SIMULATION AND DESIGN OF COMPACT INTEGRATED CONVERTERS MOTOR DRIVES FOR ELECTRIC VEHICLE, HYBRID ELECTRIC VEHICLE APPLICATIONS

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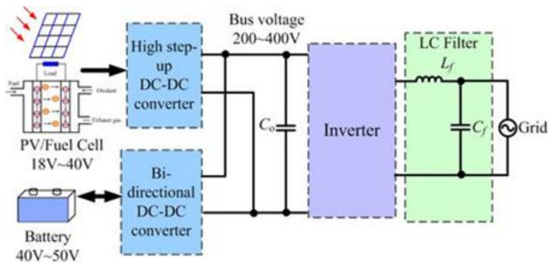
Abstract

The recent emergence of plug-in electric vehicles in a global market can offer big challenges and opportunities for both basic and applied research. Although the electrical architecture of a Electric Vehicle (EV) or an Hybrid Electric Vehicle (HEV) can be considered standardized, the development of its different building blocks is an open problem whose solution could contribute to improve significantly the global performance of the vehicle.

Keywords:DC–DC converter, HEV, Boost converter.

I.INTRODUCTION

A DC–DC converter with a high step-up voltage gain is used for many applications, such as high-intensity discharge lamp ballasts for automobile headlamps, fuel cell energy conversion systems, solar-cell energy conversion systems and battery backup systems for uninterruptible power supplies. Theoretically, a dc–dc boost converter can achieve a high step-up voltage gain with an extremely high duty ratio. However, in practice, the step-up voltage gain is limited due to the effect of power switches, rectifier diodes and the equivalent series resistance (ESR) of inductors and capacitors.



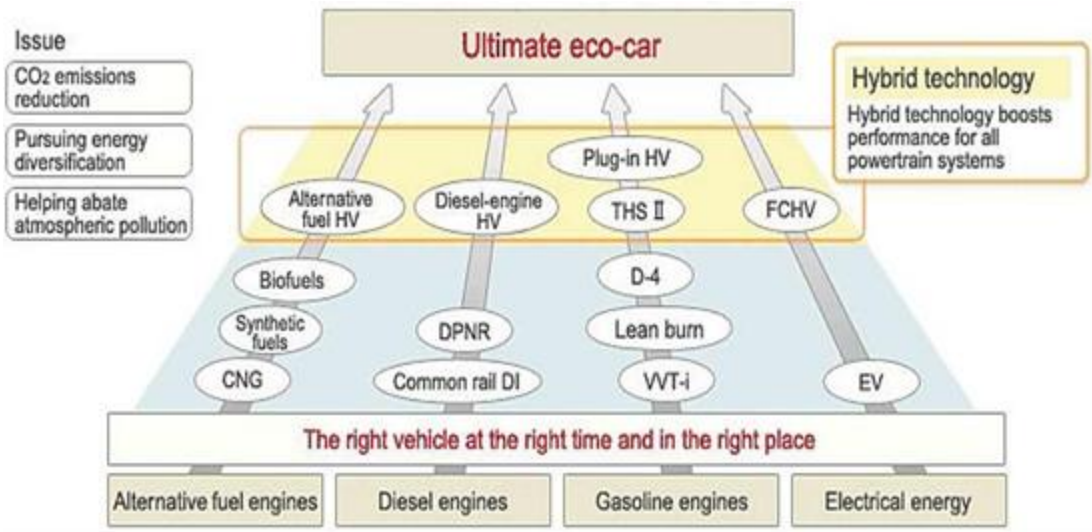
A high step-up dc–dc converter is shown in Fig.1.1 with an integrated coupled inductor and a common mode electromagnetic interference reduction filter. Here a Sepic –flyback converter with a coupled inductor and an output voltage stacking is developed. A high step-up converter, which utilizes a coupled inductor and a voltage doubler technique on the output voltage stacking to achieve a high step-up voltage gain, is introduced. A high step-up boost converter that uses multiple coupled inductors for the output voltage stacking is proposed

II.HYBRID ELECTRIC VEHICLE

Hybrid Electric Vehicle (HEV) is an emerging technology in the modern world because of the fact that it mitigates environmental pollutions and at the same time increases fuel efficiency of the vehicles. Multilevel inverter controls electric drive of HEV of high power and enhances its performance which is the reflection of the fact that it can generate sinusoidal voltages with only fundamental switching frequency and have almost no electromagnetic interference. This paper describes precisely various topology of HEVs and presents transformer less multilevel converter for high voltage and high current HEV. The cascaded inverter is IGBT based and it is fired in a sequence. It is natural fit for HEV as it uses separate level of dc sources which are in form of batteries or fuel cells. Compared to conventional vehicles, hybrid electric vehicles (HEVs) are more fuel efficient due to the optimization of the engine operation and recovery of kinetic energy during braking. With the plug-in option (PHEV), the vehicle can be operated on electric-only modes for a driving range of up to 30–60 km. The PHEVs are charged overnight from the electric power grid where energy can be generated from renewable sources such as wind and solar energy and from nuclear energy. Fuel cell vehicles (FCV) use hydrogen as fuel to produce electricity; therefore they are basically emission free. When connected to electric power grid (V2G), the FCV can provide electricity for emergency power backup during a power outage. Due to hydrogen production, storage, and the technical limitations of fuel cells at the present time,

III.NEED OF EV'S AND HV'S

Vehicles equipped with conventional internal combustion engines (ICE) have been in existence for over 100 years. With the increase of the world population, thedemand for vehicles for personal transportation has increased dramatically in the past decade. This trend of increase will only intensify with the catching up of developing countries, such as China, India, and Mexico. The demand for oil has increased significantly. Another problem associated with the ever-increasing use of personal vehicles is the emissions. The green house effect, also know as global warming, is a serious issue that we have to face. There have been increased tensions in part of the world due to the energy crisis. Government agencies and organizations have developed more stringent standards for the fuel consumption and emissions. Nevertheless, with the ICE technology being matured over the past 100 years, although it will continue to improve with the aid of automotive electronic technology, it will mainly rely on alternative evolution approaches to significantly improve the fuel economy and reduce emissions. Battery-powered electric vehicles were one of the solutions proposed to tackle the energy crisis and global warming. However, the high initial cost, short driving range, long charging time, and reduced passenger and cargo space have proved the limitation of battery-powered EVs. The HEV was developed to overcome the disadvantages of both ICE vehicles and the pure battery-powered electric vehicle. The HEV uses the onboard ICE to convert energy from the on board gasoline or diesel to mechanical energy, which is used to drive the onboard electric motor, in the case of a series HEV, or to drive the wheels together with an electric motor, in the case of parallel or complex HEV. The onboard electric motor(s) serves as a device to optimize the efficiency of the ICE, as well as recover the kinetic energy during braking or coasting of the vehicle. The ICE can be stopped if the vehicle is at a stop, or if vehicle speed is lower than a preset threshold, and the electric motor is used to drive the vehicle along. The ICE operation is optimized by adjusting the speed and torque of the engine. The electric motor uses the excess power of the engine to charge battery if the engine generates more power than the driver demands or to provide additional power to assist the driving if the engine cannot provide the power required by the driver. Due to the optimized operation of the ICE, the maintenance of the vehicle can be significantly reduced, such as oil changes, exhaust repairs, and brake replacement. In addition, the onboard electric motor provides more flexibility and controllability to the vehicle control, such as antilock braking (ABS).



IV.HEV CONFIGURATIONS:

HEV elaborates the various configurations of HEVs highlighting its advantages and disadvantages. IGBT based cascaded multilevel has been developed and it is interface with 20kW 3-phase induction motors suitable for HEVs and simulation result in PSIM as well as MATLAB are done and results are presented.

Although a number of configurations are used for HEV power trains, the main architectures are the series, parallel and series-parallel ones. They are analyzed in this Section

i)By disregarding the losses in the electric and mechanical devices, the power consumption of the auxiliary electric loads, and the presence of gearboxes.

ii)By considering the static converters used for the interface of the electric devices as a whole with the devices themselves. Moreover, the analysis is carried out by assuming that i) the powers are positive quantities when the associated energy flows in the direction of the arrows reported in the schemes of the architectures, and iii)the driving requirements for a vehicle are the speed and the torque at the wheels, where the product of the two variables gives the required propulsion power.

Series Architecture

The Power train of a Series HEV (SHEV) has the architecture of Fig.3.6. It comprises a genset (i.e. a generation set) and a drive train of electric type, which are connected together through a common power Bus (B). To B is also connected an energy Storage system (S).

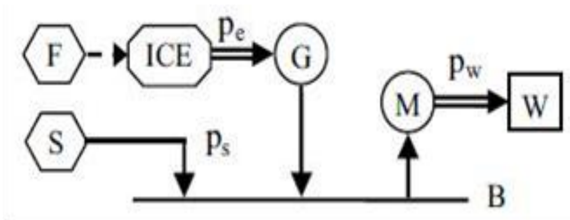


Fig.1.1: SHEV Powertrain architecture (electric and mechanical connections are traced respectively with single & double lines, whereas the fuel path is traced with dashed line).

In the genset, ICE is fed by the Fuel tank (F) and delivers the mechanical power pe to the electric Generator (G). The latter one converts pe into electric form and supplies B. The energy associated to pe can be either stored in S (in this case the power ps of Fig.2.6 is negative) or drawn by the electric drive train or both. During the engine start-up, G behaves as a crank motor energized from S. The electric drive train is constituted by one (or more) electric Motor (M) that draws the propulsion power pw from B and delivers it to the Wheels (W). Note that in this architecture the wide speed-torque regulation allowed by M may make superfluous the insertion of a variable-ratio gearbox between M and W. During the regenerative braking, M operates as a generator to recover the kinetic energy of the vehicle into S. The mechanical separation between genset and electric drive train, and the energy buffering action of S give the series architecture the maximum flexibility in terms of power management. As a matter of fact, SHEV may be considered as a purely electric vehicle equipped with a genset that recharges S autonomously instead of at a recharge station. Sometimes, the genset is undersized with respect to the average propulsion power absorbed during a typical travel mission. In this case, the genset is used to extend the operating range allowed by S, and SHEV is referred to as "range extender". Pros and cons of the series architecture may be summarized as follows. Pros:

O ICE and G are conveniently sized for the average propulsion power or even less;

O genset and electrical drive train are mechanically separated thus permitting to maximize the ICE efficiency with a consequential substantial reduction of emissions. Cons:

i)two electric machines (i.e. G and M) are required;

ii)M must be sized to provide the peak propulsion power;

iii)the power generated by ICE is transferred to W by means of at least two energy conversions (from mechanical to electrical to possibly chemical inside S, and vice-versa), with a lower efficiency than a direct mechanical connection. The series architecture is reputed to be more suited for vehicles mainly used in urban area, with rapidly varying requirements of speed (and power); it is also used in large vehicles, where the lower efficiency of both ICE and the mechanical transmission make more convenient the electric propulsion.

Parallel Architecture:

The Power train of a Parallel HEV (PHEV) has the architecture of Fig.3.7. It comprises two independent drive trains, namely one of mechanical type and the other one of electric type, whose powers are "added" by a 3-waymechanical devices -the Adder (A)- to provide the propulsion power As shown in Fig.3.7, the mechanical drive train generates the part pe of the propulsion power, whilst the electric drive train delivers the remaining part pm..

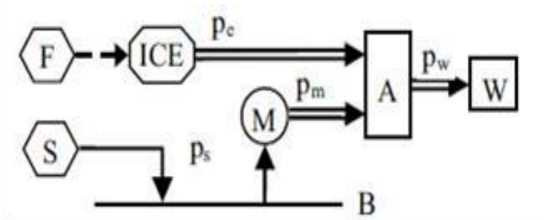


Fig. 1.2 Parallel architecture

Differently from SHEV, M acts here as generator not only during the regenerative braking but also during the normal driving, whenever S must be recharged; in the latter circumstance, M draws energy from ICE through A. As a matter of fact, PHEV may be considered as a conventional vehicle supplemented with an additional drive train of electric type that overtakes the role of the traditional generator-battery set by contributing to the propulsion. Sometimes, S is chosen to have small storable energy but high power capability, and M is sized with a wide overload margin. In this case the electric drive train is used as a power boost to supplement ICE during fast changes of the propulsion power, thus permitting ICE to adapt slowly to the driving conditions. The modifications required to convert a conventional vehicle into PHEV may be somewhat moderate, and this makes easier the manufacturing of PHEVs using the existing production processes. A vehicle built up accordingly is termed "minimal" or "mild" HEV depending on the extent of the modifications introduced in the original Power train. Pros and cons of the parallel architecture may be summarized as follows. Pros:

i)Only one electric machine is needed;

ii)The peak power requirement for M is lower than in SHEV since both M and ICE provide the propulsion power;

iii)The power generated by ICE is transferred to W directly, which is more efficient than through a double energy conversion. Cons: i) an additional 3-way mechanical device is required to couple together ICE, M and W; ii) such coupling imposes a tighter constraint on the power flow compared to SHEV, possibly turning into worse operation of ICE. The parallel architecture is reputed to be more suited for small- and mid-size vehicles mainly travelling along extra urban routes, where the range for the required propulsion power is not too wide.

Series-Parallel Architecture:

The Power train of a Series-Parallel HEV (SPHEV) has the architecture of Fig.3.3. It may be viewed as a mix of the SEHV and PHEV architectures, obtained by employing a Power split apparatus (P) with 2 mechanical ports and 1 electric port. The 3 ports are connected to ICE, A and B, respectively. P divides the power generated by ICE into two parts, i.e. the part pd, which is delivered directly in mechanical form to W via A, similarly to PHEV, and the part pb, which is delivered in electric form to B, similarly to SHEV. The task of the power split apparatus is then24twofold; besides dividing the power generated by ICE, it must convert mechanical energy into an electric form.The series-parallel architecture has two main features: the propulsion requirements are decoupled from the ICE operation and the overall losses are lower since a fraction of the power generated by ICE is delivered to W without any intermediate energy conversion. The former feature makes the management of the power flow very flexible, enabling in principle to optimize the ICE operation in a wide range of driving conditions

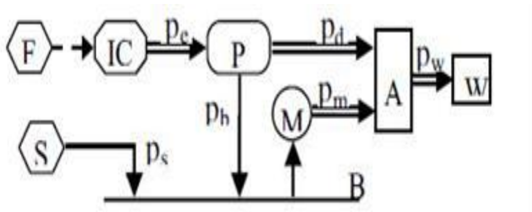


Fig. 1.3Series-parallel architecture

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This project provides an overview of the state of the art of electric vehicles (EVs), HEVs and FCVs, with a focus on HEVs. Section II tries to answer a fundamental question: why EV, HEV, and FCV? It also looks at the key issues of HEVs and FCVs. Section III reviews the history of EVs, HEVs, and FCVs. Section IV highlights the engineering philosophy of EVs, HEVs, and FCVs. Section V presents the architectures of HEVs and FCVs. Section VI provides an overview of the current status of HEV and FCV

V.ARCHITECTURE OF HEV:

HEVs are propelled by an ICE and an electric motor/ generator (EM) in series or parallel configurations. The ICE provides the vehicle an extended driving range, while the EM increases efficiency and fuel economy by regenerating energy during braking and storing excess energy from the ICE during coasting. Design and control of such power trains involve modelling and simulation of intelligent control algorithms and power management strategies, which aim to optimize the operating parameters to any given driving condition. Traditionally, there are two basic categories of HEV, namely series hybrids and parallel hybrids. In series HEV, the ICE mechanical output is first converted to electricity using a generator.

The converted electricity either charges the battery or bypasses the battery to propel the wheels via an electric motor. This electric motor is also used to capture the energy during braking. A parallel HEV, on the other hand, has both the ICE and an electric motor coupled to the final drive shaft of the wheels via clutches. This configuration allows the ICE and the electric motor to deliver power to drive the wheels in combined mode, or ICE alone, or motor alone modes. The electric motor is also used for regenerative braking and for capturing the excess energy of the ICE during coasting. Recently, series– parallel and complex HEVs have been developed to improve the power performance and fuel economy.

Series HEV:

In series HEVs, the ICE mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the same electric motor and mechanical transmission. Conceptually, it is an ICE-assisted EV that aims to extend the driving range comparable with that of conventional vehicle. Due to the decoupling between the engine and the driving wheels, it has the definite advantage of flexibility for locating the ICE generator set. Although it has an added advantage of simplicity of its drive train, it needs three propulsion devices, the ICE, the generator, and the electric motor. Therefore, the efficiency of series HEV is generally lower. Another disadvantage is that all these propulsion devices need to be sized for the maximum sustained power if the series HEV is designed to climb a long grade, making series HEV expensive. On the other hand, when it is only needed to serve such short trips as commuting to work and shopping, the corresponding ICE generator set can adopt a lower rating.

There are six possible different operation modes in a series HEV:

1)Battery alone mode: engine is off, vehicle is powered by the battery only;

2)Engine alone mode: power from ICE/G;

3)Combined mode: both ICE/G set and battery provides power to the traction motor;

4)Power split mode: ICE/G power split to drive the vehicle and charge the battery;

5)Stationary charging mode;

6)Regenerative braking mode

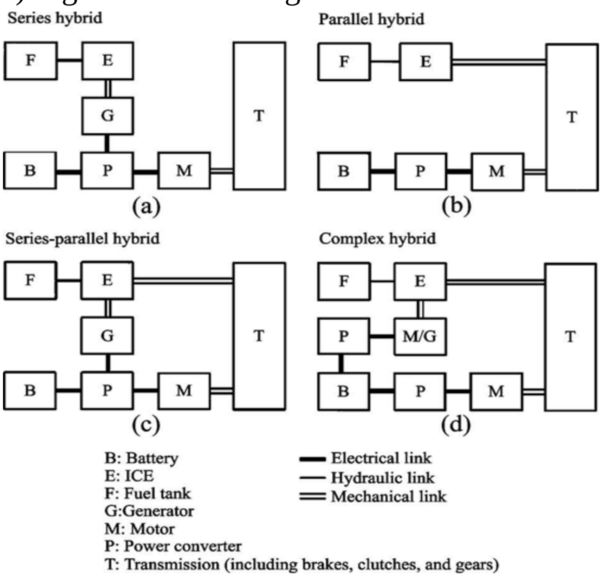

Fig. 1.4 Four common architectures of HEV.

Parallel HEV

Differing from the series hybrid, the parallel HEV allows both the ICE and electric motor to deliver power in parallel to drive the wheels. Since both the ICE and electric motor are generally coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by the ICE alone, by the electric motor, or by both. Conceptually, it is inherently an electric-assisted ICEV for achieving both lower emissions and fuel consumption. The electric motor can be used as a generator to charge the battery by regenerative braking or by absorbing power from the ICE when its output is greater than that required to drive the wheels. Better than the series HEV, the parallel hybrid needs only two propulsion devices with the ICE and the electric motor. Another advantage over the series case is that a smaller ICE and a smaller electric motor can be used to get the same performance until the battery is depleted. Even for long-trip operation, only the ICE needs to be rated for the maximum sustained power while the electric motor may still be about a half. The following are the possible different operation modes of parallel hybrid:

1)Motor alone mode: engine is off, vehicle is powered by the motor only;
2)Engine alone mode: vehicle is propelled by the engine only;
3)Combined mode: both ICE and motor provides power to the drive the vehicle;
4)Power split mode: ICE power is split to drive the vehicle and charge the battery (motor becomes generator);
5)Stationary charging mode;
6)Regenerative braking mode (include hybrid braking mode).

Series–Parallel HEV:

In the series–parallel hybrid, the configuration incorporates the features of both the series and parallel HEVs, but involving an additional mechanical link compared with the series hybrid and also an additional generator compared with the parallel hybrid. Although possessing the advantageous features of both the series and parallel HEVs, the series–parallel HEV is relatively more complicated and costly. Nevertheless, with the advances in control and manufacturing technologies, some modern HEVs prefer to adopt this system.

FCV

Fuel cell vehicles can be considered as series-type hybrid vehicles. The onboard fuel cell produces electricity, which is either used to provide power to the propulsion motor or stored in the onboard battery for future use.

To meet some of the aspect of HEV cascaded multilevel inverter is used so as to meet high power demands. The multilevel voltage source inverters with unique structure allow them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized switching devices. The general function of the multilevel inverter is to synthesize a desired voltage from several levels of dc voltages. For this reason, multilevel inverters can easily provide the high power required of a large electric drive. As the number of levels increases, the synthesized output waveform has more steps, which produces a staircase wave that approaches a desired waveform. Also, as more steps are added to the waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases. As the number of levels increases, the voltage that can be spanned by summing multiple voltage levels also increases. The structure of the multilevel inverter is such that no Voltage sharing problems are encountered by the active devices.

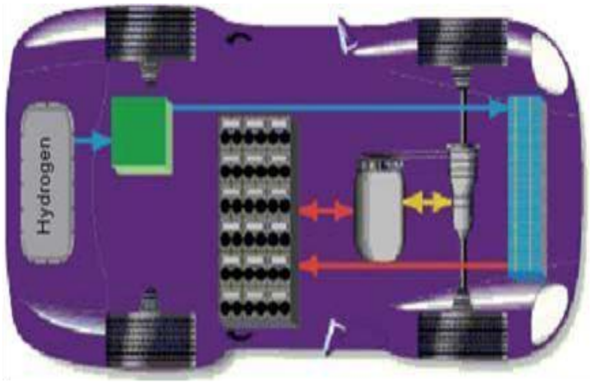

Fig. 1.5. Architectures of fuel cell HEV.

VI. HEV CONFIGURATIONS:

HEV elaborates the various configurations of HEVs highlighting its advantages and disadvantages. IGBT based cascaded multilevel has been developed and it is interface with 20kW 3-phase induction motors suitable for HEVs and simulation result in PSIM as well as MATLAB are done and results are presented.

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ii)the driving requirements for a vehicle are the speed and the torque at the wheels, where the product of the two variables gives the required propulsion power.

VII.PROPOSED CONCEPT

In Parallel hybrid electric vehicle (HEV) and electric vehicle (EV) system as shown in Fig. 4.1, the converter is used for boosting the battery voltage to rated dc bus for an inverter to drive motor. In the multi motor drive system, the system will use two or more motors to boost torque, especially under low speed and high-torque region as shown in Fig. 4.2. For such applications, two or more inverters/converters are required. Fig. 4.3 shows the application of the proposed integrated circuit for motor drives with dual-mode control for EV/HEV applications. As shown in Fig. 4.3, the proposed integrated circuit allows the permanent magnet synchronous motor

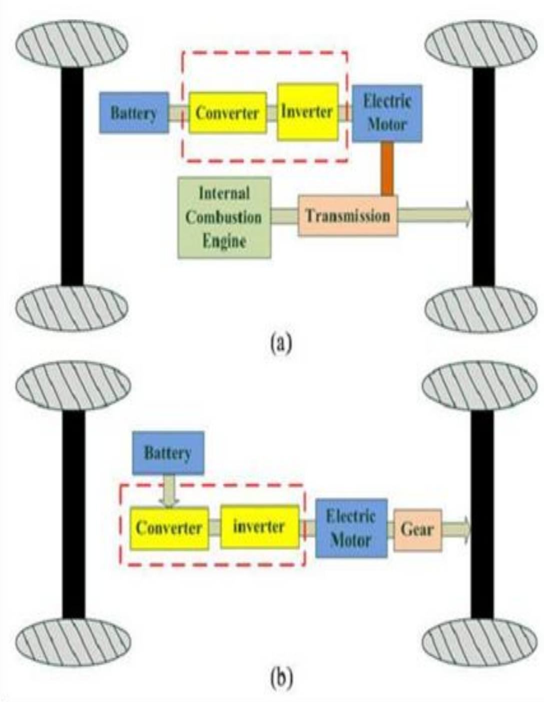

Fig. 1.6.HEV and EV system. (a) Parallel HEV drive train. (b) EV drive train

VIII.PROPOSED INTEGRATED CIRCUIT AND CONTROL TECHNIQUE:

When the integrated circuit is operated in inverter

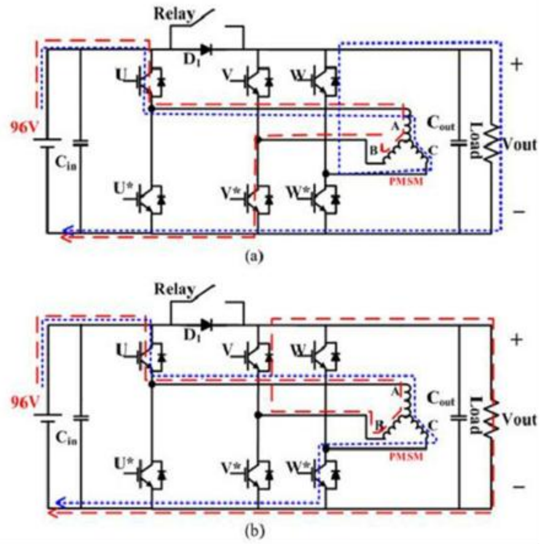

Fig. 1.6. Proposed interleaved boost mode. (a) PhaseB: Charge; Phase

C:Discharge. (b) PhaseB: Discharge; PhaseC:Charge.

(motor) mode, relay will be turned ON and six power devices(IGBTs) are controlled by pulse width modulation(PWM) control signals. Details of the component specifications are shown in Table 4.1.When the proposed integrated circuit is operated in the converter mode, relay is turned OFF. And a single-phase or interleaved control method will be applied to control of the power devices depending upon the load conditions. Figs.1.6show the single-phase and two-phase interleaved boost converters. the single-phase boost converter uses power switch V∗, stator winding "A" and winding "B" to boost the output voltage. In Fig. 1.6, two-phase interleaved boost converter uses power switches V∗ and W∗, stator winding "A" winding "B" and winding "C" to boost the output voltage and reduce the current ripple.

IX.MATLAB/SIMULATION RESULTS:

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modelling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

MATLAB/SIMULINK RESULTS:

Here the simulation carried by two different cases they are 1) Proposed interleaved boost converter multiplier module 2) PV as input source of proposed converter with interleaved boost converter

Case-1Proposed interleaved boost converter

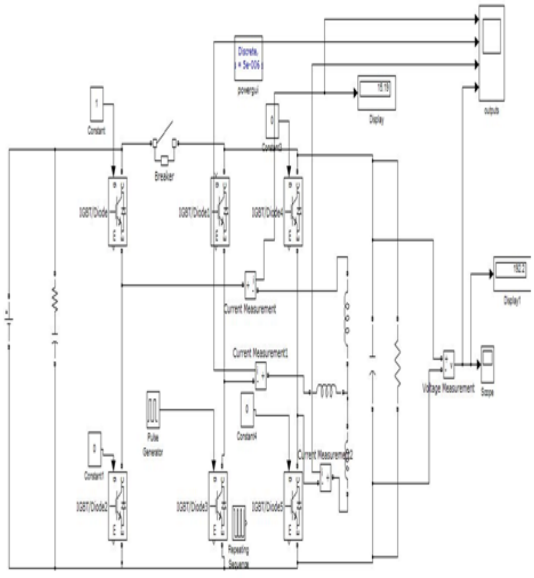

Fig.1.7 MATLAB/Simulink model of the integrated circuit and controller

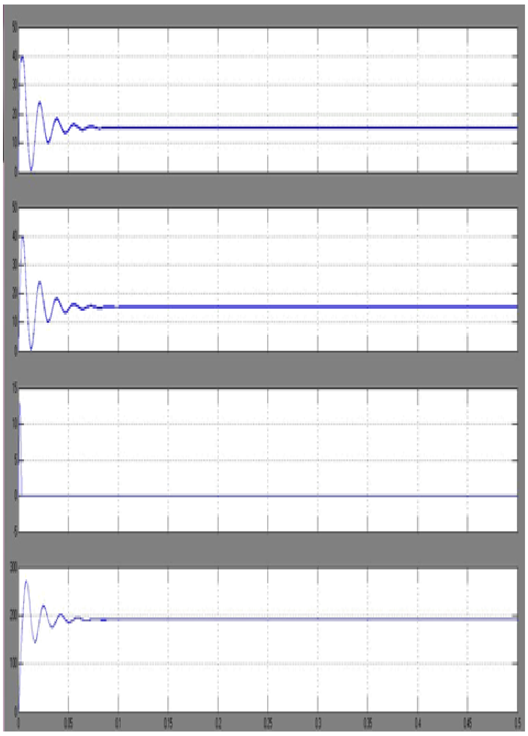

Fig.1.8 measured current with and without interleaved control, Single-phase interleaved boost converter

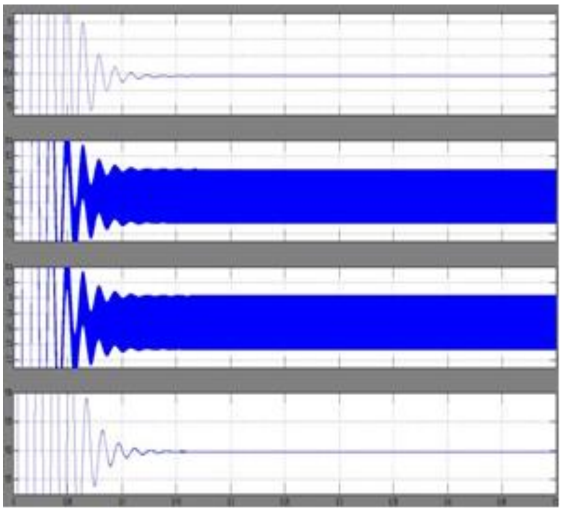

Fig.1.9 measured current with and without interleaved control, Two-phase interleaved boost converter

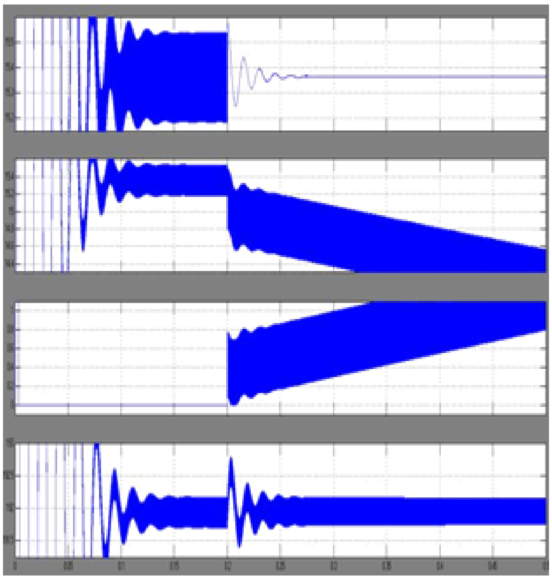

Fig. 1.10 Simulated waveforms for the transition between single-phase control and two-phase interleaved control from two-phase interleaved to single-phase modes.

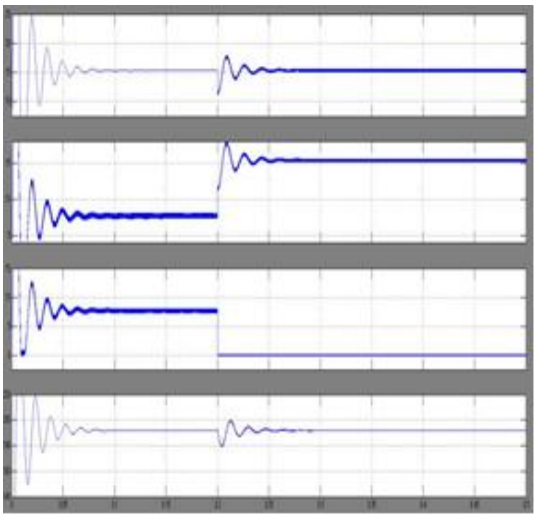

Fig. 1.11 Simulated waveforms for the transition between single-phase control and two-phase interleaved control single-phase to two-phase interleaved modes

X.CONCLUSION & FUTURE SCOPE

CONCLUSION

An HEV intelligently gets around the individual problems associated with the gasoline engine and the electric vehicle. It diminishes the production of emissions and the use of fuel. The problem of batteries for the electric vehicle is conquered. An HEV charges itself – it never has to be plugged in. When not in use providing power, the motor can run as a generator to transfer energy from regenerative braking and from the gasoline engine to the batteries. The only recharging necessary is refuelling by going to the gas station. Also, there is not the same demand on the batteries as there would be in an electric vehicle, where the batteries must store all the energy the car needs. Proposal of a new integrated inverter/converter circuit of motor drives with dual-mode control for EV/HEV with PV cell application to significantly charge the battery and to reduce the volume and weight, proposal of a new control method for the integrated inverter/converter circuit operating in boost converter mode to increase the efficiency, verification of the proposed integrated inverter/converter circuit.

FUTURE SCOPE

At present the major challenge with utilizing the solar energy is the high cost of the PV cells. However, in future as the use of the PV cells for various applications increase, cost of manufacturing technology for PV cells is sure to come down. This will promote greater use of the PV cells and continuous sliding down of the prices. The solar car will become affordable cost wise in the next five years or so. The proposed concept can be implemented in real time, the number of components can be decreased in the proposed converter which decreases the cost and size of the converter and increases the efficiency of overall concept

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