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An examination of the DC-DC converter for electric vehicles based on the SVM

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ABSTRACT

Using a bidirectional DC/DC converter, which is common in battery-powered EVs, this research suggests a method for switching between different operational modes (EVs). When the DC-link voltage is too high, the suggested design switches the converter from boost to buck mode. This method is proposed to lessen the EV energy storage system's carbon footprint and boost its efficiency (ESS). To increase the DC-link voltage when driving and to charge the battery while braking, a buck-boost DC/DC converter is used. Through the use of PI control of the DC-link voltage, the DC-link voltage is kept stable throughout driving operations while in boost mode. Reducing battery voltage ripples is one of the goals of the buck mode's PI control of battery voltage. Current control techniques are used in both modes of operation to ensure that the converter modules are distributing the battery current in an equitable manner. A simulation is carried out and tested using an EV propulsion system to verify the performance of the proposed strategy.

KEYWORDS: srm, dc-dc converter, electric vehicle , EV

1. INTRODUCTION

Air pollution, global warming, and the ever-increasing demand for fossil fuels have all contributed to the fast expansion of the electric vehicle (EV) market in recent years. Power electronic converters and drive systems are the main parts of EVs, and several research projects are conducted to achieve higher density and efficiency in these converters. Pure electric cars (PEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs) will soon hit the market. All of these vehicles will use electric motors powered by batteries and coupled to the motor through voltage source inverters (VSIs). Electric vehicles (EVs) have emerged as a viable alternative to traditional gas-engine cars in light of the increased interest in reducing fossil fuel use and pollution. Because of the limited EV battery capacity, widely dispersed charging stations are necessary for the development and growing use of EVs. Overloading the grid at peak times, voltage drops, and power gaps are all potential problems that arise when a high number of charging stations are directly linked to the electrical grid. The integration of photovoltaic (PV) generating with EV charging infrastructure has been explored by some academics, although it is currently seen as contributing only a negligible amount of electricity to EV charging stations. Rapid advancements in PV production optimise power use during peak hours, which is especially important given the increasing demand for high-speed charging throughout the day. Battery energy storage (BES) may be used to control DC bus or load voltage, balance power gap, and smooth PV power in response to the intermittent nature of solar energy.

2. ELECTRIC VEHICLES

The traction power in a standard EV comes from a battery pack wired to an electric motor through a transmission. An external source, like a wall outlet, is used to power a battery charger, which in turn charges the batteries. When the vehicle's speed is reduced by using regenerative braking, the motor doubles as a generator, feeding energy back into the batteries. The primary benefit of an EV is its simple design and low number of components. The main drawback of EVs is that their driving range is capped by the capacity of their batteries, and recharging them can take anywhere from 15 minutes to 8 hours, depending on how far the vehicle was driven before being recharged, the type of battery used, and the charging method.

3. PROPOSED CIRCUIT CONFIGURATION:

Direct current (DC) to direct current (DC) converters with digital control are often used to provide electricity for charging and refilling the EV's batteries. It uses power switching devices based on semiconductors to change the voltage at different points in a circuit. In a non-linear system, the switching action of semiconductor devices manifests as a delay. Different methods of control may be used to stabilise the system's output voltage and boost its overall performance [1]. The DC-DC converters often employ a standard control method, such as a Proportional-Integral-Deferential (PID) based approach, because of the simplicity of its design and implementation. Traditional PID controllers rely on mathematical models with constants that have already been defined and adjusted. PID controllers rely on fixed parameters to ensure steady operation. Commonly utilised to boost system performance in a wide variety of industrial applications, PID controllers are a staple of the field. It is demonstrated in Fig. 1 how the DC-DC converter is used in conjunction with the most typical form of control structure. It has a digital control and gate driver in addition to a DC-DC converter and a signal conditioning device.

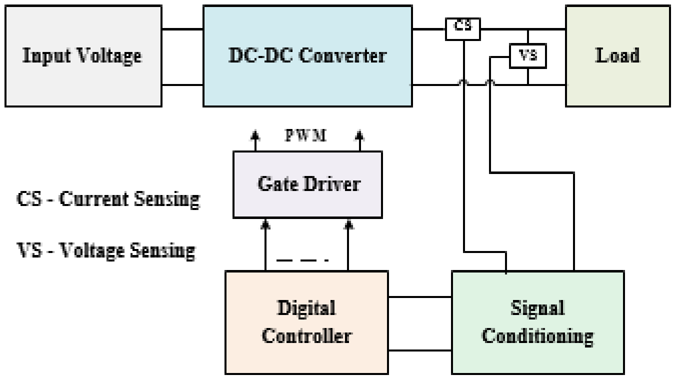

Fig. 1. Conventional control approach of DC-DC converter

The multiphase interleaved converter is often studied because of its straightforward design and straightforward control setup. It's put to work in situations calling for non-isolation, a step-down conversion ratio, a large output current with minimal ripple, and so on. An essential consideration for tiny form factor applications is the flexibility provided by a multi phase design's output inductor selection. In order to guarantee the best possible converter performance, a multiphase operation offers a number of advantages, such as flexible phase combinations and phase shedding.

Operation Modes of the Proposed Converter:

The suggested converter is not only multidirectional, but also uses multiple inputs and outputs as described in [10]. The suggested structure improves the converter's efficiency by allowing for many charging modes, such as the battery discharge mode, battery charging via the inputs, and battery charge mode in the braking mode. In the sections that follow, each of the aforementioned modes is further developed and mathematically evaluated separately. The utilisation of the multi-stage m-level multiplier circuit causes a minimal voltage stress on the S0 of the suggested converter.

Power supply mode with battery discharge:

In this configuration, the converter uses power from the battery and any other connected input sources to power the linked load. There are two inputs (the battery and one primary source) and two outputs (the two possible outcomes) in the mathematical analysis. In this configuration, the brake switch (S3 and Sb) is always off, the transfer switch (ST) is always on, and all the other switches are likewise on. With the help of switches S0, S1, and S2, the output voltage (VO) may be adjusted in this setting. The primary waveforms of the converter in this mode are shown in Fig. 2 and the converter in its operational state is depicted in Fig. 3. In this mode, the converter's switching orders are stated as follows (see Fig. 4):

1) Time interval 0<t<D1T:

In this configuration, the battery and the other sources are both used to power the load connected to the converter. As a result, it is possible to use all linked resources at once. There are two inputs and two outputs in the mathematical analysis. In this setup, all switches except for S3 and Sb are active. In this mode, the output voltage (VO) is managed by a series of switches whose on/off sequence is determined by the values of S0, S1, and S2.

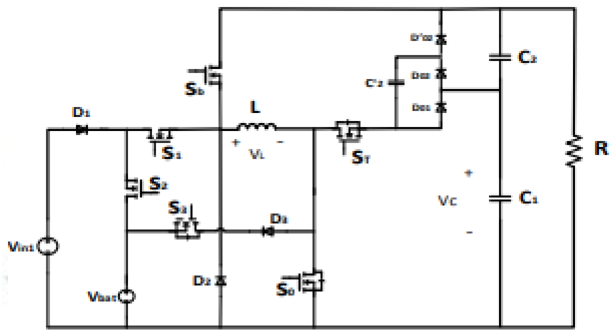

Figure 2: Proposed converter with two-input and two-output

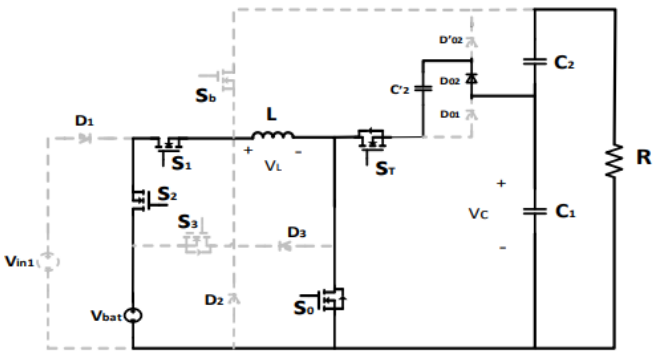

Figure 3: equivalent circuits of the converter in mode A at time interval 0<t<D1T

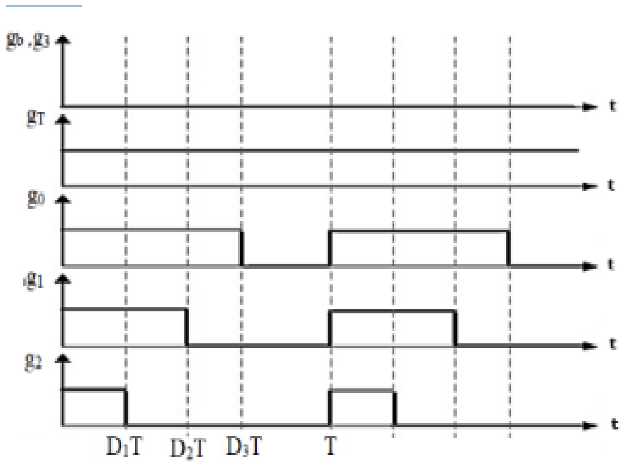

Figure 4: switching states of power supply mode with battery discharge

Time interval D1T <t<D2T:

The S0 is active, while the S1 is inactive, and the rest of the circuit looks like Fig. 4. The inductor is charged by the primary power source (fuel cell, for instance). The inductor's voltage is the same as the mains voltage, and the inductor current rises in a straight line with a shallower slope (Vbat > Vin1). Its inductor current looks like this while operating in this mode:

Time interval D2T <t<D3T:

Here, we have S0 turned on and S2 and S1 turned off. The inductor acts as a current path, activating diode D2. Using KVL with a circuit consisting of a diode, an inductor, and S0:

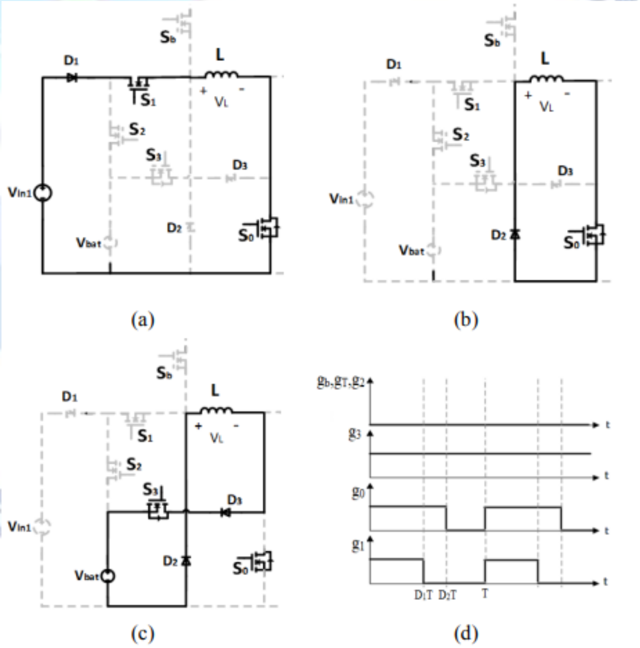

Figure 5: Switching state in battery charge mode via input sources (a) switching state1 (b) switching state 2 (c) switching state 3 (d) switching sequence in this mode.

Battery charge mode via input sources:

The battery is being charged by the input sources while in this mode. This state is reached by the battery whenever there is no load being carried and the battery must be recharged. As shown in Fig. 2.10, all but switch S1 are always ON, while switches S2, ST, and Sb are always OFF. Three different converter switching states are studied in this mode.

Time interval 0 <t<D1T:

Both S0 and S1 switches are active in this switching state. As a result, there is no current flowing through the D3 and S3 diodes since they are reverse biassed. Charge is applied to inductor L from the input source (Vin1), and the current flows steadily upwards. This leads us to the following equation for the current in an inductor:

Battery Charging Mode in Braking Operation:

The motor vehicle may function as a generator and store energy in the battery when braking or travelling downhill. Transducer performance is optimised in this mode of operation. To achieve this result, a switch is installed in the reverse circuit to convert the high voltage to the lower voltage of the battery, so conserving power. All other switches are on and functioning normally, whereas S0, S1, and ST are constantly turned off. In this mode, Sb regulates the battery's output voltage (Vbat. The converter is a standard buck converter while in the braking mode. There are a few of different ways that the switch may be thrown:

1) Time interval 0 <t<D1T:

The Sb mode is activated here. What this means is that the inductor's voltage is defined as the difference between Vo and Vbat. So, here is a linear progression of the inductor current:

$$i_{L3} = I_{LV3} + \frac{1}{L}\int_0^t V_L\,dt$$

Space Vector Modulation Technique:

Instead of using a standard pulse width modulation method, this system takes use of the two phase vector components—d and q—to provide gate triggering signals. Figure 6 depicts the 8 space vector switching pattern locations of the inverter, each of which represents a different space vector representation of the neighbouring vectors V1 and V2.

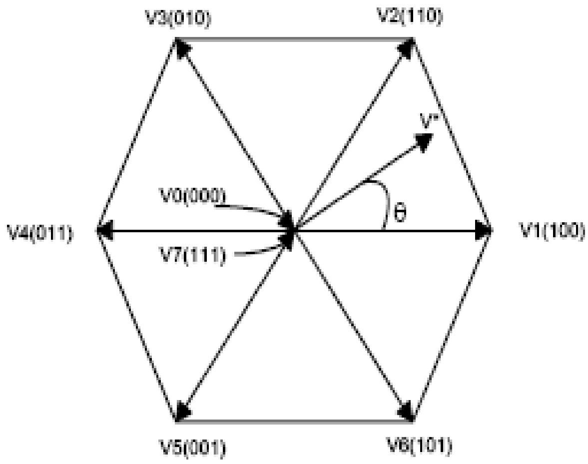

Fig 6: Space Vector Modulation Technique

By using the Space Vector Modulation Technique, one of the most widely used pulse width modulation techniques for three-phase voltage source inverters, we can reduce harmonic distortion in the applied ac motors' voltage and current. In this research, we use the space vector modulation method to produce reference vectors by varying the switching time sequence of space vectors over six distinct sectors, as seen in Fig. 6. Figure 6 shows that six switching sectors are used for inversion, with two sectors behaving similarly to null vectors. The following methods may be used to carry out space vector modulation:

To convert three-phase values to two-phase ones.

2) Calculate T1, T2, and T0.

The following phrase creates the voltage reference signals, the V0–V7 switching time sequences, and the switching times themselves.

$$V^* T_z = V_1 * T_1 + V_2 * T_2 + V_0 * (T_0/2) + V_7 * (T_0/2)$$

4. SIMULATION DIAGRAMS AND RESULTS

The suggested converter is shown via simulation, and its performance across all three modes of operation is validated. The MATLAB/Simulink environment is used for the simulations, and the settings for those simulations are shown.

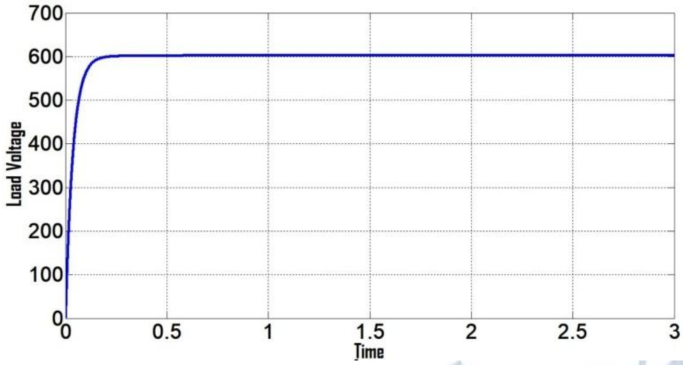

Fig 7: Load voltage of converter (V0) during battery discharge mode using PWM

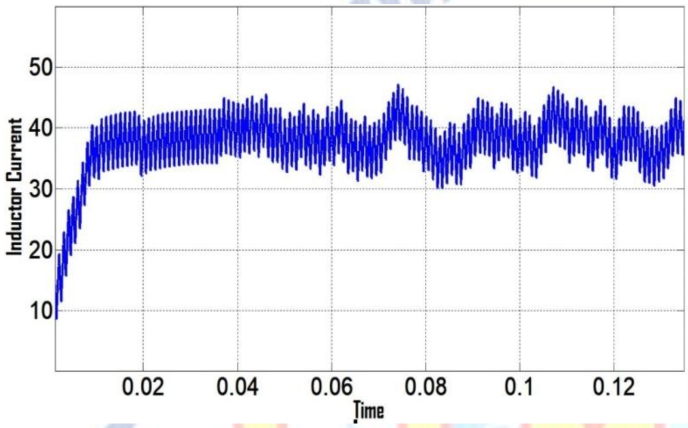

Fig 8: Inductor current(il) during battery discharge mode using PWM

SimulationResults duringbatterycharge inbrakingmodeusingPWM:

The battery is charged by the regenerative energy, and the load voltage is used as an input. When the brakes are applied, just switch Sb is on, and charging power for the battery is delivered via that. The converter functions as a buck converter, with the load voltage serving as the charging power source.

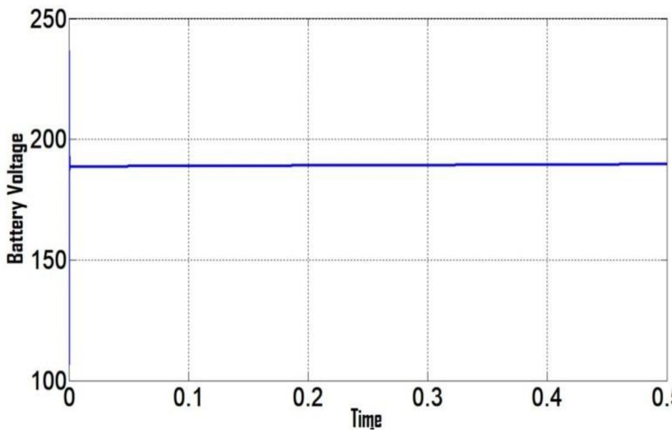

Fig 9: Voltage of battery (Vbat) during battery chargein braking mode using PWM

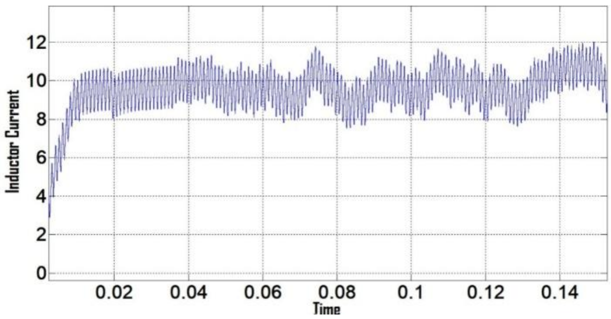

Fig 10:Inductor current(il) during bttery charge in braking mode using PWM

SimulationresultsduringbatterydischargeusingSVM:

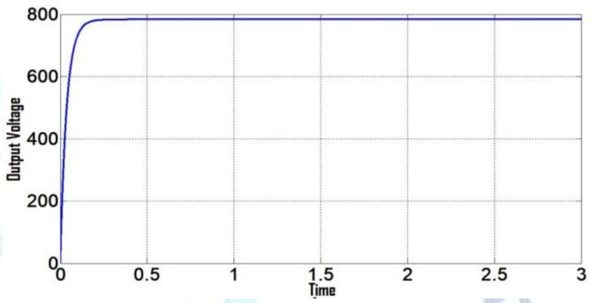

Fig 11: Load voltage of converter (V0) during battery discharge mode using SVM

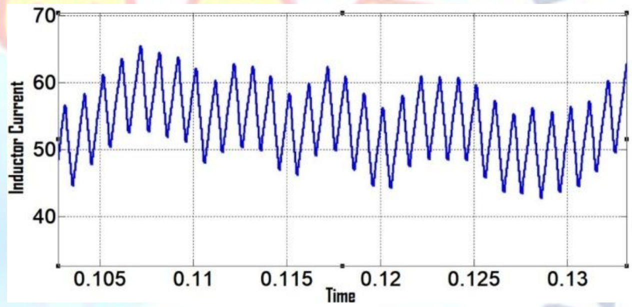

Fig 12: Inductor Current of converter during battery discharge mode using SVM

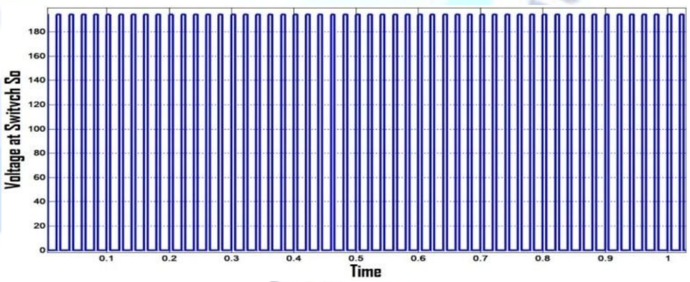

Fig 13: Voltage across switch (So) during battery discharge mode using SVM

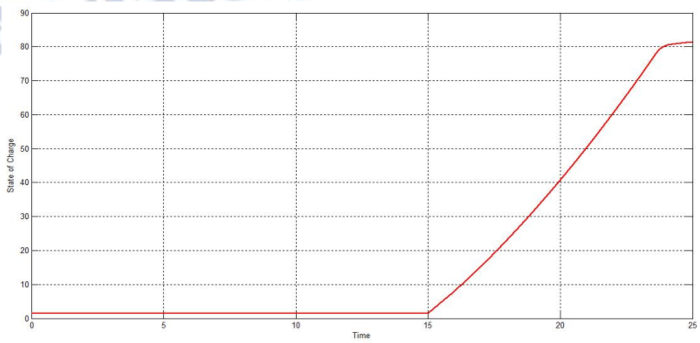

Fig 14: EV Battery Charging Conditions using PWM Controller

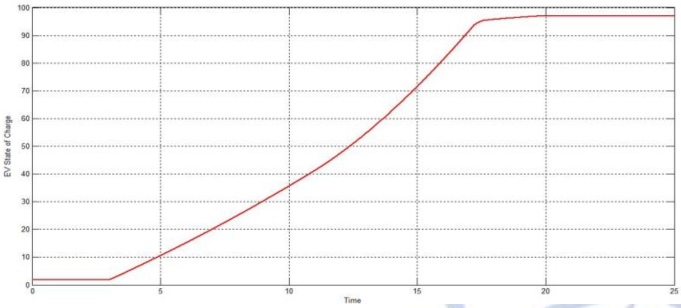

Fig 15: EV Battery Charging Conditionsusing SVM Controller

5. CONCLUSION

In order to boost the efficiency of dc-dc converters, this research suggests a novel design for bidirectional non-isolated converters using Space vector modulation. The suggested converter's key benefits are its high voltage gain without using a high duty cycle and high-frequency switching, and its flexibility to transfer energy across resources with varying voltage and current profiles. Furthermore, the presence of the voltage multiplier inverter in the output greatly reduces voltage stress on the primary switch. The suggested converter is capable of both buck and boost operation. The various converter modes were shown in this project. Validation of a two-input, two-output converter's simulation results was performed to ensure the suggested design would work as intended. Comparatively, the switching action of a space-vector-modulation-based converter is less taxing on the voltage supply, allowing for more freedom in structuring the switching sequence to meet specific needs.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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