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Ann Based Single-Input Mutli Output Dc-Dc Buck Boost Converter for Electrical Vehicle

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ABSTRACT: In this paper an isolated DC-DC SIMO Converter is presented. The operational theory and modes of operation have been thoroughly explained. The suggested arrangement is straightforward and makes no assumptions on the inductors' charging or operating duty cycle. With independent regulated voltages, it can produce the output voltages for buck, boost, and buck-boost. The proposed topology does not have cross regulation issues, hence the quick change in inductor and load currents has no impact on the output voltages. Simulation results are presented and compared with theoretical results.

KEYWORDS: DC-DC Converters, Multiports, Duty Ratio, SIMO Converter

I. INTRODUCTION

Power electronics-based DC–DC converters hold a critical role in contemporary electrical systems, facilitating effective voltage regulation and power transmission across a diverse array of applications. Among the multitude of applications, electric vehicles (EVs) stand as a prominent exemplar. EVs epitomize the vanguard of sustainable transportation solutions, with the electrification of automotive powertrains becoming increasingly pervasive. A fundamental facet of EV power management is the DC–DC buck–boost converter, which plays a pivotal role in maintaining stable DC voltage levels as necessitated by various vehicle subsystems. This article introduces a single-input and multi-output (SIMO) DC–DC buck–boost converter topology tailored for EVs, with a focus on elucidating its operational characteristics, advantages, and constraints.
DC–DC buck–boost converters, aptly named for their ability to both lower voltage (buck operation) and elevate voltage (boost operation) from a solitary input voltage source, function via the regulation of duty cycle, orchestrating energy transfer between input and output stages. Precision in voltage regulation is realized through common control methods such as pulse-width modulation (PWM).

Numerous DC–DC buck–boost converter types have been proposed for EV applications. This classification encompasses non-isolated, isolated, and bidirectional converter categories. Non-isolated buck–boost converters are lauded for their simplicity and efficiency, rendering them apt for low- to medium-power applications in electric vehicles. This article delves into an array of non-isolated buck–boost converter topologies, notably the inductor–capacitor–inductor (L-C-L) and inductor–capacitor–diode (L-C-D) configurations. Noted for their uncomplicated design, non-isolated buck–boost converters incorporate fewer components compared to their isolated counterparts, translating into cost-effectiveness and superior overall efficiency, thus rendering them an appealing choice for low- to medium-power applications in EVs.

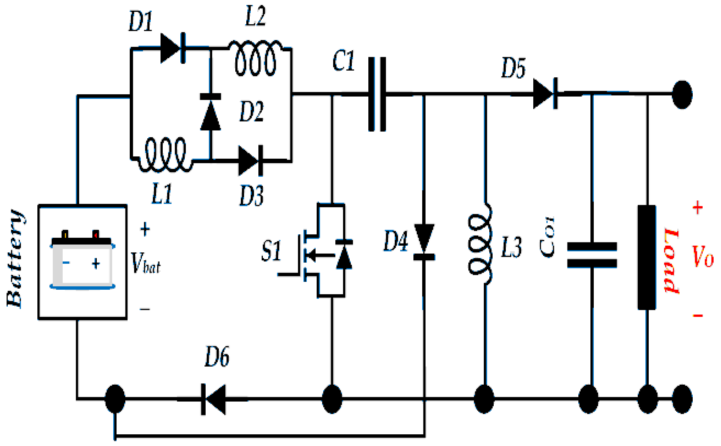

Fig 1: A Proposed Single-Input Multi-Output Battery

The compact form factor of these converters lends itself to facile integration within confined spaces in electric vehicles, harmonizing with the constraints prevalent in modern EV design. Their exceptional adaptability allows them to uphold steady output voltage levels even amid fluctuations in the input voltage, a pivotal advantage in EVs where battery voltage undergoes considerable variation contingent on charging and discharging conditions. However, non-isolated buck–boost converters exhibit a notable limitation, as they lack galvanic isolation between input and output. In scenarios where isolation is paramount, whether for safety or noise mitigation in high-voltage EV systems or sensitive electronic circuits, this deficiency presents challenges. Additionally, non-isolated buck–boost converters may demonstrate amplified voltage ripple on their output compared to their isolated counterparts, necessitating supplementary filtering measures to meet voltage quality standards. Although highly efficient for low- to medium-power applications, the inherent design limitations make them less suitable for high-power EV systems, where isolated converters are often favored, offering the requisite isolation and scalability.

Isolated buck–boost converters garner preference in high-power EV applications, where galvanic isolation assumes a pivotal role in safety and performance. These converters encompass diverse isolation techniques, such as transformer-based and coupled-inductor topologies, each accompanied by their distinct advantages and trade-offs. Foremost among the benefits of isolated buck–boost converters is their competence in ensuring galvanic isolation, thus mitigating the risk of electrical shock and reducing the potential for ground faults. The role of isolation extends to curtailing electromagnetic interference (EMI) and radiofrequency interference (RFI) by containing electrical noise within the converter, particularly invaluable in EVs housing sensitive electronic components and communication systems, necessitating a low-noise environment to ensure peak performance. Isolated buck–boost converters exhibit flexibility in maintaining stable output voltage levels despite the fluctuating battery voltages typical of EV charging and discharging cycles. However, it is important to note that isolated converters tend to be more intricate and expensive to design and manufacture than their non-isolated counterparts. The inclusion of isolation components, such as transformers, introduces energy losses, diminishing overall efficiency when compared to non-isolated converters. This efficiency trade-off may be acceptable in certain applications, but may not align with the stringent efficiency benchmarks of high-performance EV systems. The need for isolation components and associated circuitry results in a larger physical footprint for isolated buck–boost converters, which can pose challenges in EVs with constrained space for power electronics.

II. BACKGROUND OF WORK

The bidirectional operation of these converters necessitates intricate control algorithms to accurately manage bidirectional power flow, often requiring advanced DSP or microcontroller-based control systems. While bidirectional buck–boost converters excel at energy recovery, they may not consistently achieve the same high efficiency as unidirectional converters due to the added complexity involved in managing bidirectional power flow. Energy losses during bidirectional operation can impact overall efficiency. The incorporation of bidirectional functionality and associated control circuitry can escalate the cost and physical size of these converters compared to their unidirectional counterparts, potentially posing challenges in space-constrained EV power electronics designs.

This study introduces a single-input and multi-output (SIMO) DC–DC buck–boost converter. Multi-output buck–boost converters are renowned for their versatility in generating multiple DC voltage outputs from a single input source. This versatility is particularly advantageous in EVs where diverse subsystems and components may necessitate varying voltage levels for optimal performance. These converters can accommodate the varied voltage requirements of propulsion systems, auxiliary loads, and energy storage systems within the vehicle. In the confined confines of an electric vehicle, where efficient space utilization and weight management take precedence, multi-output buck–boost converters assume a pivotal role. By consolidating multiple voltage conversion functions into a single device, these converters curtail the overall footprint and weight of power electronics, freeing up space for other essential components like batteries or passenger amenities. This consolidation contributes to cost savings and simplifies the bill of materials, reducing manufacturing complexity and potential points of failure, ultimately enhancing reliability. These converters are engineered to optimize energy efficiency by minimizing energy losses during the conversion process. In the context of electric vehicles, where energy conservation is paramount for extending driving range, multi-output buck–boost converters are instrumental in optimizing power utilization and consequently elevating overall efficiency. Furthermore, these converters facilitate compliance with voltage standards and safety requirements for EVs, ensuring precise regulation and maintenance of voltage levels within permissible limits to guarantee the safe and reliable operation of various vehicle systems.

FLC excels in handling complex and nonlinear systems, rendering it well suited for the dynamic and diversified voltage regulation requirements in EVs. It possesses the capacity to adjust the duty cycle and control parameters in real time, accommodating fluctuations in input voltage, load conditions, and temperature. This control approach incorporates linguistic variables and rules, effectively handling imprecise or uncertain information—a vital attribute in EVs where variable operating conditions and component variations can challenge conventional control methods. FLC presents a relatively straightforward implementation and tuning process compared to other control methods, diminishing development time and costs. Nevertheless, it is important to acknowledge that while fuzzy logic controllers offer advantages in handling imprecise and uncertain data, they may not be the optimal choice for all control applications, especially in complex and safety-critical systems like buck–boost converters in EVs. The choice of a control method should be contingent on a comprehensive evaluation of the specific requirements, constraints, and characteristics of the system in question. Possible disadvantages of FLC encompass rule base complexity, performance tuning, limited transparency, resource intensity, challenges in managing nonlinearity, and limited adaptability.

MPC can optimize control actions over a future prediction horizon, positioning it to deliver superior performance when addressing the variable and dynamic voltage requirements inherent in EVs. It is capable of simultaneously controlling multiple variables, affording more comprehensive power management in EVs. Nevertheless, MPC algorithms can be computationally intensive and complex to implement, potentially limiting their real-time applicability in certain EV systems. The predictive nature of MPC may introduce a delay in control actions, potentially posing challenges in applications necessitating rapid responses.

PID control is celebrated for its stability and robustness in regulating systems, a quality that proves advantageous in maintaining precise voltage levels within EVs. These controllers offer a straightforward tuning process, enabling the adjustment of proportional, integral, and derivative gains to achieve the desired response. The deployment of a PID controller in a buck–boost converter for EVs delivers stability, rapid response, eradication of steady-state error, noise rejection, adaptability, simplicity of implementation, and a proven track record of success. These advantages collectively contribute to the efficient and reliable operation of power electronics in EVs, ensuring consistent power delivery and safeguarding sensitive electronic components.

III. METHODS

The key advantages and innovations in this study can be condensed into the following: the adoption of a straightforward control mechanism, underpinned by the fact that the proposed topology features just one power switch; the high efficiency of the topology, making it well suited for high-power applications; the capacity to generate a broad voltage range, particularly when employing VDC and VMC cells; and the operation of the inductors in a continuous conduction mode (CCM), ensuring a consistent current state for the load.

the suggested single input, three output DC-DC arrangement is shown. The components used in this structure are DC input voltage source (VD), three power semiconductor switches (SW1-SW3), three diodes (D1-D3), three inductors (L1-L3) and three capacitors (C1 – C3). This structure can provide three different output voltages at three different stages of DC-DC conversion. The three different voltages are Boost (VBST), Buck (VBK), Buck – Boost (VBK-BST) with positive polarity. With the duty cycles D1, D2, and D3, the suggested converter can independently control the output voltages.

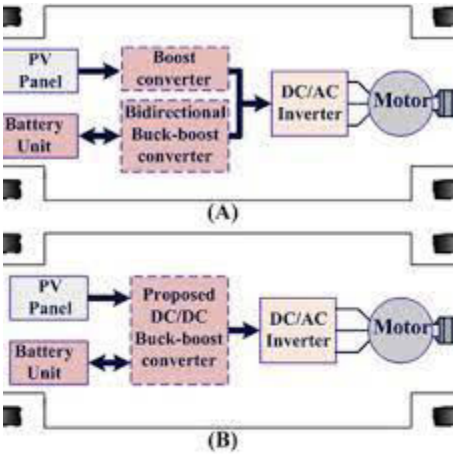

Fig 2: A, General structure of EV; B, proposed structure of EV with power

The automobile business is severely impacted by the depletion of fossil fuels, which is influenced by environmental problems such as global warming and an increase in carbon emissions. Power converter integration with green energy technologies like photovoltaic (PV) and fuel cells easily resolves these problems. However, their penetration is made more difficult by the diversity of renewable energy sources and power converters. In Electric Vehicles (EVs) and grid-tied converters, the DC-DC converters are typically applicationspecific and appropriate for low to high-power applications [1], [2]. The development of EVs and hybrid electric vehicles (HEVs) has recently received significant support from the automotive industry and funding from numerous national governments in an effort to reduce reliance on fossil fuels while offering consumers ecologically friendly, energy-efficient transportation. The increase in EV and HEV purchases.

Over the past few decades, the demand and use of renewable energy sources has increased dramatically in electric vehicles, grid connected applications and auxiliary power [3] – [6]. As opposed to numerous separate single-input DC-DC converters, multiport DC-DC converters (MPCs) lower the system's component count, complexity, and cost by enabling the hybridization of power sources in these applications MPC converters have been made available over the previous ten years. In [10], a brand-new SIMO converter is suggested. This structure simultaneously generates distinct boost, buck, and inverted outputs. However, 'n' voltage levels must be produced using n plus 2 switches, increasing the converter's overall size and expense. Unexpected errors in the computation of the output voltages and state-space formulae for a SIMO converter are addressed and corrected in [11]. In comparison to single inductor SIMO converters, the single linked inductor-based SIMO buck

IV. RESULT ANALYSIS

The proposed converter, on the other hand, comprises a total of 12 components, excluding the input rectifier circuit. When considering the input rectifier circuit, the total number of power components increases to 16. Notably, the most expensive elements within these converters are the inductors and power switches. However, the proposed converter distinguishes itself by utilizing only one power switch and three inductors. This approach places the overall component cost of this converter at a medium level.

An important advantage of the proposed converter is its minimal number of power switches. This simplicity streamlines the control process and avoids complex control flowcharts and implementations, making it a notable feature of the converter.

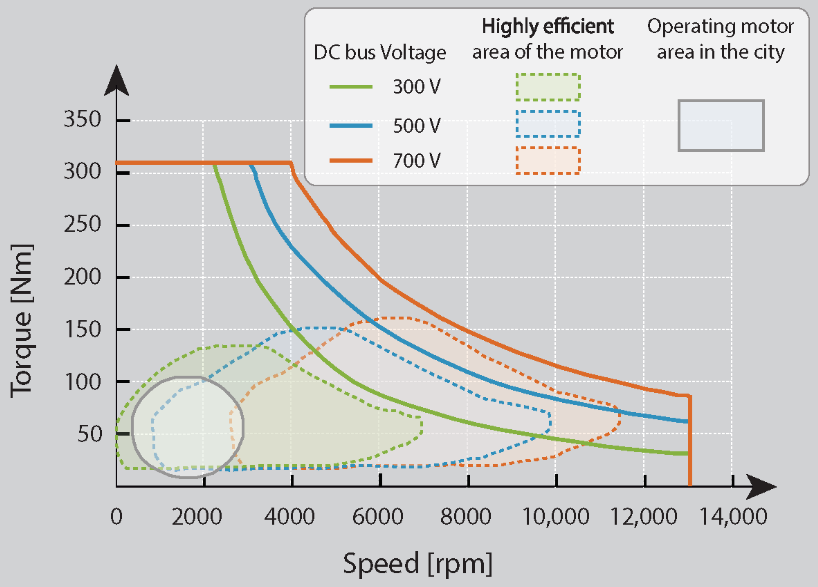

Fig 3: A Composite DC–DC Converter Based on the Versatile Buck–Boost Topology for Electric Vehicle

The inductors in the proposed converter operate in what is known as continuous conduction mode (CCM), which is an essential requirement in power converters. In contrast, working in a discontinuous current mode (DCM) for an inductor implies that the inductor current drops to zero during certain time intervals, potentially leading to issues with supplying the load current.

By assuming a 12 VDC input voltage source and excluding the VDC and VMC circuits, the proposed converter generates output voltages ranging from 12 to 430 VDC, covering a wide voltage range. With the incorporation of VDC and VMC blocks, this voltage range can be expanded even further, from 6 to 860 VDC. This expanded voltage flexibility represents the second notable feature of the suggested converter.

Additionally, the presented converter exhibits efficiencies ranging from 84 to 96 percent, and it is evident that efficiency increases with higher power levels. This quality positions the converter as well suited for high-power applications, emphasizing its potential for use in such scenarios.

A higher switching frequency is advantageous, as it ensures a smaller converter volume and reduced cost. In **Table 1**, the various converters are switched at frequencies ranging from 20 to 60 kHz. The proposed converter's performance at 50 kHz is considered entirely satisfactory and falls within an acceptable range.

V. CONCLUSION

In the context of electric vehicles (EVs), there is a critical need for different DC voltage levels to power various components. These voltages are typically sourced from a fixed DC voltage supply, such as a battery system. To meet this requirement, power converters are employed to generate the necessary voltages, which can sometimes exceed the battery voltage or be lower than it. Additionally, in EVs, multi-output configurations are crucial, allowing multiple DC voltages to be generated for different loads. The proposed converter in this study incorporates a switched-inductor cell suggested to minimize input current ripples from the battery pack. It is equipped with two voltage divider and doubler cells, enabling it to provide three different DC voltage outputs in a conventional operational mode. Moreover, by cascading the VDC or VMC cells, even higher DC voltage levels can be generated. The converter's voltage gain is quite significant. For example, when the input battery voltage is set at 48 VDC with a duty cycle (D) of 0.8, the resulting outputs are substantially amplified, producing voltages 18, 36, and 72 times the input voltage. Conversely, when using a reduced D of 0.2 while maintaining the input voltage at 48 VDC, the converter yields reduced voltages of 0.1875, 0.375, and 0.75 times the initial voltage. This versatility allows for the generation of various DC voltages as needed.

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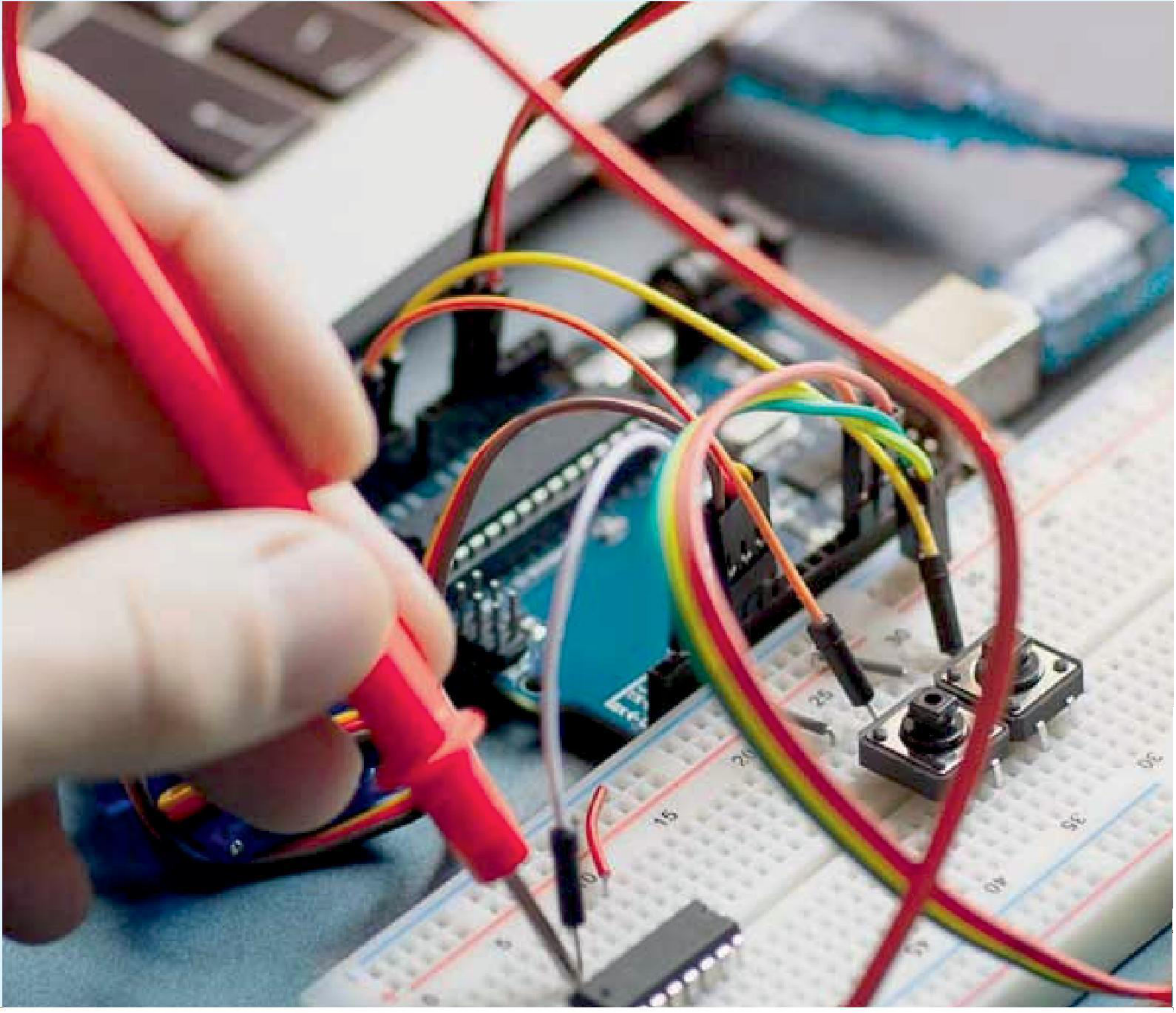

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