International Journal of Applied and Advanced Scientific Research (IJAASR)
International Peer Reviewed - Refereed Research Journal, Website: www.dvpublication.com
Impact Factor: 5.655, ISSN (Online): 2456 - 3080, Volume 11, Issue 1, January - June, 2026

MULTIFUNCTIONAL INTEGRATED DC-DC CONVERTER FOR ELECTRIC VEHICLE

R. Sathish*, R. Barath, M. Bhavithran**, B. Devaraj** & S. Gurudeva****

* Assistant Professor, Department of Electrical and Electronics Engineering, Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur, Tamil Nadu, India

** UG Student, Department of Electrical and Electronics Engineering, Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur, Tamil Nadu, India

Cite This Article: R. Sathish, R. Barath, M. Bhavithran, B. Devaraj & S. Gurudeva, "Multifunctional Integrated DC-DC Converter for Electric Vehicle", International Journal of Applied and Advanced Scientific Research, Volume 11, Issue 1, January - June, Page Number 87-91, 2026.

Type of Review: Peer Reviewed as per |C|O|P|E| Guidance.

DOI: https://doi.org/10.5281/zenodo.19811970

Abstract:

The rapid growth of Electric Vehicles (EVs) has increased the demand for compact, efficient, and intelligent Power conversion systems capable of supporting multiple operational modes within a single architecture. Conventional EV designs typically rely on several independent converters to manage high-voltage traction Needs, low-voltage auxiliary loads, regenerative braking, and on-board charging. While effective, this multi-Converter approach increases component count, reduces efficiency, and adds unnecessary weight and Complexity. To address these limitations, this paper proposes a Multifunctional Integrated DC-DC Converter (MIDC) that unifies several power conversion functions into a single, optimized system. The proposed converter incorporates a Dual Active Bridge (DAB) stage to enable isolated, bidirectional Power flow between the high-voltage battery and the low-voltage bus, making it highly suitable for Regenerative braking and controlled energy transfer. Additionally, an interleaved buck stage provides stable and efficient low-voltage regulation for auxiliary loads, improving thermal performance and reducing current Ripple. By combining these functionalities, the MIDC achieves higher power density, lower switching losses, and reduced hardware redundancy compared to traditional converter arrangements. Simulation studies and theoretical analysis demonstrate that the integrated design enhances overall energy Utilization, simplifies system architecture, and improves reliability in EV applications. The multifunctional Nature of this converter positions it as a promising solution for next-generation electric vehicle platforms that require high performance, adaptability, and compact power electronics.

Key Words: Electric Vehicle (EV), Multifunctional Converter, Dual Active Bridge (DAB), Regenerative Braking, DC-DC Conversion, Integrated Power Architecture

1. Introduction:

Electric Vehicles (EVs) have emerged as a crucial component of modern transportation systems as the global community seeks sustainable alternatives to internal combustion engine vehicles. Growing concerns over climate change, rising fuel prices, and the push for cleaner energy technologies have accelerated the shift toward electrified mobility. In an EV, electrical energy stored in a high-voltage battery must be efficiently converted, distributed, and regulated to support various subsystems. This requirement places significant emphasis on the design of advanced power electronic converters that ensure reliable operation under diverse driving and environmental conditions. Consequently, the development of multifunctional and integrated power converters has become an important area of research.

Traditional EV power architectures typically rely on multiple dedicated DC-DC converters, each serving a specific function such as high-voltage traction support, low-voltage auxiliary supply, or regenerative braking energy recovery. While this modular approach allows functional independence, it leads to increased component count, reduced overall efficiency, and more complex thermal management. Multiple converters occupying significant space also add to system weight, making the vehicle less energy efficient. Moreover, coordinating power flow among several independent converters introduces additional control challenges, often resulting in higher implementation costs. As EV adoption continues to grow, these limitations highlight the need for power conversion systems that can integrate several functionalities into a compact, unified structure without compromising performance or reliability.

The concept of a Multifunctional Integrated DC-DC Converter (MIDC) aligns closely with current trends in EV power electronics, which emphasize high efficiency, compactness, and robust operational capability. By leveraging shared magnetic components, optimized switching strategies, and coordinated control algorithms, a MIDC can manage energy flow across high-voltage and low-voltage domains with greater precision. This consolidated architecture not only simplifies physical design but also enhances reliability by reducing the number of interconnections and potential points of failure. Furthermore, the integrated nature of the converter allows for better utilization of semiconductor devices, improved fault tolerance, and smoother transitions between operational modes, particularly during charging and regenerative events.

2. Related Works:

Various research works related to Multifunctional Integrated DC-DC Converter For Electric Vehicle are reviewed in this section.

- Multifunctional Isolated DC-DC Converter for Electric Vehicles: This paper presents a multifunctional isolated DC-DC converter designed specifically for electric vehicles (EVs) to address the growing demand for compact, efficient, and integrated power electronics. The authors propose a system that combines multiple DC-DC conversion tasks, such as high-voltage to low voltage conversion, bidirectional power flow for regenerative braking, and auxiliary load management, into a single isolated converter topology. The converter leverages advanced control strategies to coordinate these functions seamlessly while maintaining high efficiency and stable voltage regulation. The authors highlight that conventional EV architectures rely on multiple discrete converters, leading to redundancy, increased weight, thermal issues, and complexity. By integrating multiple functionalities into one platform, the proposed system achieves reduced component count, improved thermal performance, and higher power density. Experimental results provided in the paper demonstrate significant efficiency improvements during both forward and regenerative power flow conditions. The study also emphasizes the converter's ability to handle varying load conditions while maintaining voltage stability and minimizing ripple. Furthermore, the authors discuss the importance of isolation in EV applications to ensure safety and mitigate electromagnetic interference. Overall, this research provides a foundational framework for the development of next-generation multifunctional converters that improve energy utilization, reduce system size, and enhance the overall reliability and performance of electric vehicles. The paper's insights serve as a benchmark for integrating multiple power management functions into a single EV converter platform.

- Research of a multifunctional integrated electromagnetic component as an LC filter in DC/DC converters: This research focuses on the development of a multifunctional integrated electromagnetic component used as an LC filter in DC-DC converters, emphasizing its potential applications in electric vehicles. The authors propose combining the inductance and capacitance elements into a single integrated module to enhance compactness, reduce system weight, and minimize electromagnetic interference (EMI). Traditional DC-DC converters employ separate inductors and capacitors for filtering, which can lead to bulky systems and increased parasitic losses. By integrating these components into a multifunctional LC module, the study aims to improve both electrical and thermal efficiency. The paper includes detailed modeling and simulation of the integrated LC filter under varying load conditions to evaluate performance, including voltage ripple suppression, current handling capability, and transient response. Results demonstrate that the integrated design effectively reduces voltage ripple and improves stability while decreasing the number of discrete components required in the system. Furthermore, the authors highlight the implications of such integration for multifunctional DC-DC converters in EVs, where space and weight constraints are critical. The proposed approach not only enhances system compactness but also simplifies the assembly process and reduces costs. Additionally, the paper discusses how this integrated LC module can support bidirectional power flow, contributing to more efficient regenerative braking and energy management. The study's findings provide a practical solution for improving converter performance and compactness in next-generation EV power electronics.
- Experimental Determination of the Transformer Equivalent Circuit Parameters in the Electric Vehicle Charger DC/DC Converter: In this study, the authors investigate the experimental determination of transformer equivalent circuit parameters for DC-DC converters used in electric vehicle chargers. The paper emphasizes the critical role of transformers in isolated DC-DC topologies for providing voltage step-down or step-up functionality while maintaining galvanic isolation between high voltage batteries and low-voltage loads. The researchers present a systematic methodology for accurately measuring transformer parameters, including primary and secondary winding resistances, leakage inductances, magnetizing inductances, and parasitic capacitances. Accurate determination of these parameters is crucial for precise modeling, simulation, and design optimization of EV charger converters. The authors demonstrate how inaccuracies in transformer parameters can lead to inefficient operation, excessive voltage ripple, and increased thermal losses, which are critical concerns in high-power EV systems. The paper includes experimental validation using laboratory prototypes and compares measured results with theoretical calculations, highlighting the importance of precise transformer characterization. Additionally, the study discusses the implications of transformer parameter variations on converter performance during both charging and regenerative operation, showing how optimized transformers can improve energy efficiency and minimize losses. The findings contribute to more reliable and high-performance EV chargers and provide valuable guidance for designers seeking to improve the efficiency and compactness of multifunctional DC-DC converter systems. The research also emphasizes the need for integrating such transformers into advanced EV architectures to support multifunctionality and energy optimization.

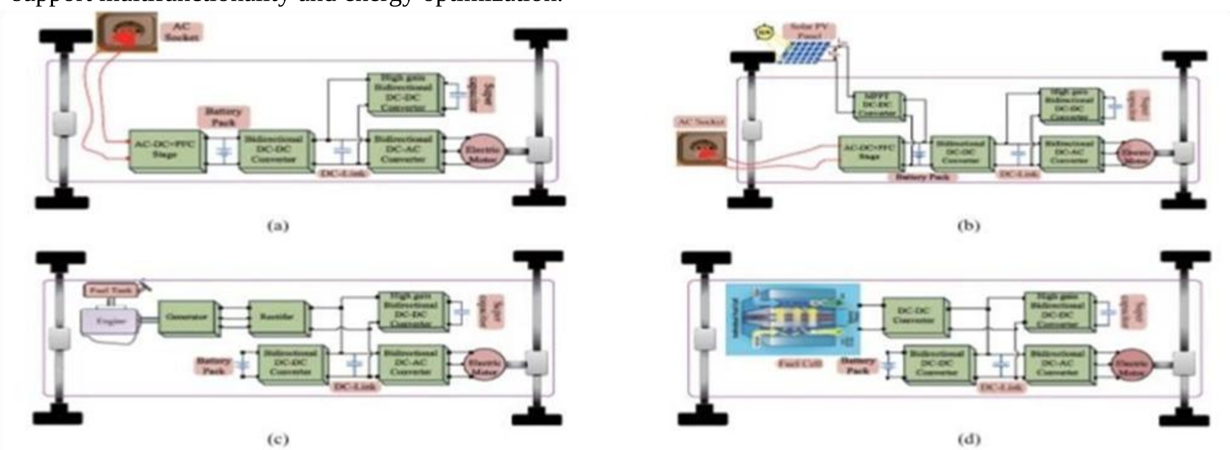

Figure 1: Existing System Block Diagram

3. Proposed System:

The proposed system focuses on the development of a multifunctional integrated DC-DC Converter designed to meet the power conversion and energy management requirements of electric Vehicle (EV) applications. The system integrates multiple functional blocks such as power Conversion, control, monitoring, and thermal management into a single compact unit, thereby improving efficiency, reliability, and system performance, the proposed system is a hardware Implementation of a multifunctional integrated DC-DC converter designed to demonstrate Essential power conversion and management functions used in electric vehicle (EV) applications. The system is built by integrating multiple subsystems such as a power source, DC-DC converter, Control unit, display module, and thermal management components onto a single platform. A Lithium-ion battery pack serves as the primary DC input source, providing portable energy similar To EV battery systems. Additionally, an AC supply through a step down transformer is incorporated to enable operation using mains power, thereby allowing flexibility for testing and backup purposes. The input power from either source is fed into a high-frequency switching DCDC converter circuit, which consists of MOSFET switching devices, a toroidal inductor for energy Storage, and capacitors for filtering and voltage stabilization. The converter operates on the Principle of rapid switching, where electrical energy is alternately stored and released through the Inductor to achieve regulated output voltage with improved efficiency.

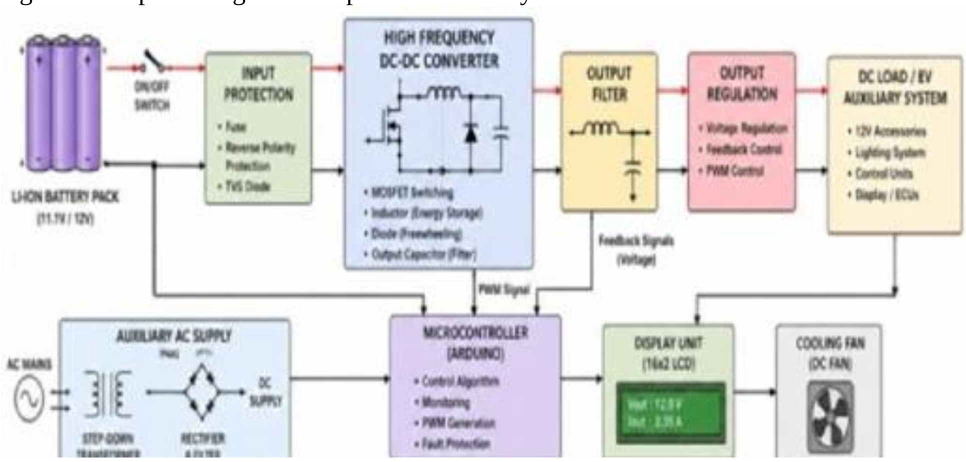

Figure 2: Proposed Block Diagram

The hardware block diagram of the proposed system represents the integration of various functional units required for efficient DC power conversion, control, and monitoring. The system is designed using multiple interconnected blocks, each performing a specific function to ensure reliable operation; the system begins with the input power source block, which consists of a lithium-ion battery pack acting as the primary DC supply. In addition to this, an auxiliary AC supply block is included, which uses a step-down transformer followed by rectification and filtering to provide an alternative DC input. These input sources are connected through an ON/OFF switching mechanism and an input protection circuit, which includes components such as fuses and protection diodes to safeguard the system from over current and reverse polarity conditions. The regulated input is then fed into the DC-DC converter block, which forms the core of the system. This block consists of high-frequency switching elements such as MOSFETs, an energy storage inductor, fast recovery diodes, and filter capacitors. The converter operates on switching principles to step down and regulate the input voltage to a stable output suitable for low-voltage loads.

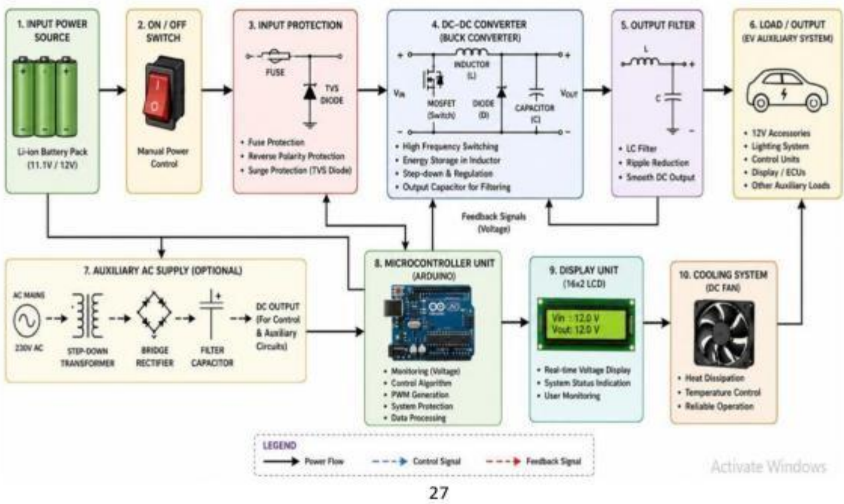

Figure 3: Proposed System Circuit Diagram

The output of the converter is passed through an output filter block, which reduces voltage ripple and ensures smooth DC output. This is followed by the output regulation block, where feedback Signals are used to maintain a constant output voltage under varying load conditions A Microcontroller unit (Arduino) is integrated into the system as the control block. It receives Feedback signals from the output, processes them, and generates control signals such as PWM to regulate the switching operation of the converter. This creates a closed-loop control system that Enhances stability and efficiency. For user interaction, a display block (16×2 LCD) is connected to the microcontroller. This block provides real-time information about system parameters such as Voltage levels and operational status, making the system more user-friendly and informative To Ensure safe operation, a cooling system block consisting of a DC fan is included. This block Dissipates heat generated by power electronic components, thereby preventing thermal damage and improving system reliability. Finally, the regulated output is supplied to the load block, which Represents EV auxiliary systems such as lighting, control circuits, and low-voltage electronics. Overall, the hardware block diagram illustrates a well-integrated system where power conversion, Control, monitoring, and protection are combined into a single platform, effectively demonstrating the working principle of a multifunctional DC-DC converter used in electric vehicle applications.

4. Simulation Results:

The hardware block diagram of the proposed system illustrates the complete architecture of a Multifunctional integrated DC-DC converter designed for electric vehicle (EV) applications. The System integrates power conversion, control, and monitoring units into a unified structure to ensure efficient energy transfer and stable operation. The design demonstrates how electrical energy from An AC source can be converted into a regulated DC output suitable for charging and powering EV Battery systems and auxiliary loads.

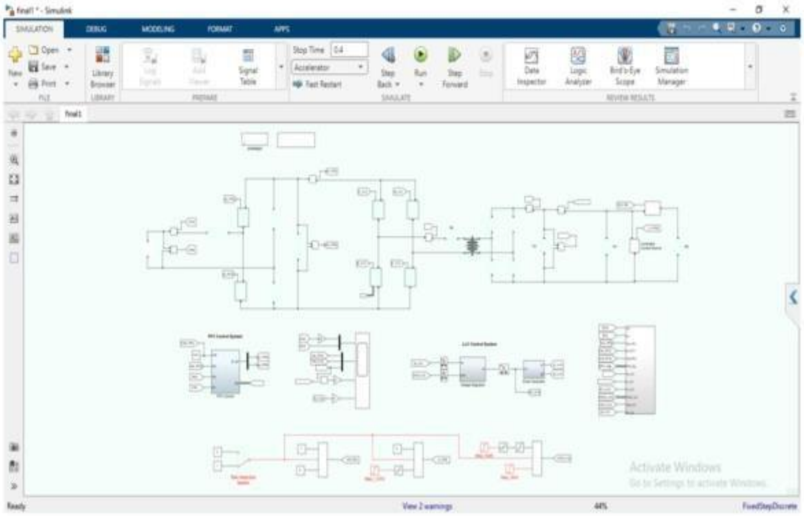

Figure 4: Simulation Diagram

The system begins with the AC input block, which represents the main power supply obtained from the electrical grid. This input is typically a high-voltage alternating current (AC), which cannot be directly used for DC-based electronic systems. Therefore, the AC input is first fed into a step-down transformer, which reduces the voltage level to a safer and manageable range. The Transformer also provides electrical isolation between the high-voltage input and the low voltage System, enhancing safety and protecting sensitive components from voltage surges.

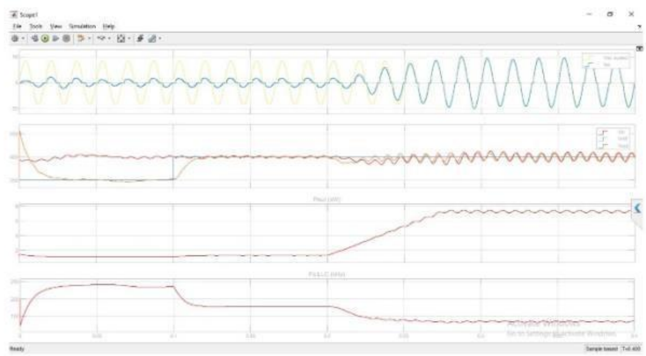

Figure 5: Output 1

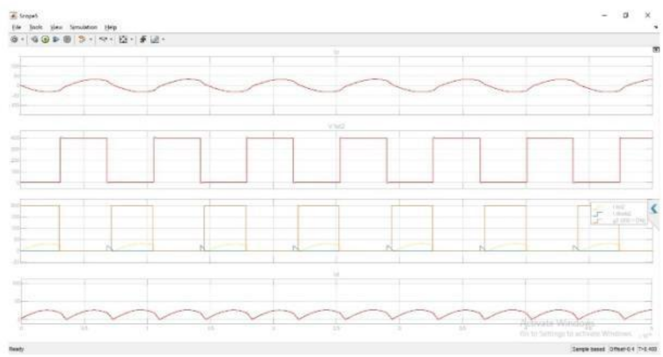

Figure 6: Output 2

Following the transformer stage, the reduced AC voltage is supplied to a bridge rectifier, which converts the alternating current into a pulsating direct current (DC). The bridge rectifier consists of four diodes arranged in such a way that both halves of the AC waveform are utilized, resulting In improved efficiency compared to half-wave rectification. The output of the rectifier is not perfectly smooth and contains ripples; however, it serves as a suitable input for the next stage of Power conversion. The design can be further Enhanced by incorporating advanced features such as bidirectional power flow, regenerative Braking, battery management systems, and current sensing modules, making it suitable for real-World electric vehicle applications.

6. Conclusion:

The development of Electric Vehicles (EVs) has placed significant emphasis on efficient, compact, And reliable power conversion systems. The DC-DC converter is a critical component in this Ecosystem, responsible for managing voltage regulation, energy flow, and bidirectional power Transfer between high-voltage battery packs and low voltage subsystems. Traditional multi-Converter architectures, while functional, suffer from hardware redundancy, lower efficiency, Complex control requirements, and thermal management challenges. These limitations highlight the need for an integrated and multifunctional approach to power conversion within modern EVs. Through simulation and analysis, the MIDC demonstrates improved energy efficiency, effective Regenerative braking support, and reliable low-voltage regulation compared to conventional multi-Converter systems. The proposed system also facilitates advanced control strategies, allowing Seamless transitions between driving, charging, and regenerative braking modes. Furthermore, the Integration of multiple functions within a single converter simplifies system architecture, reduces Manufacturing and maintenance costs, and enhances overall vehicle reliability.

7. Future Enhancement:

Future enhancements of the MIDC focus on advanced semiconductor technologies, intelligent Energy management, modular scalability, improved thermal solutions, and integration with Renewable and grid systems. These developments will strengthen the MIDC's role in next-Generation EV architectures, delivering higher efficiency, compactness, reliability, and Sustainability. The proposed enhancements position the MIDC not only as a solution for current EV requirements but also as a forward-looking platform capable of supporting emerging Technologies and future mobility trends. Finally, integration with renewable energy sources and vehicle-to-grid (V2G) applications can be explored. The MIDC could be adapted to support bidirectional energy exchange with the grid or On-site renewable energy systems, enabling more sustainable energy utilization and contributing to smart grid infrastructure. This would further enhance the versatility and future relevance of the Converter in evolving energy ecosystems.

References:

1. C. H. Jo, S. M. Kim, S. J. Jo, J. Xie, & D.-H. Kim. (2024). Multifunctional isolated DC-DC converter for electric vehicles. In Proceedings of the 2024 IEEE 10th International Power Electronics and Motion Control Conference (IPEMC-ECCE Asia) (pp. 1471-1475). https://doi.org/10.1109/IPEMCECCEAsia60879.2024.10567615
2. R. R. Sattarov, R. T. Khazieva, & M. D. Ivanov. (2023). Research of a multifunctional integrated electromagnetic component as an LC filter in DC/DC converters. In Proceedings of the 2023 5th International Youth Conference on Radio Electronics, Electrical and Power Engineering (REEPE) (pp. 1-5). https://doi.org/10.1109/REEPE57272.2023.10086824
3. M. Ivanov, & R. Khazieva. (2024). Experimental determination of the transformer equivalent circuit parameters in the electric vehicle charger DC/DC converter. In Proceedings of the 2024 International Ural Conference on Electrical Power Engineering (UralCon) (pp. 853-858). https://doi.org/10.1109/UralCon62137.2024.10719006
4. Kim, & J.-W. Park. (2024). Multifunctional integrated DC-DC converter for electric vehicles. IEEE Transactions on Power Electronics, 39(6), 7252-7263. https://doi.org/10.1109/TPEL.2024.3378278
5. N. Kamarajugadda, B. G. Fernandes, & K. Chatterjee. (2022). 7.2 kW multifunctional and integrated onboard electric vehicle charger. In Proceedings of IECON 2022 (pp. 1-6). https://doi.org/10.1109/IECON49645.2022.9968476
6. S. El Daoudi, A. El Abdallaoui, A. Margal, & A. Karama. (2024). Redistribution and management of stored energy in electric vehicles for grid integration. In Proceedings of ISAECT 2024 (pp. 1-6). https://doi.org/10.1109/ISAECT64333.2024.10799623
7. R. K. Shukla, D. Saha, & B. G. Fernandes. (2024). A multifunctional current fed triple active bridge converter for EV application. In Proceedings of PEDES 2024 (pp. 1-5). https://doi.org/10.1109/PEDES61459.2024.10961818
8. H. S. Gohari, H. Tarzamni, P. Sergeant, & H. Vansompel. (2023). PV-grid integrated multifunctional buck-boost onboard EV charger with CCM-DCM operation. In Proceedings of IECON 2023 (pp. 1-7). https://doi.org/10.1109/IECON51785.2023.10312286
9. N. Kamarajugadda, B. G. Fernandes, & K. Chatterjee. (2025). GaN-based high power density multifunctional onboard charger for electric vehicles eliminating auxiliary power module. IEEE Transactions on Industrial Electronics, 72(8), 7920-7931. https://doi.org/10.1109/TIE.2024.3525125
10. B. N. Lingaiah, & N. R. Tummuru. (2025). A multifunctional system configuration integrated with PV-grid-energy storage and IPT-based EV charging for residential energy management. IEEE Transactions on Transportation Electrification, 11(3), 8153-8163. https://doi.org/10.1109/TTE.2025.3537621
11. H. S. Gohari, L. Verkroost, P. Sergeant, & H. Vansompel. (2024). Bidirectional single-phase integrated onboard charger for ultracapacitor-battery based EVs with V2G and regenerative braking capability. In Proceedings of PEMC 2024 (pp. 1-8). https://doi.org/10.1109/PEMC61721.2024.10726376
12. Verma, & B. Singh. (2021). CAPSA based control for power quality correction in PV array integrated EVCS operating in standalone and grid connected modes. IEEE Transactions on Industry Applications, 57(2), 1789-1800. https://doi.org/10.1109/TIA.2020.3041812
13. Alosa, F. Immovilli, & E. Lorenzani. (2021). Assessment of a multi-functional converter system for traction electric drives. In Proceedings of ECCE 2021 (pp. 2696-2703). https://doi.org/10.1109/ECCE47101.2021.9595626
14. Y. Park, S. Chakraborty, & A. Khaligh. (2022). DAB converter for EV onboard chargers using bare-die SiC MOSFETs and leakage-integrated planar transformer. IEEE Transactions on Transportation Electrification, 8(1), 209-224. https://doi.org/10.1109/TTE.2021.3121172