Extended Boost DC-DC-AC Converter for Electric Vehicle Applications

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Abstract. In this paper, extended boost DC-DC-AC converter is proposed for Electric Vehicle (EV) applications. The extended boost DC-DC power converter overcomes the limitations of traditional voltage source and impedance source power converters. In addition to the DC-DC converters, charge storage systems are also evenly plays a pre-dominant role in EVs. This paper provides a comprehensible idea concerning the right selection of power converters, energy storage systems and electric drives systems. A wide research was made on electric vehicle models in the design phase, but most reached the prototype model with better efficiency. The electrical systems and combustion engines found in these vehicles are compared in order to forecast the evolution trend in terms of specifications and performance of the whole vehicle and of each system. The entire system is developed and simulated using SIMULINK tools. A prototype model of single phase extended boost DC-DC converter is developed and its results are validated.

IndexTerms—Battery systems, extended boost DC-DC power converters, electric vehicles.

1. Introduction
The Electric vehicles (EVs) put forward a massive potential to significantly dwindle carbon emissions in the present scenario from internal combustion engines and the generation companies. Plug-In Electric Vehicles (PHEVs) may perhaps activate a stepwise electrification of the complete transport sector. In recent times quite a lot of electric vehicles have been introduced and used all throughout the world. But only some vehicles has been designed and manufactured for commercial use. Some vehicles are still only in the design phase. The foremost important is regarding the long range vehicle which contributes to the major of carbon emission. Based on the predictions from the existing data the future development was made in the EVs. For low range vehicles the manufacturers prefer pure electric configuration while for the high range vehicles hybrid configuration is preferred [1]-[3]. A comparison is made between the IC engines and EVs to anticipate the performance of the system.
Reducing the level of greenhouse gas emissions attributable to the transportation sector is a major part of the environmental protection policies in many developed and developing economies. The transportation sector and individual transport in meticulous is highly dependent on fossil fuels. Due to the oil crisis most of the countries are moving towards electric vehicles [4]-[6]. From the survey it is identified that electrifying the entire transport sector diminish the energy consumption to one fifth of the present utilization. Although EVs have been around for quite some time, their limited range has hindered their wide spread use [9]. Over the past decade key technologies have progressed so that mass-market viable plug-in electric vehicles (PEVs). In this paper, ultra capacitor based AC drive is developed for plug-in electric vehicles.

This paper presents an ultra capacitor based extended boost power converter fed AC Motor Drive for EV application. The main motivation of this work is to implement the modified Z-source or impedance source inverter to activate it in high ambient temperature conditions. The enhancements made in the modified Z-source inverter will mitigate the limitations of conventional DC-DC converter topology and will get better operation in the soft switching region. The projected configuration functions as a forward boost/reverse buck or forward buck/reverse boost configuration where the functioning type is preselected by the analog or digital controller.

In this project, ultra capacitors are proposed as the storage system. Through the literature it is understood that the performance of ultra capacitor are better than the lead-acid batteries. This project provides a clean and emission free environment. Plug-in concept is introduced to charge the electric vehicle as like that of fuels [17]-[21].

In the article; Section I shows the introduction of EV system. Section II shows the introduction of extended boost power converter system for EV application. Storage system of extended boost power converters is addressed in Section III. Simulation model of the modified boost impedance source converter are presented in Section IV. Results and discussions of proposed converter are presented in Section V. Section VI concludes the development of extended boost power converters. The general structure of EV systems is represented in Figure. 1.

![Figure 1 Block diagram of conventional electric vehicle system](image)

**2. Extended boost power converters**

Theoretically, boost converter can produce infinite gain, on the other side; it is understood that the derating of the system performance is due to presence of parasitic elements. By considering all the performance parameters, the increase of duty cycle above 0.9 possibly will increase power losses and the system will lead to malfunction [10]-[16]. The voltage stresses across the inverter switches are high in conventional power converters. Without compromising the performance parameters and boost capability of conventional power converters, certain modifications made in normal boost network named “Extended Boost power Inverter”. The block diagram of proposed extended boost power converter based EV is shown in Figure. 2. Operation of shoot through state decides the setup voltage in the passive components in the modified impedance source extended boost power converter. By controlling both the stages of the converter the input voltage is get boosted to obtain the desirable AC output voltage for EV application.
The proposed impedance source inverter has two main operating states as like that of traditional Z-Source converter topology. Impedance source based maximum boost power topology can be operated in boost and buck mode. Modified Z-source converter with continuous current converter is shown in the Figure 3(a). In this topology additional switching and passive components are added with first extension [7].

Modified impedance source extended boost configuration consists of three power semiconductor diodes, three passive components such as inductors capacitors. Figure. 3(b) illustrates the equivalent-circuit for the voltage boosting stage/state called shoot-through state. The voltage equations are as follows:

\[ V_{L3} + V_{L1} = V_{C3} \]  \hspace{1cm} (1)
\[ V_{L1} = V_{C1} \]  \hspace{1cm} (2)
\[ V_S = V_{C3} + V_{C2} + V_{L1} \]  \hspace{1cm} (3)

Power flow from the source to the inductor or the capacitor to the inductor is happened when one of the passive components like capacitor is getting discharged.
By taking into account of the nominal voltage across the magnetic components such as inductors is zero for the voltage boosting stage/state of shoot-through duty ratio as $D_s$ and voltage step down stage of non-shoot-through duty ratio as $D_A$ where $D_A + D_s = 1$. Let us assign $B = 1/[(1-2D_s)(1-D_s)]$, the voltage boost factor in the DC side, Then the maximum AC supply can increased by increasing the factor of $1/(1-D_s)$. Likewise, the stable condition equations are derived for the discontinuous-current mode of modified inverter. It is achievable that the same voltage boost factor as that of the continuous current topology.

3. Review of storage systems

Due the high power density and high energy per unit mass of Lithium-ion batteries are widely used in electronics applications [8]. Majority of the components of lithium-ion batteries are recycled. By sacrificing the cost parameter of Lithium-ion batteries, it is adopted for plug-in hybrid electric vehicles. The charging characteristics of Lithium ion battery is shown in Figure. 4.

![Charging characteristics of Lithium ion battery](image)

Nickel-metal hydride batteries proffer realistic explicated energy and precise control capabilities and are adopted characteristically in processors of supercomputers and therapeutic apparatus. Nickel-metal hydride batteries encompass a great deal for longer existence in charging and discharging cycle than lead-acid batteries. Nickel-metal hydride batteries are now adopted for electric vehicle applications and are extensively adopted for hybrid electric vehicles. Apart from battery cost, the well known challenges with conventional nickel-metal hydride batteries are high self-discharge and thermal creation for high temperatures, and it needs to control hydrogen loss. The characteristics of Nickel ion battery is represented in Figure. 5.

![Charging characteristics of Lead acid battery](image)

Lead-acid batteries can be premeditated to be high authority in terms of power, energy and are reasonably priced, secure, and consistent. On the other side, low specific energy, pitiable cold-temperature concert, and diminutive schedule and cycle life hamper their utilization. Highly developed lead-acid batteries are being manufactured and commercialized for electric drive vehicles for additional systems. The charge characteristics of Lead-acid battery are shown in Figure. 6.

Ultra capacitors from miracle substance graphene charges batteries in 4 minutes. The new storage technology uses a ultra capacitor, rather than a conventional storage system, A ultra capacitor stores energy on the surfaces of materials in the form of tacit electricity as like that of super capacitor.
4. Simulation of extended boost power converter

The energy stored in the battery is converted into AC voltage with the help of inverters. In this project the proposed modified boost extended impedance source converter is used to convert Direct Current to Alternating Current and also to step up the voltage of 140V to the desired voltage of 220V (RMS). The projected modified impedance source extend boost topologies are considered for superior boost and subordinate voltage stress across the passive components like capacitors. The secure condition manoeuvre is executed to analyze the maximum stepping up capability of the modified Z-source inverter system. In this project maximum boost control topology is used for PWM pulse generation the generated gate pulses are given to the inverter switches as shown in the Figure. 7.

Figure. 8 shows the simulation of extended boost converter, which gets the input from the battery and boosted to the desired level by the switching operation of inverter switches. Based on the switching strategy of inverter the voltage levels get boosted. Obtained output voltage is given to the load system.
Figure 7 Extended boost power converter based AC load System

Figure 8 Simulation of extended boost converter

5. Results and discussion of extended boost power converter

5.1. Simulation results and analysis

The triggering pulses are engendered using a maximum boost control techniques. The reference signals are superimposed with the triangular carrier wave to synthesise the triggering scheme with the main shoot through states. When the triangular carrier waves are greater than the superior envelope $V_p$, or subordinate than the bottom packet $V_n$, the track turns into shoot through state or else it activates as a conventional inverter. Figure 9 shows the engendered switching schemes for the switches with boost have power over another method with modulation index of 0.79.
Figure 9 Gate pulses to extended step-up converter

Figure 10 Output waveforms of proposed extended step-up converter

Figure 11 Output voltage THD
Figure. 10 shows the output voltage and current waveforms of proposed extended boost impedance source inverter if the input voltage is 144 V ($V_m$). Figure. 11 shows output voltage THD analysis of modified Z-source inverter with minimum THD of 5.16%.

5.2. Experimental results and analysis

Figure. 12 Experimental setup of maximum boost impedance source system

Figure. 13 Maximum boost impedance source output

Figure. 12 shows the experimental setup of maximum boost impedance source inverter system for EV applications. Figure. 13 shows the maximum boost impedance source output, which is about 200V DC from the input of 15V. Figure. 14 shows the output waveform of impedance source inverter which is about 180V, 50 Hz. Impedance source inverter converts 200V DC supply (which is obtained from maximum boost impedance source) into 180V AC supply. The inverter output is suitable for domestic applications.
Figure 14 Inverter output voltage

6. Conclusion
The proposed modified impedance source system was simulated using MATLAB/SIMULINK tools and their results are validated. From the achieved results it is clearly inferred that the voltage anxiety in the inverter modules are reduced from end to end using auxiliary resonant soft switching system. Thus electric vehicles are more eco-friendly than any other vehicles. The need for electric vehicles will be increasing more in the future generation. The efficient utilization of the storage system is improved through the proposed extended boost power converters.

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