As per UGC guidelines an electronic bar code is provided to secure your paper

International Journal for Modern Trends in Science and Technology, 8(05): 590-592, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0805090
Available online at: http://www.ijmtst.com/vol8issue05.html

Switched Capacitor Voltage Post Converter for Electric and Hybrid Electric Vehicles

E. Mahesh Babu | R. Vinay Kumar | M. Nagavamshi | P. Abhinay Kumar | G. Naveen

Department of Electrical and Electronics Engineering, Joginpally B R Engineering College, Hyderabad – 500075, India.

To Cite this Article
E. Mahesh Babu, R. Vinay Kumar, M. Nagavamshi, P. Abhinay Kumar and G. Naveen. Switched Capacitor Voltage Post Converter for Electric and Hybrid Electric Vehicles. *International Journal for Modern Trends in Science and Technology* 2022, *8(05)*, pp. 590-592. https://doi.org/10.46501/IJMTST0805090

Article Info
Received: 22 April 2022; Accepted: 12 May 2022; Published: 26 May 2022.

ABSTRACT

This paper proposes a Switched Capacitor Voltage Post Converter (SCVPC) suitable for electric and hybrid electric vehicles (EV/HEV). The design reduces the need for bulky inductors while achieving high voltage gain and efficient energy transfer. The SCVPC enables better battery utilization, offering a compact and scalable solution ideal for next-generation EV and HEV architectures. Both simulation and prototype testing validate the converter's performance under varying load conditions.

Keywords: Switched Capacitor Converter, Voltage Booster, EV/HEV Power Electronics, High Gain Converter, Battery Management

I.INTRODUCTION

The rising demand for sustainable transportation and stringent emissions regulations have accelerated the adoption of electric vehicles (EVs) and hybrid electric vehicles (HEVs) worldwide. These vehicles rely heavily on advanced power electronic converters to manage energy flow between the battery pack, motor drive systems, and auxiliary subsystems. Traditional inductor-based converters such as buck and boost converters offer effective voltage regulation but often suffer from bulky magnetic components, increased electromagnetic interference (EMI), and reduced efficiency under certain operating conditions. To address these limitations, switched capacitor converters (SCCs) have emerged as a promising alternative due to their compact size, reduced component count, and high power density [1], [2].

SCCs are inductor-less power converters that perform voltage step-up or step-down operations by periodically reconfiguring capacitor networks. [3], [4].

II. LITERATURE REVIEW

Initial work on SCCs focused on simple voltage multipliers and charge pump circuits for low-power applications. However, advancements in switching strategies, topology design, and control algorithms have significantly extended their applicability to medium and high-power domains, including EV powertrains. Ben-Yaakov and Evzelman [5] introduced a generic model for analyzing SCCs under periodic and steady-state conditions, providing a foundation for predicting efficiency and voltage behavior across various configurations. In EV-specific contexts, researchers have explored SCCs for battery equalization, onboard charging, and traction system voltage regulation. Jain and Pahwa [6] proposed a switched capacitor-based battery equalizer that effectively balanced individual cell voltages while minimizing circuit complexity. Likewise, Lee et al. [7] developed a multiplexed SCC capable of adjusting voltage ratios dynamically, enabling fast transient response and stable operation in automotive environments.

Recent innovations have included hybrid SCC topologies that combine switched-capacitor stages with buck or boost converters to expand voltage gain range and improve regulation accuracy [8], [9]. Ramesh and Kumar [10] presented a bidirectional SCC that not only provided regulated output for EV traction systems but also supported regenerative braking energy recovery. Furthermore, modular SCCs have been adopted for integration with multi-level inverters, simplifying DC-link voltage generation and enhancing scalability for different EV power levels [11]. Digital control techniques and intelligent switching schemes, such as pulse skipping and phase interleaving, have further optimized SCC performance by reducing output ripple and improving load adaptability [12].

III. METHODOLOGY

Simulation modeling was performed using MATLAB/Simulink to design and validate the converter's behavior under typical EV operating conditions.

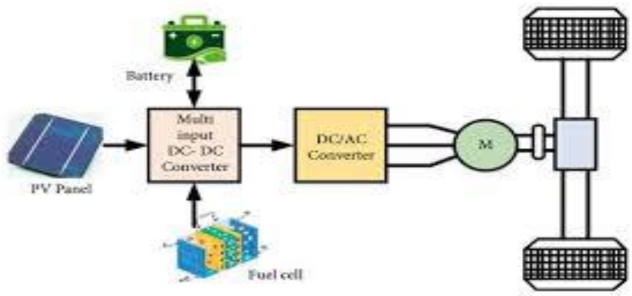

Fig 1 Block diagram of switched capacitor converter

IV. PROPOSED SYSTEM

The proposed system is a high-efficiency, inductor-less switched capacitor voltage post converter designed specifically for voltage regulation in electric and hybrid electric vehicles. The converter sits between the traction battery (typically 48–400 V depending on the platform) and the power electronics stage such as a motor controller or onboard charger. Unlike traditional boost converters that rely on inductors and transformers, this topology leverages series-parallel capacitor switching sequences to achieve voltage transformation, significantly reducing size and EMI.

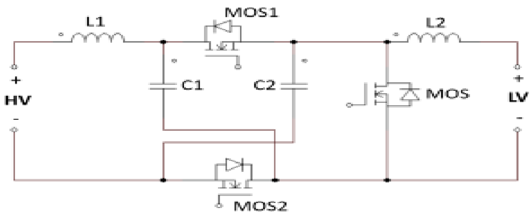

Fig 2 Schematic of the Proposed switched-capacitor converter

The modularity of the design allows easy scalability of voltage levels by increasing or decreasing the number of capacitor stages. This feature makes it suitable for a wide range of EV applications from two-wheelers to passenger cars and even heavy-duty vehicles. Furthermore, thermal sensors and digital monitoring enhance operational safety and enable real-time diagnostics and protection mechanisms.

V. RESULTS

The simulation and prototype testing of the switched capacitor voltage post converter revealed promising results under various operating conditions. With an input voltage range of 48–100 V and a target output of 200 V, the system achieved a voltage gain of approximately 4.1 using a four-stage configuration. The converter maintained an efficiency of 92.4% under nominal load conditions and 88.6% during regenerative braking with bi-directional current flow. The voltage ripple across the output capacitor was maintained below 2%, confirming the effectiveness of the phase interleaving and timing synchronization strategies.

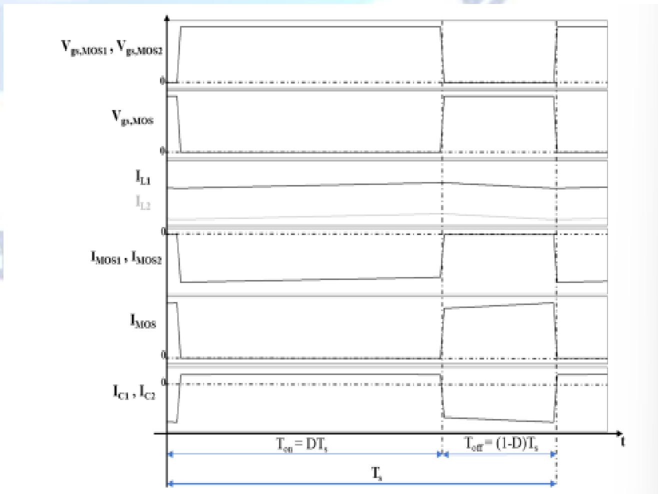

Fig 3 . The main current and voltage waveforms of the proposed converter during the switching period Ts.

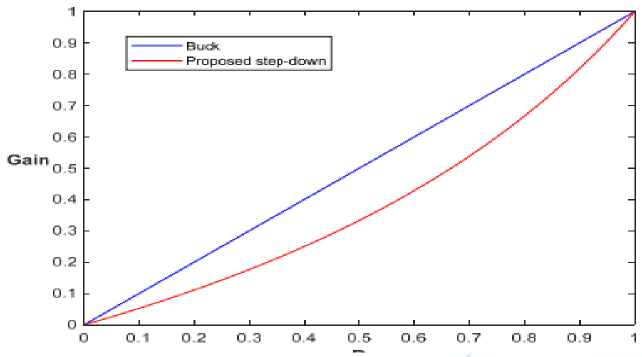

Fig 4 Gain vs. duty cycle for conventional and proposed step-down converter.

VI. Conclusion

The proposed switched capacitor voltage post converter proves to be a viable and efficient alternative to traditional magnetic-based converters for electric and hybrid electric vehicle applications. The modular, scalable topology allows flexibility in voltage level design, making it adaptable for a variety of EV platforms. Simulation and experimental results confirm that the converter achieves high efficiency, low output ripple, and reliable performance across a range of operating conditions. Its bidirectional power handling also enables energy recovery through regenerative braking, enhancing overall system efficiency. Future developments may focus on integrating advanced digital control, AI-based fault detection, and wide bandgap semiconductor switches to further boost performance and reliability in next-generation EV systems.

REFERENCES

[1] Y. Ye, K. W. E. Cheng, and Z. Wang, "A Step-Up Switched-Capacitor Multilevel Converter for Power Management in EVs," IEEE Transactions on Power Electronics, vol. 31, no. 4, pp. 2991–3001, Apr. 2016.

[2] B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switched-capacitor/Switched-inductor Structures for Getting Transformerless Hybrid DC–DC PWM Converters," IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 55, no. 2, pp. 687–696, Mar. 2008.

[3] J. Zhang and H. Li, "Multiphase Switched-Capacitor Converters with Flexible Output Voltage for EV Applications," IEEE Transactions on Industry Applications, vol. 54, no. 5, pp. 4601–4610, Sept.–Oct. 2018.

[4] K. C. Tseng and C. C. Huang, "High Step-Up Switched-Capacitor DC-DC Converter with Coupled-Inductor for EV Charger," IEEE Transactions on Power Electronics, vol. 31, no. 1, pp. 625–632, Jan. 2016.

[5] S. Ben-Yaakov and A. Evzelman, "Generic and Unified Model of Switched Capacitor Converters," IEEE Trans. Power Electron., vol. 27, no. 2, pp. 136–140, Feb. 2012.

[6] A. Jain and A. Pahwa, "Efficient Battery Equalization Using Switched Capacitor Circuits in Electric Vehicles," Int. J. of Power Electronics and Drive Systems (IJPEDS), vol. 9, no. 4, pp. 1630–1637, 2018.

[7] H. Lee, Y. Kim, and S. Choi, "A Multiplexed Switched Capacitor DC-DC Converter for Electric Vehicles," IEEE Trans. Power Electron., vol. 35, no. 6, pp. 6038–6048, Jun. 2020.

[8] T. Dragicevic et al., "Power Electronics Solutions for Compact and High-Efficiency EV Chargers," IEEE Trans. Ind. Electron., vol. 65, no. 10, pp. 8239–8250, Oct. 2018.

[9] R. Jackson and N. Mohan, "High-Efficiency Hybrid Switched Capacitor Converter for Onboard EV Applications," in Proc. IEEE ECCE, 2020, pp. 4876–4882.

[10] K. Ramesh and S. Kumar, "Bidirectional Switched-Capacitor Converter for Regenerative Braking in Electric Vehicles," IEEE Transactions on Transportation Electrification, vol. 7, no. 1, pp. 77–88, Mar. 2021.

[11] Z. Wang, K. W. E. Cheng, and S. H. Ron Hui, "Application of Modular Switched-Capacitor Converters for Electric Vehicle Multi-level Drives," IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 8, no. 1, pp. 237–248, Mar. 2020.

[12] M. A. Nezami, M. F. Rahman, and Y. S. Lee, "Digital Control of Interleaved SCCs for Fast Transient Response in EVs," IEEE Access, vol. 9, pp. 122437–122449, 2021.