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Design of 24V/800V Interleaved DC-DC Converter for Electric Vehicles

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***Abstract*—Electric vehicle (EV) powertrains demand effective connectivity between high-voltage, low-amperage drive units and low-voltage, high-amperage power supplies such as electrochemical cells or hydrogen systems. Traditional single-stage, single-leg step-up/down converters often face issues like unstable output, elevated stress on components, and complex energy flow management—particularly under conditions requiring significant voltage conversion. To address these limitations, this work explores a modular, multi-leg power processing system designed to suppress fluctuations in electrical parameters while enabling substantial voltage elevation. A unique topology utilizing a proportional-integral control mechanism is introduced, operating from 24V to 800V for mobility applications. This configuration incorporates a four-channel synchronized front end, with three stages in sequence followed by a final unit that includes a dual-floating terminal arrangement supporting reverse energy transfer.**

1. INTRODUCTION

As the global shift toward sustainable transportation accelerates, electric vehicles (EVs) have emerged as a key solution to reducing carbon emissions and dependence on fossil fuels. A critical aspect of EV performance lies in the design of efficient and reliable power conversion systems that can bridge the gap between energy storage units such as batteries or fuel cells and electric traction motors. These systems must accommodate significant differences in voltage and current levels while ensuring stable and responsive operation under varying load conditions.

Conventional DC-DC converters, particularly those employing single-stage and single-arm architectures, often fall short in meeting the demanding requirements of high-power EV applications. They tend to suffer from limitations such as voltage instability, increased component stress, and inefficient energy flow during charging and discharging cycles. These shortcomings become even more pronounced in scenarios involving wide input/output voltage ratios or bidirectional power transfer.

To overcome these challenges, advanced converter topologies with enhanced voltage gain, improved efficiency, and better ripple control are needed. This study presents a novel high-gain DC-DC converter architecture optimized for EV applications. The proposed system employs a multi-stage, multi-arm configuration with interleaving techniques and a PI control strategy to achieve high voltage conversion—from 24V input to 800V output while maintaining minimal ripple and enabling bidirectional current handling. This innovative approach aims to enhance the overall reliability and performance of EV powertrains.

2. LITERATURE SURVEY

The exploration of advanced DC/DC converter topologies is critical in the evolution of energy systems for electric vehicles and renewable integration. [1] developed an interleaved boost converter for fuel cells, emphasizing ripple suppression and scalability. Building on voltage gain enhancements. [2] analysed dual-inductor hybrid converters suitable for extreme conversion ratios. [3] proposed a full-bridge interleaved three-port structure enabling hybrid renewable compatibility.

For high step-up applications, [4] introduced a non-isolated topology with ultrahigh gain, and Yao et al. [5] provided soft-switching solutions to reduce power losses. [6] extended interleaving to buck converters, highlighting improved efficiency for step-down operations. Meanwhile, [7] presented a comparative study on multi-input configurations suited for flexible renewable integration. [8] innovated by integrating coupled inductors and switched-capacitor networks for higher conversion efficiency. [9] examined multiphase converters in fuel cell systems, while [10] focused on bidirectional converters for EVs using dynamic DC-link control to enable energy recovery. [11] designed a half-bridge-based high-gain topology for compact applications.

[12] proposed switched-boost techniques combining inductor and capacitor cells to reach elevated output levels. [13] highlighted the benefits of coupled inductor configurations in reducing electromagnetic interference and increasing gain. In energy modeling, [14] contributed a high-level battery model for system-level energy analysis. Complementing these electrical system designs, [15] integrated machine learning into MTPA control of EV motors, optimizing performance through AI-driven techniques.

3. DESIGN AND IMPLEMENTATION OF A MULTI-INPUT DUAL-FLOATING OUTPUT CONVERTER:

a. Interleaved converter concept:

The interleaving strategy in this converter employs multiple DC/DC boost modules connected in parallel, all supplying a common DC output rail. This method divides the input current by sharing the high current across several branches. This modular boost structure increases overall power capability through parallel phase coordination.

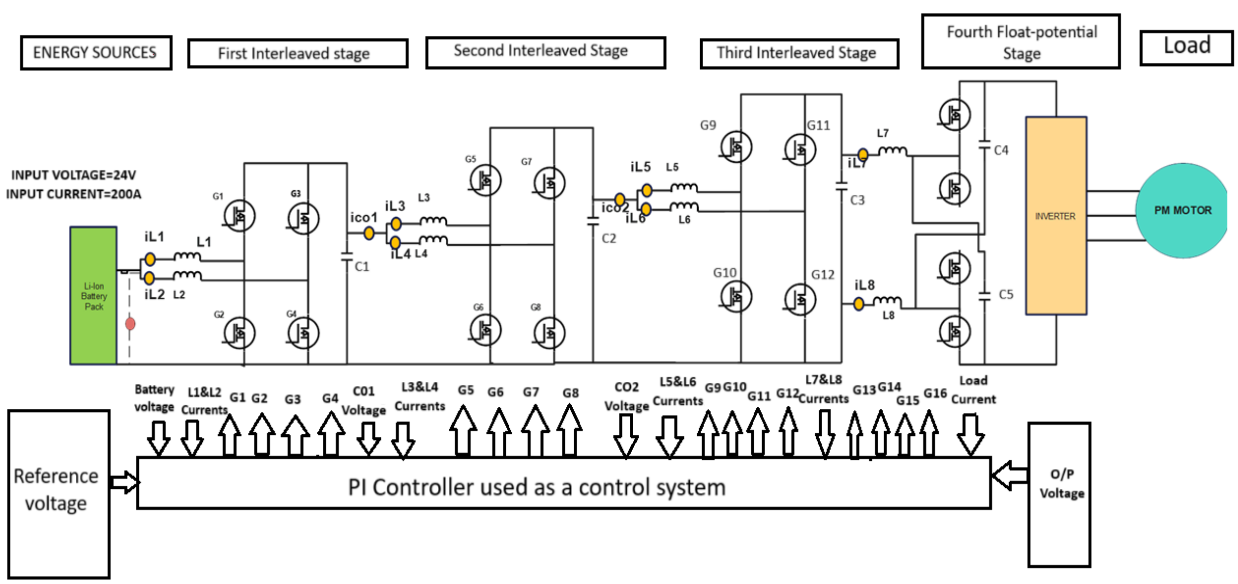

Figure 1. Topology of the suggested Four-stage 24V/800V DC/DC converter.

B. Novel Power Converter Design with Enhanced Voltage Boost Capability**:**

In Figure 1, the proposed interleaved-input dual-floating-output DC/DC architecture (IIDFOC) adopts a tri-level structure comprising parallel-connected input segments and isolated dual-output paths. Handling 24V input and delivering 4.8kW, the initial stage processes approximately 200A. A modular cascading layout was adopted to reduce size and spacing. Switches are driven with shifted timing to maintain staggered operation, supporting current distribution across input units. These two feeding circuits are serially combined at the terminal end to attain elevated voltage levels. The energy fed into the final segment (taken from capacitor Co2) aligns in sequence with Co3 and Co4, helping suppress fluctuations at the output.

C. System variables, design, and ratings

In order to enable continuous current mode (CCM) operation of both boost and buck converters, the formulas are

$$\bar{D} = 1 - \frac{V_{in}}{V_{out}} = 1 - \frac{\bar{V}_B}{\bar{V}_{co1}} \quad (1)$$

According to the selected duty, the inductance of the coils of

$$L_1 = L_2 = \frac{\bar{V}_B \bar{D}_1}{\Delta \bar{I}_{L12} F_{sw}} \quad (2)$$

are selected, and the setup system installs them.

The equivalent capacitor is then chosen with a 5% output voltage variation as

$$C_{01} = \frac{\bar{V}_{C01} \bar{D}_1}{\Delta \bar{V}_{co1} R_{dc} F_{sw}} \quad (3)$$

In the setup system, three capacitors with $C_{11} = C_{12} = C_{13} = \frac{C_{01}}{3}$ are installed in parallel.

$$V_0 = V_{Co2} - (2D3 - 1)V_{Co3} - (2D4 - 1)V_{C04} \quad (4)$$

III. The principle of operation

The proposed converter designed for a 24V input and an 800V output. In boost mode, the DC/DC converter supplies power to the DC bus to maintain a stable voltage level. During this mode, power transistors and diodes are switched on and off alternately to regulate current flow. The converter operates in 16 modes with stepping up the intermediate voltage from 600V to the final output of 800V, enabling high voltage gain while maintaining efficiency and low ripple.

A.Simulationresults

The terminal voltages of the converter's four stages are illustrated in Fig. 2. Using a 24V battery applied, the designed voltages of 90V, 250V, 600V, and 800V are achieved at each stage.

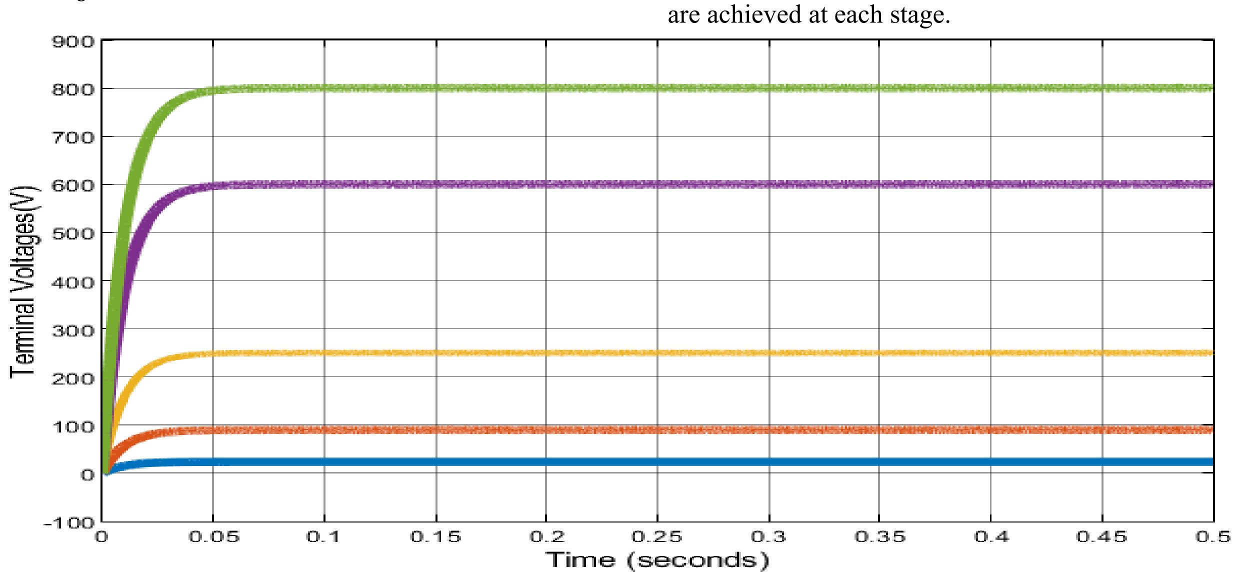

Figure 2. Terminal Voltages of all stages (simulation results)

The surge behaviour of inductor currents during the startup phase is shown in Figure 3.

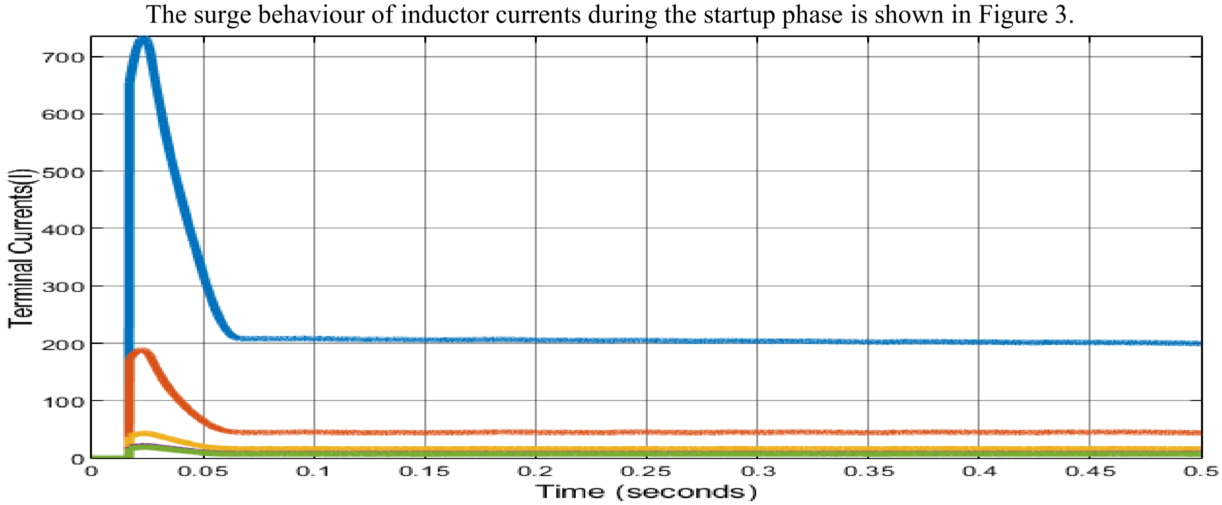

Figure 3 Terminal currents of all stages (simulation results)

Figure 4 shows 225A of input current is drawn from the battery to deliver around 6.665A at the output. The inductor currents range between 91A and 109A

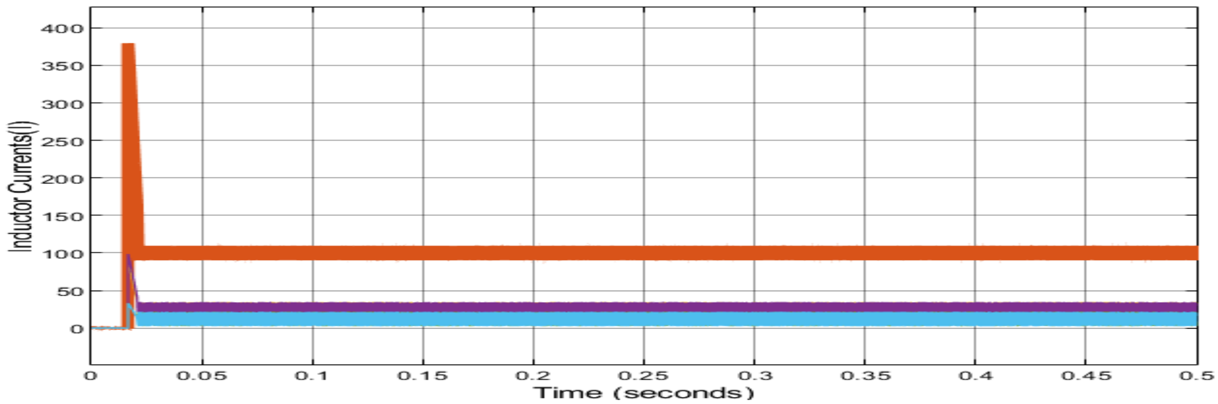

Figure 4. Inductors currents of all stages (simulation results)

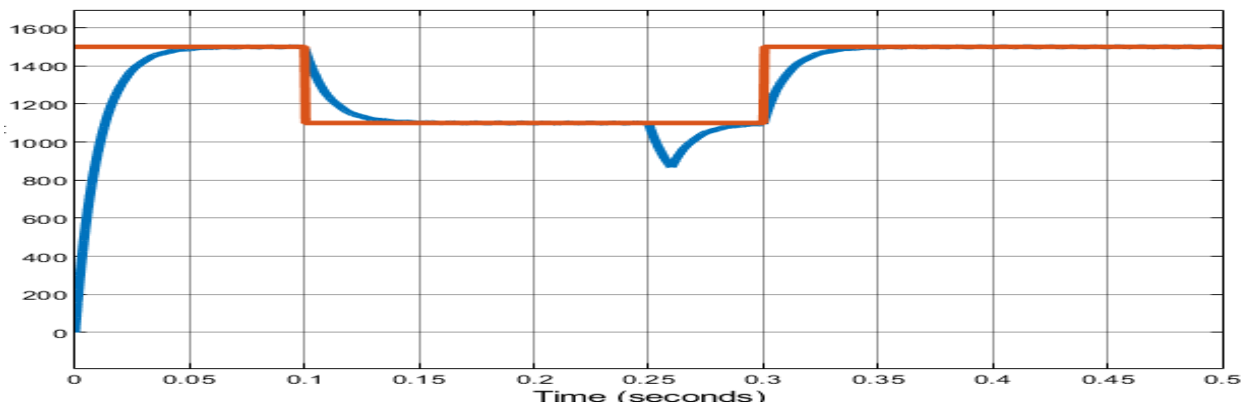

Figure 5. Speed vs Time (simulation results)

The speed versus time plot shown in Fig.5. The motor undergoes an acceleration phase followed by a steady-state operation. At the beginning, the speed increases rapidly, reflecting a swift dynamic response. After a brief transient period, the motor attains a constant speed, indicating stable performance under the applied load. This behavior validates the efficiency of the control system and the motor's capability to sustain the desired performance

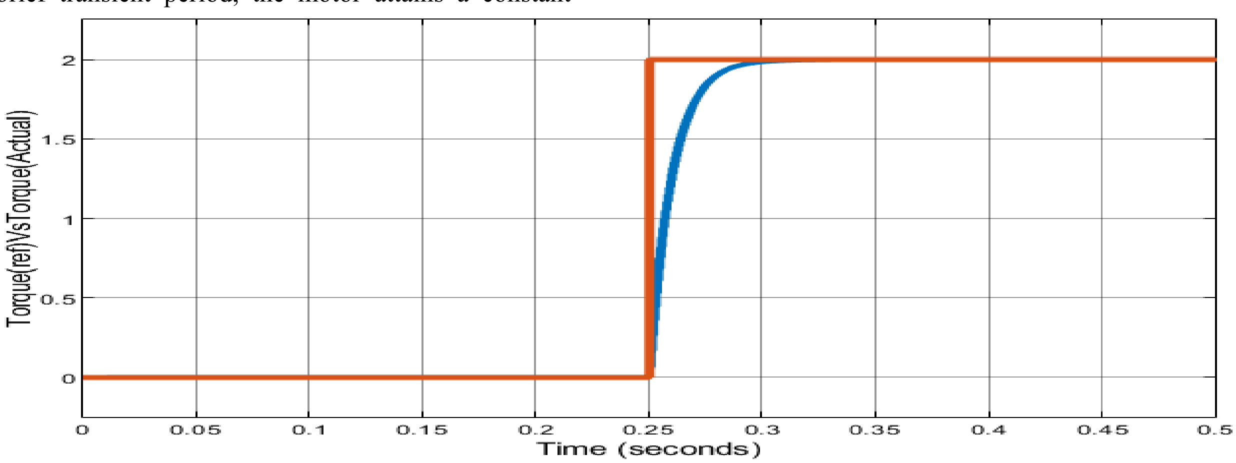

Figure 6. Torque vs Time (simulation results)

The simulation result of torque versus time is shown in Fig.6. Initially, the torque rises sharply as the motor starts, then stabilizes to a steady value once the motor reaches its operating speed.

The modulation sequence for the four levels is shown in Figure 7. The desired outputs of 90V, 250V, and 800V are obtained.

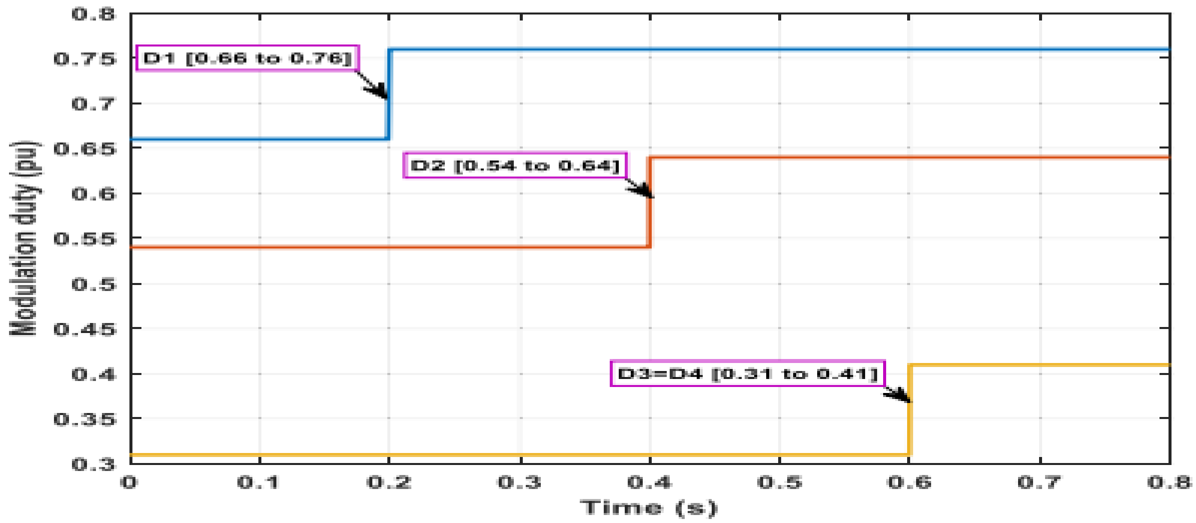

Figure 7. Terminal voltages of all stages (simulation results)

4. CONCLUSION

For battery-powered electric vehicles, a high-gain DC/DC converter is analysed through interleaved input stages. The proposed architecture delivers required output voltage with a gain of 33. Simulation results validate the low ripple currents resulting in inductor ripple reduction. The output highlights EV application because high-voltage systems reduce charging time and doubling the voltage halves the current, improves efficiency, vehicle range and performance.

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