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DESIGN AND IMPLEMENTATION OF A MULTIPORT CHARGER FOR LIGHT ELECTRIC VEHICLES WITH INTEGRATED DOMESTIC POWER SUPPLY

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ABSTRACT

Power transfer in Electric Vehicle (EV) systems conventionally includes Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), and Vehicle-to-Home (V2H) operations. However, this work introduces a novel perspective by utilizing a Light Electric Vehicle (LEV) as a mobile power transport unit for underprivileged and rural households. In this context, a multi-functional converter topology is proposed that enables LEV battery charging from both AC and DC sources, while also facilitating the supply of domestic loads directly from the LEV battery.

The proposed system consists of an active-bridge-based single-stage AC/DC converter integrated with an auxiliary DC port. A key advantage of the topology is its reduced switch count while supporting multiple operational functionalities. The single-stage AC/DC conversion minimizes high-frequency switching devices, improving efficiency and reducing system complexity. Additionally, the DC/DC interface reuses partial converter circuitry to perform bidirectional power transfer without requiring extra high-frequency switches

The converter operates in three distinct modes: (i) Mode I – LEV battery charging from the AC grid, (ii) Mode II – LEV battery charging from another EV or external DC battery source, and (iii) Mode III – Supplying household appliances from the LEV battery. Each operating mode is analyzed independently to evaluate system performance. The AC/DC interface ensures unity power factor operation and maintains low harmonic distortion. Simulation studies are carried out in the MATLAB/Simulink environment, and experimental validation is performed on a laboratory-scale prototype. The results confirm satisfactory operation in all modes, with grid current Total Harmonic Distortion (THD) maintained within the limits specified by IEC 61000-3-2 standards.

Keywords:
Electric Vehicle (EV), Multiport Converter, Household Appliance, Power Transport

I INTRODUCTION

Contemporary concerns regarding climate change and rising global temperatures have placed a strong emphasis on integrating sustainable solutions into daily life. Consequently, the transportation sector is shifting from fossil fuels to electric vehicles (EVs), driving significant research into both onboard and offboard charging systems. Bidirectional chargers have further enabled EVs to integrate with the grid through G2V and V2G power transfers, allowing EV fleets to serve as energy storage for renewable-based microgrids. However, the widespread adoption of EVs increases the load on the power grid. Research has focused on optimal scheduling and management to ensure uniform grid demand and provide frequency support. Beyond grid interaction, EV capabilities have expanded to vehicle-to-home (V2H) and vehicle- to-load (V2L) applications, where the battery provides local power for appliances or acts as a backup during blackouts. Smart homes now facilitate the seamless integration of these vehicles. These various capabilities are collectively known as V2X, where "X" represents the grid, home, battery, or any other load.

In Southeast Asia, there has been a significant rise in e-rickshaw usage for last-mile connectivity in both cities and remote villages. This study recognizes the potential for e- rickshaws to provide electricity to rural households lacking grid access. The paper proposes viewing LEVs as energy transport devices for underprivileged areas. A charged LEV returning home can power basic household appliances at night, necessitating a multiport charger with G2V and V2H capabilities. Since e-rickshaws often lack onboard chargers and rely on portable units, this work focuses on a multiport converter solution. While various multiport converters exist, many are limited by high switch counts, complex multi-winding transformers, or a lack of mode-dependent partial operation. This research is motivated by the need for a converter that allows LEVs to charge from AC or DC sources and power domestic devices like fans and lights in areas without reliable grid access.

II LITERATURE SURVEY

The 2021 climate report by the Intergovernmental Panel on Climate Change highlighted that Earth is warmer than it has been in 125,000 years, emphasizing the urgent need for electrification and clean energy solutions. Supporting this vision, Rastogi et al. (2019) discussed the feasibility of achieving all-electric vehicles within a decade, addressing energy security and charging challenges. Shi et al. (2018) proposed a 3.3-kW three-phase integrated onboard charger using a PMSM with 92.6% efficiency, near-unity power factor, and 4.77% THD. Sharma and Singh (2022) developed a functional link neural network–based bidirectional onboard charger for e-rickshaws with IEEE-519 power quality compliance and vehicle-to-grid capability. Kesler et al. (2014) demonstrated a 12.5-kVA bidirectional offboard charger capable of four-quadrant operation and reactive power support without affecting battery charging. Xuan et al. (2021) introduced a 3.5-kW three-level CLLC resonant DC–DC converter supporting a wide 200–700 V range with balanced flying capacitor voltages. Mahfouz and Iravani (2020) presented a battery-enabled DC fast charging station with grid-connected and islanded modes to reduce stress on weak AC grids. Kwon and Choi (2017) proposed a 3.3-kW electrolytic capacitorless bidirectional charger for V2G and V2H applications with zero-current switching and high efficiency. Dicorato et al. (2019) developed an integrated DC microgrid solution combining photovoltaic systems, storage, and EV fleet charging with smart control and ancillary services. Finally, Wang et al. (2020) proposed integrating EV fleets into a virtual power plant with large-scale wind power using optimization techniques to smooth fluctuations and enhance battery lifetime.

III EXISTING SYSTEM

The existing electric vehicle (EV) charging infrastructure primarily focuses on conventional onboard and offboard chargers that support Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G), and in some cases Vehicle-to-Home (V2H) operations. According to the 2021 report by the Intergovernmental Panel on Climate Change, rapid electrification of transportation is essential due to increasing global temperatures, which has accelerated research in EV charging technologies. Traditional onboard chargers such as the three-phase integrated charger proposed in 2018 utilize the propulsion motor as part of the charging circuit and achieve high efficiency (~92%) with near unity power factor. Advanced bidirectional chargers enable reactive power support to the grid and operate in four quadrants, but they require complex control strategies and higher component count. Resonant DC–DC converters like three-level CLLC topologies are used in DC microgrids to support wide battery voltage ranges (200–700 V), but they involve multiple switches and sophisticated modulation techniques. Fast-charging stations integrated with battery energy storage systems help reduce stress on weak grids; however, they increase system cost and complexity.

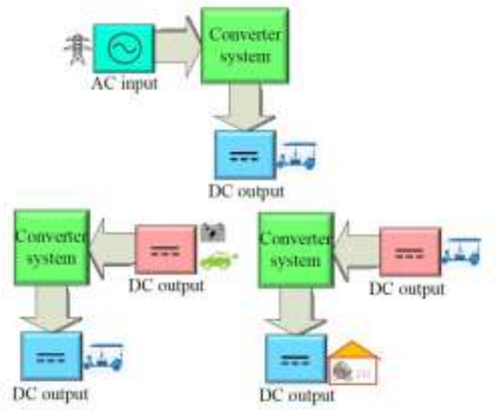

Fig 3.1: Existing electric vehicle (ev) charging infrastructure

Electrolytic-capacitorless bidirectional chargers improve lifespan and enable V2G and V2H applications, yet they still primarily focus on grid interaction rather than rural or standalone energy access. Integrated DC microgrid solutions combine photovoltaic systems, storage, and EV charging for fleet management, but these systems are mainly designed for urban smart-grid environments. Virtual power plant models integrate EV fleets with wind power to smooth renewable fluctuations, relying on advanced optimization algorithms and centralized coordination

IV PROPOSED SYSTEM

The proposed system presents a novel multiport charger designed for light electric vehicles (LEVs) with the additional capability of powering domestic appliances, as introduced in *"A Multiport Charger for Light Electric Vehicles With Function of Powering Domestic Appliances"* (2023). Unlike conventional chargers that mainly focus on grid interaction, this system enables three operating modes: (i) charging the LEV battery from the AC grid (Mode I), (ii) charging the LEV battery from another DC source or battery (Mode II), and (iii)

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supplying power from the LEV battery to household DC appliances (Mode III). The converter structure integrates an interleaved totem-pole AC front-end, a current-fed dual active bridge (CF-DAB) for isolated DC–DC conversion, and an interleaved buck/boost stage, reducing switch count while supporting multi-mode functionality.

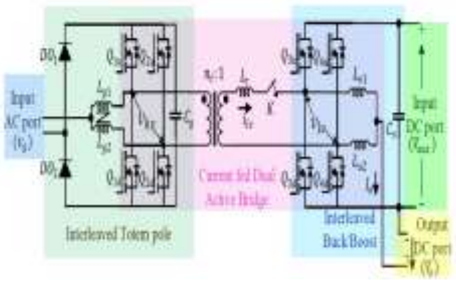

Fig 4.1: Block diagram

In Mode I, the system operates as a single-stage isolated AC–DC converter with unity power factor correction and maintains grid current THD within IEC 61000-3-2 limits. In Mode II and Mode III, the system functions as an interleaved DC–DC buck converter to provide ripple-free charging or stable DC output voltage for loads such as LED lights and DC fans. The converter supports wide voltage ranges (AC input 220 V RMS, DC auxiliary 60–96 V, output 12–60 V) and operates at a switching frequency of 50 kHz. Experimental validation demonstrates approximately 91% efficiency at rated conditions. The proposed system is particularly suitable for rural or underprivileged areas where grid access is limited, as it allows LEVs (such as e-rickshaws) to act as mobile energy transport devices, thereby extending EV applications beyond traditional G2V, V2G, and V2H concepts.

SIMULINK DIAGRAM:

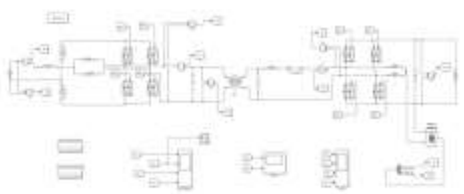

Fig 5.1: Simulink Diagram

V RESULTS

The performance of the proposed multiport charger was validated through both simulation and experimental investigation under all three operating modes. In Mode I (AC grid to LEV battery charging), the converter operated as a single-stage isolated AC–DC converter with unity power factor correction. For an input of 220 V RMS, the system successfully charged a 60 V battery with rated current up to 50 A. The grid current was nearly sinusoidal with Total Harmonic Distortion (THD) below 5% (around 3.8%), satisfying the IEC 61000-3-2 standard. The high-voltage DC bus reached approximately 630 V peak, and the low-voltage DC bus operated around 130 V. The overall efficiency of the prototype reached nearly 91% at rated condition. Although a second harmonic (100 Hz) ripple was observed in the output current due to single-stage conversion, it did not adversely affect battery performance.

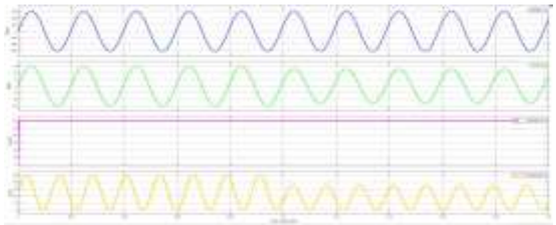

Fig 6.1: Mode I

In Mode II (DC-to-DC charging from auxiliary battery), the system functioned as an interleaved buck converter. With input DC voltage ranging from 72 V to 96 V, the converter efficiently charged a 60 V battery. The interleaved inductors significantly reduced output current ripple, and the controller accurately tracked changes in reference charging current (e.g., 10 A to 5 A). Since the AC front-end and high-frequency transformer were disconnected in this mode, switching and conduction losses were reduced compared to Mode I, resulting in stable and efficient operation.

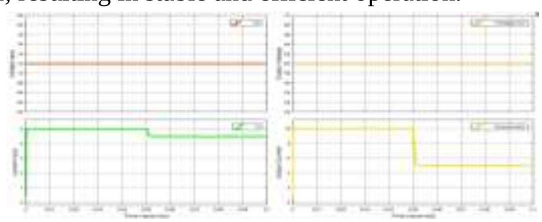

Fig 6.2: Mode II

In Mode III (Battery to Domestic Load), the LEV battery supplied power to DC loads such as 12 V LED lights and DC fans. The voltage controller maintained constant output voltage even during load variation (e.g., resistance change from 12 Ω to 6 Ω). The system demonstrated stable dynamic response and minimal voltage fluctuation, proving its suitability for rural household applications.

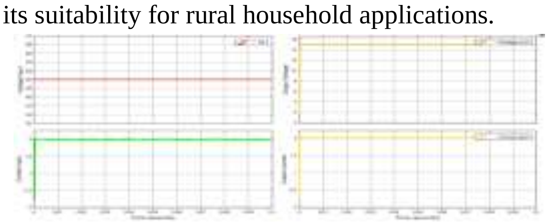

Fig 6.3: Mode III

Overall, the experimental results closely matched simulation results, confirming the feasibility of the proposed multiport converter. The system achieved high efficiency, reduced harmonic distortion, smooth current control, and reliable multi-mode operation, demonstrating its practical applicability for LEV charging and rural energy support applications.

VI CONCLUSION

This project presented a multiport charger for light electric vehicles (LEVs) with the additional capability of powering domestic appliances, addressing both transportation electrification and rural energy access challenges. The proposed system successfully integrates AC–DC and DC–DC conversion stages into a compact and efficient architecture capable of operating in three distinct modes: grid-to-vehicle charging, DC-to-vehicle charging, and vehicle-to-load power supply. Experimental validation confirmed stable operation in all modes, with near-unity power factor, low total harmonic distortion (THD within standard limits), and an overall efficiency of approximately 91% at rated conditions.Compared to conventional EV chargers that mainly focus on grid-connected charging or V2G applications, the proposed system extends functionality by enabling LEVs to act as mobile energy sources for household DC appliances. The interleaved structure reduces current ripple, improves efficiency, and enhances reliability, while the simplified control strategy ensures smooth mode transition and stable output under varying load conditions.

Overall, the system demonstrates a practical, efficient, and cost-effective solution for integrating EV charging with decentralized energy usage, particularly suitable for rural and semi-urban areas where grid reliability may be limited. The proposed design not only supports sustainable transportation but also contributes to distributed energy utilization and improved energy accessibility.

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