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EFFICIENCY OPTIMIZATION THROUGH INTERLEAVED BOOST CONVERTER A SOLUTION FOR ELECTRIC VEHICLE POWER MANAGEMENT

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Abstract: This abstract proposes an innovative approach to enhance the efficiency of Electric Vehicle (EV) power management systems through the integration of interleaved boost converters. By employing interleaved operation, this solution aims to address challenges associated with conventional power converters enabling improved energy utilization and overall system efficiency. The study investigates the performance gains achieved through interleaving in the context for EVs, emphasizing its potential for enhanced power delivery and reduced losses. The findings contribute valuable insights to the ongoing efforts in advancing power management solutions for electric vehicles, aligning with the broader goal of optimizing energy utilization in sustainable transportation.

Keywords:**Two-Phase Interleaved Boost Converter, Electric vehicles, dc-dc converters**

I. INTRODUCTION

The global shift toward sustainable transportation has accelerated the development and adoption of electric vehicles (EVs), Marking a notable stride in curbing greenhouse gas emissions and diminishing dependence on fossil fuels`` [1] - [3].As the electric vehicle industry continues to evolve, a critical challenge lies in optimizing power systems for efficiency and performance, ultimately extending the range of EVs [4]. In this context, advanced power electronics technologies play a pivotal role. This paper delves into the topic of efficiency optimization in electric vehicle power management, focusing on the application of an Interleaved Boost Converter (IBC)[5]. The IBC stands out as a promising solution due to its efficient regulation of voltage and current, minimizing energy losses and maximizing power transfer. By interleaving the operation of multiple boost converters, the IBC provides a robust pla tform for enhancing overall efficiency in electric vehicle power systems.

A. BATTERY ELECTRIC VEHICLES(BEVS)

To provide graceful power flow between the external Source and battery the high capacity needed a systematic operational charger [3]. This battery charging system can be classified (a) Onboard and (b) offboard charges. vehicles has simple and low components. Charge time and charge cycle is most important factor to determine the battery life.

B. FUEL CELL ELECTRICAL VEHICLES(FCEV)

(FCEVS) is the replacement of BEV, Fuel store in FCEV sin volves either mounting it in a tank or extracting it from the fuel processor.[9].In this FCEV, In a fuel cell, energy conversion occurs as chemical energy is transformed into electrical energy via an electrolyte medium [11],[13]. The result of this Conversion gives that heat and water as a by- product.

C. PLUG IN HYBRID ELECTRIC VEHICLES(PHEV)

A plug-in hybrid electric vehicle (PHEV) integrates an internal combustion engine with electric propulsion to create a hybrid vehicle. PHEVs are designed to offer drivers the Flexibility of using both electric power and traditional internal combustion engines, providing increased fuel efficiency and reduced emissions compared to conventional vehicles [10].Unlike standard hybrids, PHEVs have a larger battery pack, allowing them to run on pure electric power at slower speeds. PHEVs can be charged externally by plugging into an electric power source.

CONVENTIONAL DC-DC BOOST CONVERTER

A boost converter, also recognized as a step- up converter, is a variant of DC-to- DC converter. Its primary function is to increase voltage while decreasing current from the input (source) to the output (load) [16]. Boost converters are categorized within the realm of switched-mode power supplies (SMPS).They typically contain at least two semiconductor components: a diode and a transistor, along with an energy storage element (such as a capacitor or inductor).

A BOOST CONVERTER OPERATES AS FOLLOWS:

During the ON state of the transistor, energy is stored in the inductor. When the transistor switches to the OFF state, the stored energy is transferred to the output [13]-[14]. This energy transfer process results in the output voltage being greater than the input voltage. The boost converter effectively "steps up" the source voltage .The output voltage of the boost converter is higher than the input voltage due to the energy transfer process described above [12],[16]. The voltage amplification is a result of the inductor storing energy during the ON state and releasing it during the OFF state, effectively" boosting" the output voltage. The magnitude of the output voltage is determined by the duty cycle, which is the ratio of the time the transistor is ON to the total switching period.

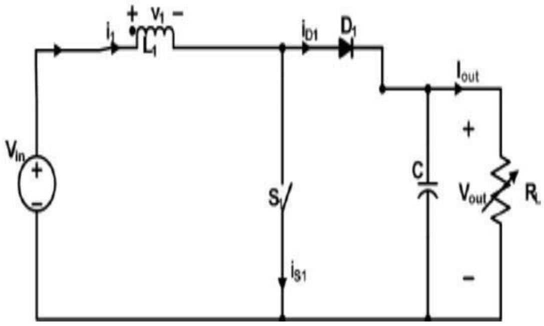

Fig1: Conventional DC-DC boost converter

The above figure shown that inductors L stores Energy during the on state of the transistor. Transistor acts as a switch to control energy flow. when designing a boost converter, it is essential to meticulously evaluate component values, switching frequency and control mechanisms to guarantee its effective operation and optimal efficiency.

Ideal wave forms of Boost Converter :

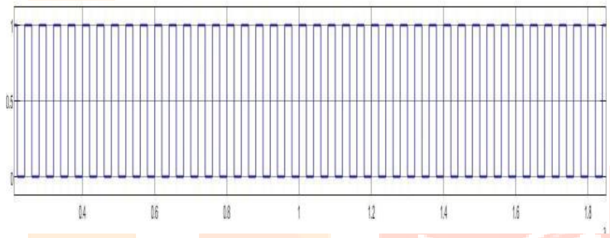

Fig2(a): on and off state waveforms of boost converter

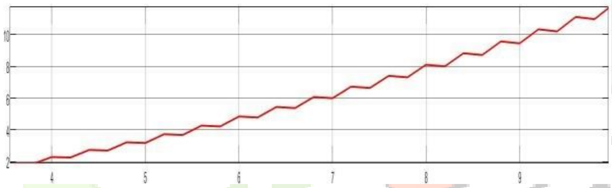

Fig2(b) : wave forms of boost converter with50% duty cycle

The figures 2(a) and 2(b) shows that waveforms in a DC-DC boost converter visually depict voltage and current variations over time, illustrating the converter's operation." This shown by the fig 2. This waveform illustrates the on-off switching behavior of the transistor in the boost converter. When in the on state, the transistor conducts, and in the off state, it remains nonconducting. The switching frequency typically operates at a high rate, with the duty cycle dictating the duration that the transistor remains in the on state While DC-DC boost converters provide several advantages, they also come with disadvantages and limitations that must be taken into account for specific applications.

- Boost converters can produce high peak input currents during the on-state of the switching transistor. This phenomenon can exert stress on the input power source and may necessitate the inclusion of additional input filtering components.
- The rapid switching behavior of boost converters can produce electromagnetic interference, necessitating the inclusion of additional filtering components and shielding to meet regulatory standards.

INTERLEAVED BOOST CONVERTER :

The interleaved boost converter represents a sophisticated and highly efficient DC-DC converter architecture that builds upon the foundation of the traditional boost converter. In this design, multiple power stages are integrated and operated in parallel, creating a synchronized and interleaved power processing system.

This innovative configuration addresses several challenges encountered in high-power applications, making it particularly well-suited for electric vehicle power management, renewable energy systems, and high power electronic devices. One of the primary advantages of the interleaved boost converter lies in its enhanced power processing capability [7].By employing multiple interleaved stages, the overall power handling capacity is significantly increased. Each individual stage contributes to the total power conversion, allowing the converter to efficiently handle larger amounts of electrical power [6]. This scalability makes the interleaved boost converter particularly attractive for applications with varying power requirements.

Reducing input and output current ripple is another key feature of interleaved operation. In a single boost converter, high current ripples can be problematic, leading to increased energy losses and potential electromagnetic interference (EMI). However, by interleaving the operation of multiple stages, the input and output currents are distributed among the stages, resulting in lower current ripples [17]. This reduction in current ripple contributes to improved overall converter performance and efficiency. The interleaved boost converter also excels in thermal management. The distributed nature of power stages ensures that heat generation is spread across multiple components, preventing localized hotspots and enhancing overall thermal performance [18]. This is crucial for maintaining the reliability and longevity of the converter, particularly in high power applications where thermal stress can be a significant concern.

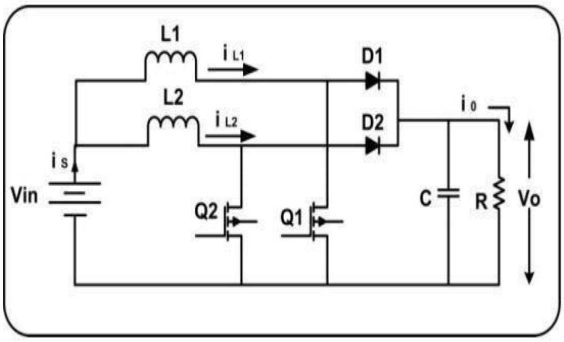

Fig 3: Circuit diagram of Interleaved Boost Converter

Fig 3: Circuit diagram of Interleaved Boost Converter The switch (usually a transistor) regulates the flow of current within the circuit. It toggles between the on- state (conducting) and the off state to facilitate the boost operation. Commonly used transistors for this purpose include MOSFETs or BJTs.

These are mentioned in the above fig 3. The inductor stores energy during the on-state and releases t during the off-state. It plays a critical role in energy transfer and voltage boosting. The capacitor, usually positioned at the output, serves to mitigate voltage ripple and maintain a stable voltage across the load (RL).

Table:1 simulation parameters for two-segment interleaved boost converter

Table Head	Simulation domains		
	Designator Meaning	Value at δ=0.20	Value at δ = 0.50
V_i	Input voltage	25V	25V
Io	Output current	6.236A	8.576A
Vo	Output voltage	50.38V	80.57A
fs	Switching frequency	50kHZ	50kHZ
L	Inductor	0.8mH	0.8mH
C	Capacitor	µ F	50µF
R	Resistance	Ω	Ω
Δ Vo	Output voltage ripple	3.87V	2.73V
Δ Io	Output current ripple	0.789A	0.326A
ΔIL	Inductor voltage ripple	0.362A	0.16A

Table :1 shows that the individual components of the interleaved boost converter, such as inductors, capacitors, diodes, and switches(usually MOSFETs), must be accurately modeled.

Simulating an interleaved boost converter entails utilizing software tools to model and analyze the converter's behavior under various conditions. This simulation process aids engineers in comprehending the converter's performance, optimizing its design, and anticipating its behavior before actual hardware implementation.

Table 2 : simulation parameters for dual phase interleaved boost converter

Table Head	Simulation domains		
	Designator Meaning	Value at δ=0.20	Value at δ = 0.50
V_i	Input voltage	25V	25V
Io	Output current	6.236A	8.576A
Vo	Output voltage	50.38V	80.57A
s	Switching frequency	50kHZ	50kHZ
L	Inductor	0.8mH	0.8mH
C	Capacitor	µ F	50µF
R	Resistance	Ω	Ω
Δ Vo	Output voltage ripple	3.87V	2.73V
Δ Io	Output current ripple	0.789A	0.326A
ΔIL	Inductor voltage ripple	0.362A	0.16A

Table 2 shows that While the above steps provide a general outline of the simulation process, the term 'simulation table' is not commonly used in this context. Engineers typically analyze simulation results using plots, graphs, and numerical data obtained from the simulation tool. The number of boost converter stages operating in parallel. Interleaved boost converters use multiple stages to distribute the power and reduce the current ripple.

Waveforms of IBC with 0.5 duty cycle:

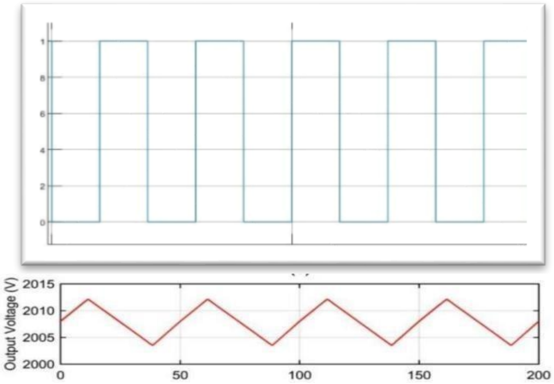

Fig4: wave forms of 2-phase interleaved boost converter with 0.5 duty cycle

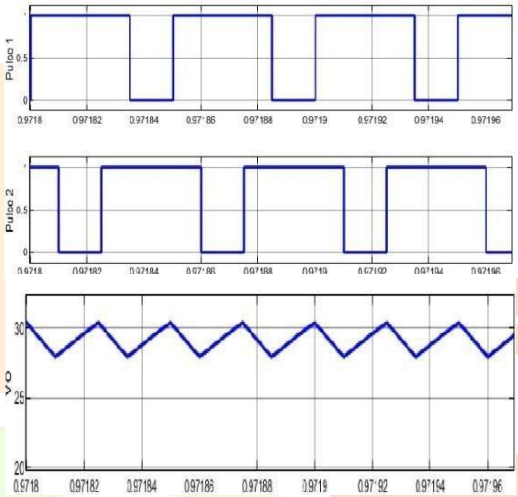

Fig 5 :wave forms of 2-phase interleaved boost converter with 0.2duty cycle

From the above waveforms fig 4 shows that the when the pulse width is 0.5 duty cycle then the output current and output voltage is equal. And then next coming to the Fig 5the interleaved boost converter works in the 0.2 duty cycle in this condition the off time is higher than the on time so the output current are varies.

CONCLUSION

The research on Efficiency Optimization through Interleaved Boost Converters provides valuable insights into enhancing electric vehicle (EV) power management. By exploring various DC-DC converter topologies, including the conventional boost converter, interleaved boost converter (IBC), and multi-port DC-DC converter (MPC), the study sheds light on their advantages and disadvantages. The IBC emerges as a promising solution for EV applications due to its significantly reduced input current ripples and output voltage ripples corelated to the conventional boost converter. As we move toward more efficient and sustainable electric transportation, the IBC's performance characteristics make it a compelling choice for managing power in electric vehicles.

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