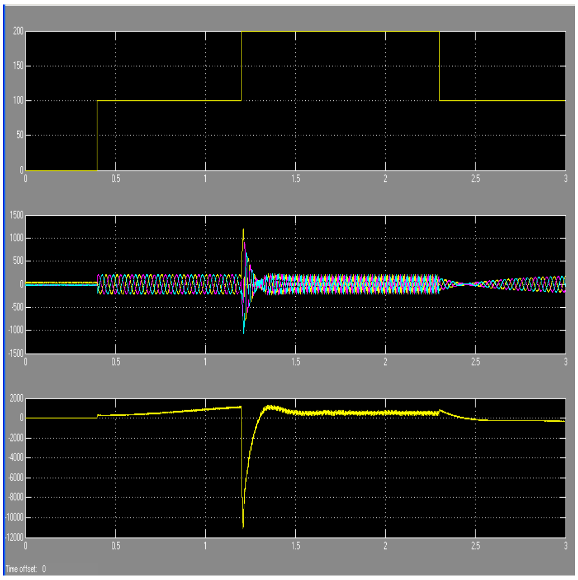

Figure 15: motor output wave form

VII.CONCLUSION:

In this paper, a novel integrated power electronic interface has been proposed for BEVs to optimize the performance of the powertrain. The proposed IPEI combines the features of the BMDIC and the ESI. The proposed IPEI and its performance characteristics have been analyzed and presented. Different control strategies are designed to verify the performance of the proposed IPEI during different operating modes. It should be pointed out that the IFOC based on PWM voltage and PSO is more efficient than IFOC based on PWM voltage which is used to drive the EM during traction and braking modes. Moreover, a boost converter is added to the proposed IPEI in order to achieve a high power factor correction, and can achieve a low THD for the input current during charging mode from the ac grid.

As is clear from the simulation results, the proposed IPEI can reduce the current and voltage ripples, can improve the efficiency and reliability, and can provide a compact size for the BEV power train. Furthermore, the battery lifespan can be increased due to the ripple reduction. Finally, the simulation results have demonstrated that the proposed IPEI has been successfully realized and it promises significant savings in component count with high performance for BEVs compared to other topologies. Therefore, it can be expected that these topologies can be utilized for development of high efficiency BEV power trains.

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