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Implementation and Design of Boost Converter using Super Capacitor for Solar PV Based Electric Vehicle (EV)

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ABSTRACT: Utilisation of more than one energy source in the electric vehicle (EV) ensures the reliable riding of the vehicle without range anxieties. Solar PV, battery and ultra-capacitor are viable sources to power the EV. A dual input–dual output dc–dc converter is proposed for the integration of the above sources for the EV application. The converter can be used to transfer power between the input sources and loads/utility grid/other EVs. The proposed converter can be operated in ten different modes using the same structure by controlling the appropriate switches. The equivalent circuits with the analytical waveforms of significant modes of operation of the converter are discussed in this study. The proposed converter effectively utilises the solar PV power by operating in six different modes. Also, it has the advantages of wide range of speed control and reduces the number of conduction devices in each mode, thereby enhancing the efficiency. This study presents detailed operating waveforms and dynamic analysis of the proposed DISB DC–DC converter.

I. INTRODUCTION

Now days we are looking for alternate sources like electric vehicles, in order to cut down the pollution from automobiles which are growing rapidly. In electric vehicles, A DC-DC converter is used to boost the voltage from solar photo voltaic (PV) array and isolated bidirectional DC-DC converter (IBDC) is used to charge and discharge the battery. Renewable energy technologies such as fuel cell and solar are gaining popularity for vehicle application. Not only these energy sources reduce gas in the cities but they also reduce dependability on the fossil energy. As a platform to exchange ideas and research findings related to solar vehicles, North American Solar Challenge. One of the highlights of the event is the solar racecar. This initiative ignites interests of many researchers to develop high efficiency power generated solar, improve aerodynamic and reduce losses in mechanical and electrical in the car. As solar power depends on the sunlight, such vehicle needs secondary sources to drive at night or in cloudy conditions. Alternatively, fuel cell can work all day long as long as hydrogen is available in the tank.

In the past few decades there has been a steady transition from petroleum–based to electric-based transportation in all sectors, including aircraft, trains, ships, and electric vehicles (EVs). This shift is expected to rapidly advance, particularly with EVs, as the benefits, political incentives, and falling prices, including due to large-scale production, aid the market. Clearly, alternatives to fossil fuels need to be developed for transportation, electricity generation, etc. For transportation, EVs have been a recognized solution and continue to become widely accepted as the technology develops and economic feasibility becomes a reality. EVs offer increased efficiency (energy savings) through better fuel economy, reduced emissions/pollution and EVs help the U.S. to have a greater diversity of fuel choices for transportation. Almost all U.S. electricity is produced from domestic sources, including natural gas, coal, nuclear, and renewable sources.

Electric Traction System Specifications

When designing a bidirectional DC/DC converter suitable for Power Electronic Interface (PEI) between the Energy Storage System (ESS) and the electric traction drive, it is important to indicate the specifications of the electric traction system. These specifications include identifying the level of hybridization of the vehicle; as well as the choice of hybrid drive train configuration, ESS, electric AC drive system, and DC/DC PEI configuration.

A. Level of Hybridization

In order to determine the dc-link voltage and the energy storage unit capacity at the DC/DC converter terminals, it is empirical to specify the vehicle hybridization level. A full HEV is chosen with large traction motor, high-capacity energy storage pack and main DC bus voltage around 200-300V.

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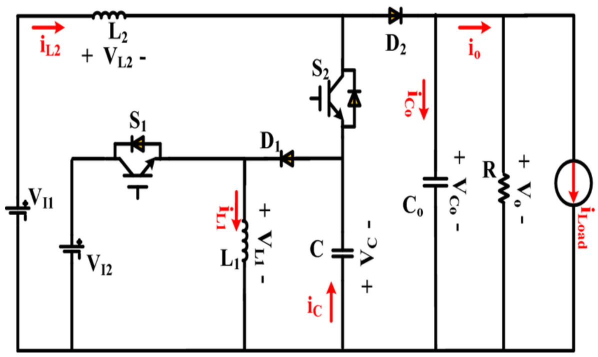
B. Choice of Hybrid Drive train Configuration

A parallel hybrid drive train rather than a series one is chosen for several reasons. As shown in Fig.1, the vehicle can be driven by the ICE alone, the EM alone or both engines at the same time utilizing the best performance of each. Unlike series hybrids, parallel hybrids require less number of energy conversion stages and feature less power demands on the electrical system which makes parallel hybrids less expensive and more energy efficient.

II. CURRENT WORKING SYSTEM

According to the aforementioned theory in commercial EVs, the solar PV charges the battery through separate charge controller and simultaneously battery drives the vehicle through a bidirectional converter. In addition, it has the provision to charge through an external source. a novel dual input super boost (DISB) DC–DC converter for solar-powered EVs. The proposed converter effectively utilises the solar PV power by operating in six different modes. Also, it has the advantages of wide range of speed control and reduces the number of conduction devices in each mode, thereby enhancing the efficiency.

Block Diagram



III. DC-DC CONVERTER WITH ENERGY STORAGE SYSTEM

A. Choice of Hybrid Energy Storage System

HEVs rely on the capability of their ESSs not only to store large amounts of energy but also to discharge according to load demand. A high power, high energy, and high efficiency ESS can be obtained by utilizing a hybrid battery /UC combination. The UC will increase the ESS power handling capability and reserve the amount of regenerative energy dissipated in the friction brakes due to the low power handling capability of the battery. The UC is used during transient pea k power demands and to capture regenerative energy which greatly reduces the voltage variations and stresses across the battery terminals and releases the burden of power converter interfacing the battery.

B. Choice of Power Electronics Interface Configuration

To get full control over the power flowing to and from the battery and to limit the fluctuating voltage levels at the UC terminals, it is necessary to utilize a DC/DC PEI between the storage units and the AC drive. The choice of a power converter as simple yet as efficient as possible to interface the HESS is discussed in [2]. The proposed multi-input bidirectional DC/DC converter interfacing the battery/UC HESS and the traction drive in the HEV consists of two bidirectional half-bridge cells as shown in Fig. 3. Each half-bridge cell consists of an energy storage element (inductor), two IGBT power transistors, and two diodes for bidirectional current flow. IGBT s are chosen since they are suitable for low frequency, high power applications such as the full hybrid vehicle considered. An input capacitor interfacing the source acts as a filter limiting the source current ripple and the circulation of high-frequency components through the sources. This filtering is mainly used due to the Equivalent Series Resistance (ESR) of each of the battery and UC pack. Finally, one common output capacitor is shared between the two cells to minimize the voltage ripple at the DC bus and the inverter input terminals while t he battery and UC voltages remain at a level lower than that of the dc-link.

IV. DUAL INPUT SUPERBOOST (DISB) DC–DC CONVERTER

A typical idea enables the proprietor to recharge the batteries from number of sources like grid and other energy source/storage medium. These EVs could give the fuel adaptability, clean, and smooth operation with batteries.

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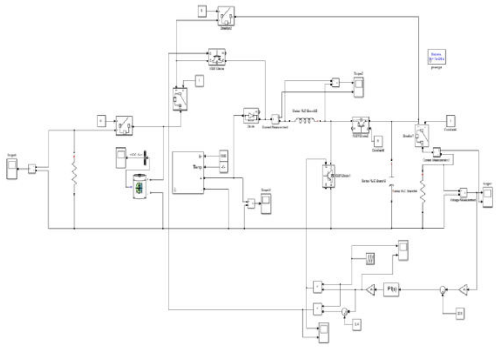
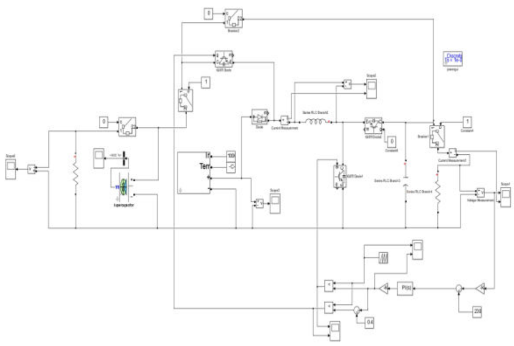
When EVs are interfaced with the utility grid in public parking locations, it provides back-up power and supports the utility.



Moreover, it helps the utility gird to maintain voltage and frequency and also offers to mitigate the peak demand. The bidirectional DC–DC (BDC) converters are used to exchange the power in bidirectional way, and they can be operated in both buck and boost modes with better dynamic response for effective transportation.

V. DC-DC SUPERCAPACITOR

In super capacitor and battery combined energy storage technologies to PHEVs have been discussed. Integration of fuel cell (FC) technologies with other energy storage medium is gaining much attention of industrial interests. Different on-board bidirectional battery charging topologies for PHEVs to achieve improved the performance and unit sizing for satisfactory operations. But super capacitor has been proposed to optimise the performance of EVs.



VI. IMPLEMENTATION

In the proposed work, a typical idea enables the proprietor to recharge the batteries from number of sources like grid and other energy source/storage medium. These EVs could give the fuel adaptability, clean, and smooth operation with batteries. When EVs are interfaced with the utility grid in public parking locations, it provides back-up power and supports the utility. Moreover, it helps the utility gird to maintain voltage and frequency and also offers to mitigate the peak demand. The bidirectional DC–DC converters are used to exchange the power in bidirectional way, and they can be operated in both buck and boost modes with better dynamic response for effective transportation.

The proposed DISB converter operatesunder six different modes in which five modes operates undereither buck or boost operation. In high speed operation, the DISBconverter drives the vehicle from both battery and solar PVsources. This mode of operation is called superboost modewhich isone of the unique feature of the proposed converter. The operatingwaveform of the DISB converter operated under superboost modeand it clearly depicts the gating signal of $S1$,$S2$, and $vL$and iLwaveforms. From 0 to $t1$, $S1$ is ON and theinductor current start rises from $iL0$ to $iL1$ due to $V1$ source. At theinstant $t1$, $S1$is turned OFF and the inductor current rises from $iL1$ toiLPdue to source $V2$ during $t1$ to $t2$. After instant $t2$, $S2$ is turnedOFF and the inductor discharges the energy to the load. During $t2$to Ts, the voltage appears across the inductor is ($v2$–$v0$).According to the voltage–time balance principle of the inductor,the average value of inductor voltage is zero at every cycle. Theexpression shall be written as$v1d1 + v2(d2 - d1) + (v2 - v0)(1 - d2) = 0$ (1)

where$d1$ is the duty ratio of $S1$ and $d2$ is the duty ratio of the $S2$.

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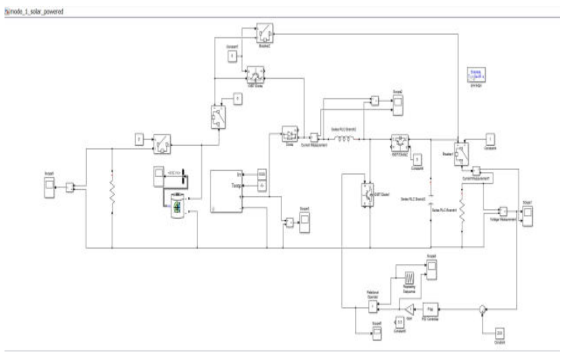
After simplifying (1), the output voltage of the DISB converter insuperboost operation is
$V0 = v1d1 + v2(1 - d1)$
$(1 - d2)$ (2)

The maximum output voltage can be obtained at $d1 = 0.6$ and $d2 = 0.8$ for superboost mode and written as $V\mathrm{max} = 3V1 + 2V2$ (3)

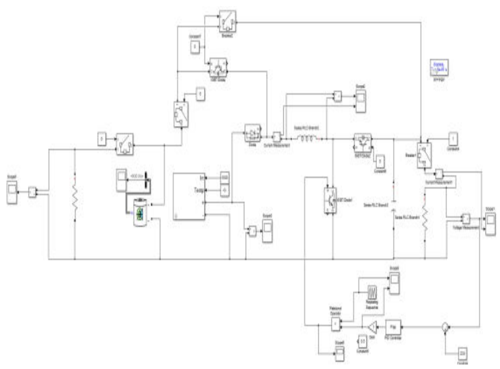
For further analysis, unified output voltage (Vp.u) can be written as
$V\mathrm{p\,.\,u} = V0$
$V\mathrm{max} = k + d1(1 - k)$
$(3 + 2k)(1 - d2)$ (4)

where$k$ is the source ratio ($V2/V1$). The characteristic of unified output voltage with duty ratios ($d1$ and $d2$) for $k = 0.5$



VII. EXPERIMENTAL RESULTS

Similarly, the simulation and experimental results are observed in regenerative braking mode.



It is quite harder to perform this mode of operation in experiments; therefore, the external supply voltage is applied at load end and DISB converter made to operate under buck mode.

The experimental setup is built with the super capacitor which included 6 modules for 230voltage rated power. In order to correlate the simulation and the results parameters have been used in 230voltage rated powerfor the simulation setup. The simulation In order to validate the operation of proposed DISB converter with different six modes, the simulation has been carried out. It is concluded that the experimental results are good agreement with theoretical study and simulation results.

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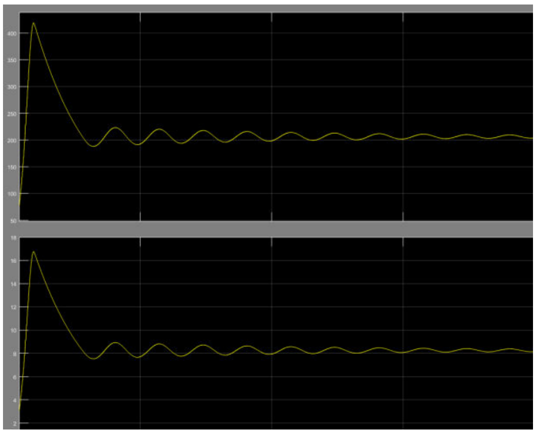

VIII. CONCLUSION

The topology of DISB DC–DC converter has been proposed for solar powered EVs applications. The detailed operating waveform and different mode of operations are presented. The performance characterisation of unified output voltage for proposed DISB converter is discussed. To extract the transfer function of the proposed DISB converter design, a small signal modelling has been developed based on the state space averaging technique. The eigenvalues of system matrix show clearly that the system is stable. The simulation results have been presented to verify the operation and performance of proposed DISB converter and confirmed through experimental results. Both simulation and experimental results validate that the proposed DISB converter is more suitable for EVs application.

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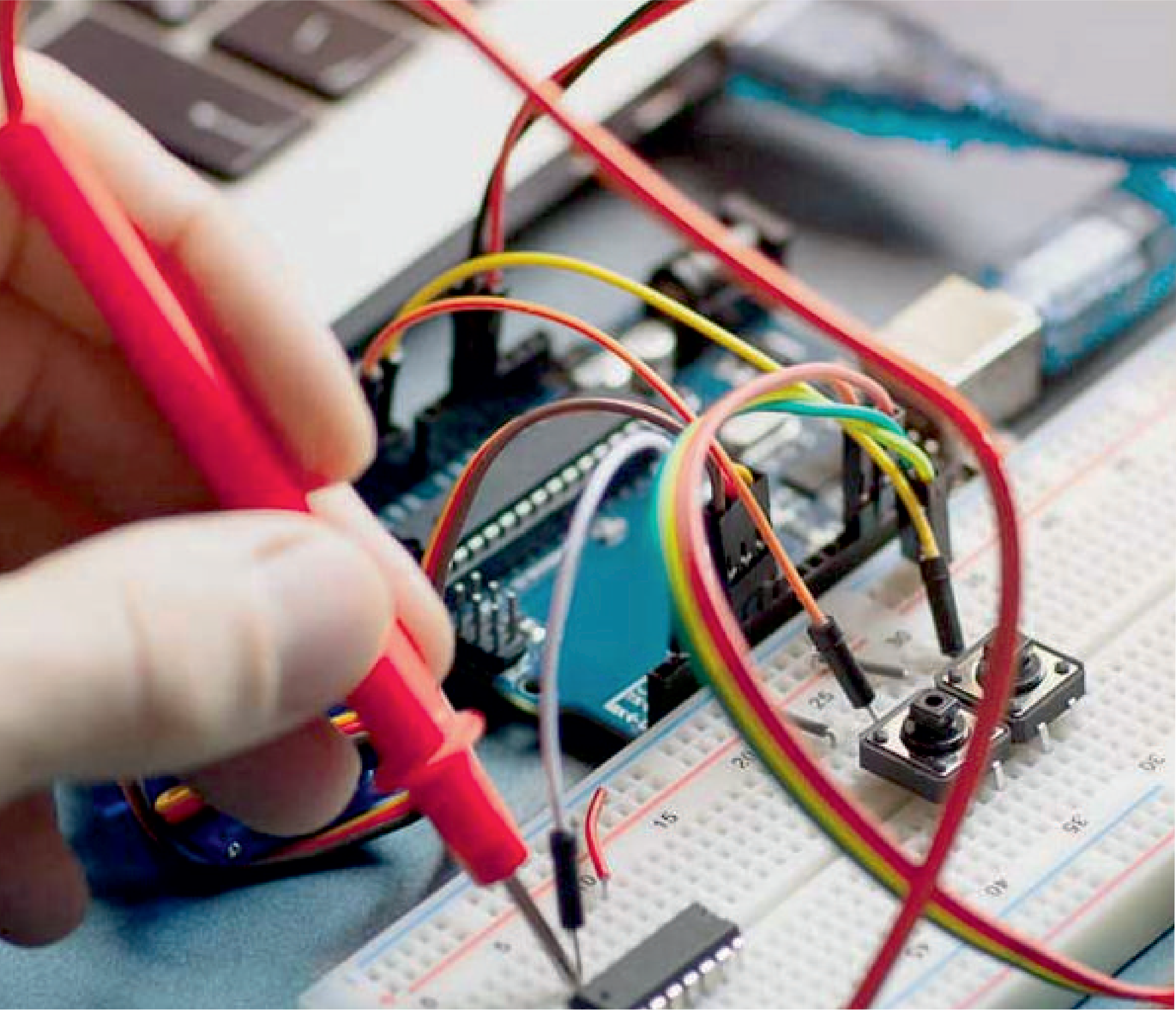

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