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BIDIRECTIONAL WIRELESS EV CHARGING SYSTEM

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Abstract: A innovative bidirectional wireless electric vehicle (EV) charging system is presented in this work, facilitating Vehicle-to-Grid (V2G) applications and effective energy transfer between EVs and the grid. By combining communication protocols, power electronics, and wireless power transmission, the system enables convenient charging and high efficiency (>90%). Bidirectional energy transmission, smart grid integration, wireless charging (inductive/capacitive coupling), and communication protocols (Wi-Fi, Bluetooth) are some of the salient features. The method encourages better EV uptake, lower infrastructure costs, and increased grid stability. Successful V2G functioning and excellent efficiency (>92%) are demonstrated by experimental validation. By transforming the EV charging experience, this creative approach promotes environmentally friendly mobility. The suggested system supports the shift to a low-carbon transportation sector by providing a dependable, effective, and practical charging solution for upcoming EV applications.

Keywords: Electric vehicles, Bidirectional charging, wireless power transfer, vehicle-to-grid

I. INTRODUCTION

The growing popularity of electric vehicles (EVs) demands new charging solutions that prioritize efficiency, convenience, and sustainability. Bidirectional wireless charging systems have emerged as a promising option, allowing energy to flow between the grid and EVs, including Vehicle-to-Grid (V2G) capabilities. By removing the need for cables, this technology not only lowers infrastructure costs but also enhances user experience. The integration of wireless power transfer, power electronics, and advanced communication systems enables smooth energy exchanges, improving both grid stability and EV performance. With bidirectional charging, EVs can even send energy back to the grid, helping to stabilize it and potentially earning revenue for their owners.

Despite these advantages, current wireless charging systems face challenges such as low efficiency, limited power transfer, and inconsistent standards. To tackle these issues, this research introduces a new bidirectional wireless EV charging system that emphasizes efficient energy transfer, V2G integration, smart grid compatibility, and advanced communication methods. The goal is to enhance charging efficiency, bolster grid stability, boost EV adoption, and promote sustainable transportation.

The advancement of bidirectional wireless EV charging has major implications for the transport sector, facilitating the use of renewable energy, reducing greenhouse gas emissions, and improving energy efficiency. As the global EV market expands, innovative charging solutions will be vital in shaping the future of sustainable transport. This research aims to develop effective, convenient, and eco-friendly EV charging solutions to aid the transition to a low-carbon transportation system.

By examining the design, implementation, and performance of this new charging system, this study addresses key challenges and opportunities, such as optimizing wireless power transfer, implementing advanced control strategies, and ensuring smart grid integration. The results of this research will guide the creation of next-generation wireless EV charging systems, fostering innovation and sustainability in the transport sector.

Overall, this research has the potential to revolutionize the EV charging landscape by enabling efficient, convenient, and sustainable energy transfer. By advancing bidirectional wireless EV charging technology, it supports the broader adoption of EVs, paving the way for a cleaner and more sustainable future in transportation..

II. ABRIDGMENT

A bidirectional wireless electric vehicle (EV) charging system facilitates efficient energy transfer and supports Vehicle-to-Grid (V2G) functionalities. This system features wireless power transfer, enabling energy to flow in both directions, along with smart grid integration and advanced communication protocols, achieving over 90% efficiency. It consists of a charging pad, power electronics, a communication module, and energy storage components.

The benefits are substantial: users enjoy convenient charging, while overall efficiency improves, infrastructure costs decrease, grid stability enhances, and EV adoption rises. This technology is applicable for electric vehicles, V2G systems, smart grids, renewable energy integration, and sustainable transportation.

With a power rating of 10-50 kW and operating at frequencies of 100-200 kHz, the system's efficiency exceeds 90%. Future developments will focus on refining control strategies, integrating with renewable energy sources, enhancing scalability and standardization, and improving cybersecurity. Overall, this innovative system is set to reshape the EV charging landscape, encouraging broader EV adoption and contributing to a cleaner, more sustainable transportation future, which is essential for the global shift toward sustainable energy solutions..

III. OPERATING PRINCIPLE

The Bidirectional Wireless EV Charging System uses magnetic resonance/inductive coupling to wirelessly transfer energy, allowing for enhanced control and communication protocols in both Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) modes.

A. Wireless Energy Transfer: This system allows energy to be sent without physical connections between the charging pad and the electric vehicle (EV) by using technologies like magnetic resonance or inductive coupling.

B. Two-Way Energy Flow: It supports bidirectional energy transfer, meaning energy can flow from the grid to the EV (Grid-to-Vehicle or G2V) and also back from the EV to the grid (Vehicle-to-Grid or V2G).

C. Smart Grid Compatibility: The system features advanced communication protocols that enable it to interact seamlessly with smart grids, optimizing how energy is managed.

D. Control Unit Functionality: An advanced control unit is integral to the system, managing and monitoring the energy transfer process. This ensures that operations are both efficient and safe.

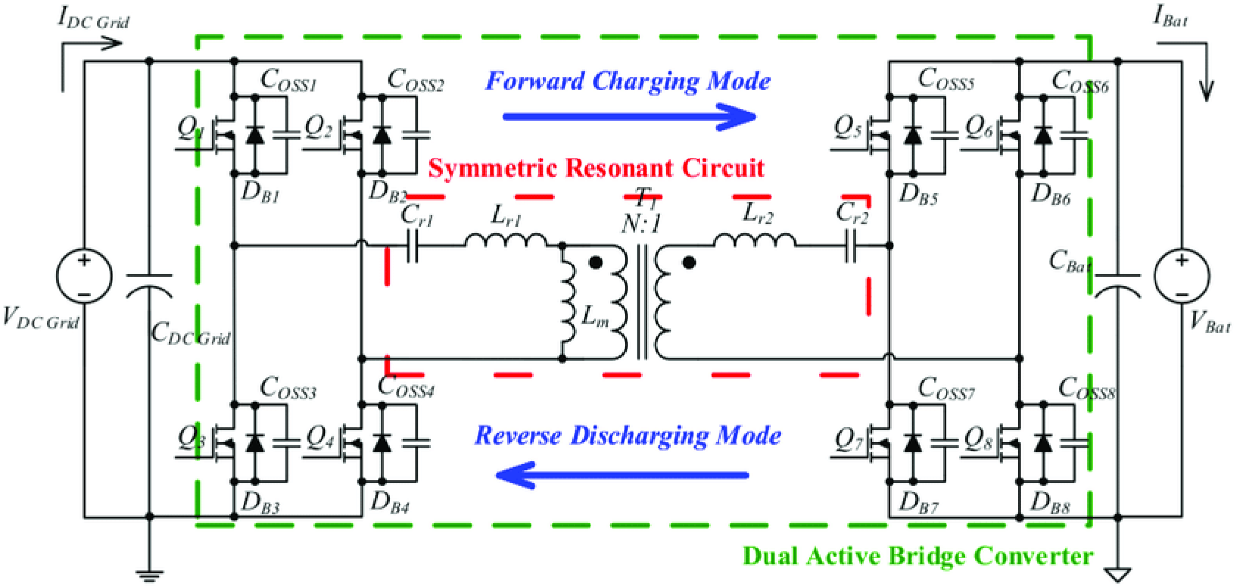


Fig.1. Circuit diagram for the bidirectional symmetrical resonant converter

The Dual Active Bridge (DAB) converter is an advanced power converter commonly used in systems such as energy storage, electric vehicles, and renewable energy setups. Its main advantage is that it can efficiently transfer power in both directions between two DC voltage sources, making it highly adaptable for modern energy solutions.

At its core, the DAB converter consists of two sets of switches (Q1-Q8), typically MOSFETs or IGBTs, which form two full bridges. One bridge is connected to a DC grid, and the other to a battery. A transformer sits between these two bridges, providing electrical isolation and enabling voltage adjustment (either stepping up or stepping down). Additionally, a resonant circuit made of inductors and capacitors (Lr1, Lr2, Cr1, Cr2) is integrated to help the system achieve soft-switching, which reduces energy losses by switching at minimal voltage or current. This design also includes parasitic capacitances (COSS1-COSS8) and bulk capacitors (Cgrid, Cbat) to smooth the voltage on both input and output sides, ensuring stable operation.

The converter operates in two modes: *Forward Charging Mode* and *Reverse Discharging Mode*. In Forward Charging Mode, power flows from the DC grid to the battery. The left bridge (connected to the grid) generates an alternating current (AC) signal that passes through the transformer to the battery side. On this side, the switches convert the AC signal back to direct current (DC) to charge the battery. In Reverse Discharging Mode, the process is reversed, and energy flows from the battery back to the grid. The battery-side bridge generates an AC signal, which travels through the transformer to the grid side, where it’s converted back to DC and fed into the grid.

The symmetrical layout of the DAB converter ensures efficient power transfer in both directions. The resonant circuit enables soft-switching, further increasing efficiency by minimizing switching losses. This high-efficiency, bidirectional power flow makes the DAB converter ideal for applications where energy needs to be stored and transferred reliably.

IV. SIMULATION AND RESULTS

The converter's actual circuit parameters and the selection of power components and the design follows these specifications. If an analog control circuit were used, the overall design would become complicated. The number of components would increase significantly, and designing the system would be challenging, especially due to the bidirectional control needed for the converter. This complexity can result in a bulkier circuit and more difficulties in maintaining stability.

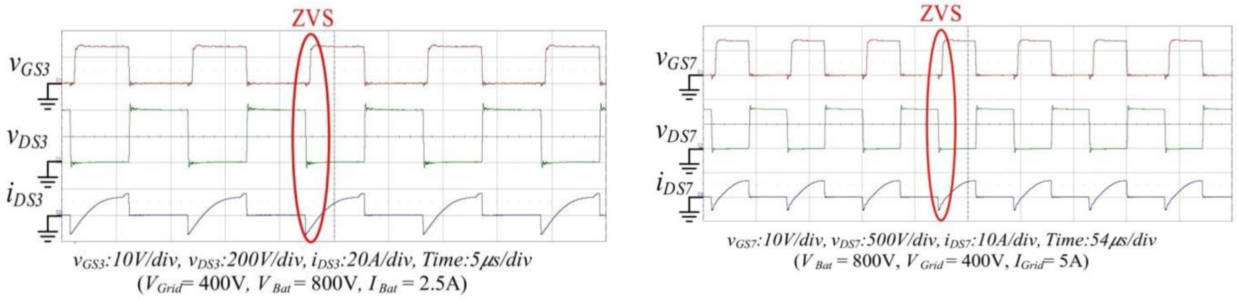
To avoid these issues, this study uses the TMS320F28335 digital signal processor (DSP) from Texas Instruments as the core controller for the converter. By choosing a digital control solution, the system can regulate power between the DC grid and battery more effectively. The DSP simplifies the circuit by reducing the number of components needed for control and decreasing the circuit’s size. Moreover, this digital approach enhances the stability and reliability of the system, ensuring smoother and more efficient bidirectional power flow.

Overall, using the DSP for control not only minimizes the design complexity and size of the converter but also provides improved performance compared to traditional analog control methods. This allows for a more efficient, reliable, and compact solution for managing power exchange between the DC grid and the battery.

In forward charging mode, the converter was tested at full load with an input voltage of 400V (VGrid) and an output voltage of 800V (VBat). The measured waveforms of vGS3 (gate-source voltage), vDS3 (drain-source voltage), and iDS3 (drain-source current) are shown in Figure 26. These waveforms indicate that when the power switch S3 is turned on, iDS3 flows in reverse. This reverse current helps discharge the energy stored in the parasitic capacitance of the power switch, reducing it to zero.

By doing so, the voltage across the power switch decreases, which minimizes switching losses and improves the converter's efficiency. This process is critical because managing the energy in the parasitic capacitance directly affects the overall performance, especially during full load operation. The ability to control and reduce these losses plays a key role in achieving higher efficiency in power conversion.

In reverse discharging mode, the converter operates with an input voltage of 800V from the battery (VBat) and outputs 400V to the grid (VGrid) at full load. Figure 29 displays the waveforms for vGS7 (gate-source voltage), vDS7 (drain-source voltage), and iDS7 (drain-source current), illustrating the converter's behavior during power transfer from the battery to the grid.



(a) wave forms in forward charging mode (b) wave forms in reverse discharging mode

Fig.2. wave forms in forward charging mode and reverse discharging mode

V. CONCLUSION

The Bidirectional Wireless Electric Vehicle Charging System is transforming how energy is transferred and utilized in Vehicle-to-Grid (V2G) applications. By combining wireless power transfer with advanced control algorithms and communication protocols, this innovative system enhances grid stability, reduces infrastructure costs, and encourages the widespread adoption of electric vehicles (EVs).

Among its many advantages are the convenience of charging, impressive efficiency rates exceeding 90%, improved resilience of the grid, and an overall enhanced user experience. This technology effectively addresses key challenges in EV charging, fostering a more sustainable transportation ecosystem.

Future research will focus on developing better control strategies, integrating renewable energy sources, ensuring scalability and standardization, and strengthening cybersecurity measures. The Bidirectional Wireless EV Charging System has significant implications for the global transition to sustainable energy and transportation, supporting a cleaner and more efficient future.

By implementing this technology, we can substantially reduce greenhouse gas emissions, improve energy efficiency, and stimulate economic growth. As the transportation sector evolves, this system will play a vital role in creating an environmentally conscious and technologically advanced landscape. Ultimately, the Bidirectional Wireless EV Charging System paves the way for broader EV adoption, reshaping transportation for generations to come and contributing to a healthier, more sustainable world.

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