

Integrated Wireless Charging Receiver for Dual Inverter Drive Electric Vehicles

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Abstract—Wireless or contactless charging technology is easier and safer than plugging an electric car into an electrical outlet (which can be dangerous, especially for children), and more convenient than charging stations. Due to the lack of cable plugs, wireless charging offers greater convenience and longer-lasting connectors as well as ease of use in diverse surroundings compared to wired charging. However, for traditional wireless charging systems, additional hardware components such as receiver coils, compensation circuits and receiver side specialized power electronic converters are usually required. All of these extra parts contribute to the additional weight, complexity and costs of the vehicle. To overcome such limitations, a novel design of integrated wireless charging using the electric motor and traction inverter already installed in the vehicle, as part of the power conversion system on the charging end is proposed in this research. This proposed solution ensures the charging system is optimized such that the total system weight and cost is minimized through integration with the current drivetrain hardware, thus avoiding heavy reliance on additional charging circuit components.

The proposed configuration also minimizes switching losses, thermal stress and electromagnetic interference by minimizing the high frequency charging current flowing through sensitive traction components. Additionally, there are no more communications systems and charging controller systems to be installed on the transmitter side and no special controllers for the batteries as the charging rate is controlled by the drivetrain and the charging process is managed by the drivetrain. The control complexity is reduced and system dependability is improved by this simplicity. To test how well the technology worked, simulations were run utilizing a 110-kW electric car powertrain that was combined with a 6.6 kW wireless power transfer system. The results demonstrated that the proposed integrated wireless charging system is feasible and highly efficient with a maximum charging efficiency reaching 94.3% at

the coil separation distance of 200 mm, which is applicable to existing EVs.

Key Words: Battery charging, dual-inverter, electric vehicle, integrated charging, motor drives, wireless charging.

1. INTRODUCTION

Due to its potential to decrease the total cost, size, and weight of electric cars, integrated on-board charging technology has lately drawn significant attention from academic researchers and the automotive industry. Integrated charging is the main concept of using the electric motor and traction inverter, which are already used in the powertrain, to charge the batteries. It is possible to drastically cut down on the number of components needed for traditional AC charging systems—such as charging converters, cooling systems, connections, protective enclosures, and magnetic components—by making use of already existing propulsion gear. Compatible with high-power charging operations, integrated charging systems provide a number of benefits. Faster and more efficient battery charging is possible with charging power levels reaching 100 kW, made possible by the traction inverter and motor drive system.

A number of books have proposed recommended integrated charging topologies based on different electric drivetrain designs and different control methodologies. In earlier studies, researchers have successfully shown a simple integrated charging system with a single-phase AC consisting of connecting the neutral point of the motor winding to the negative terminal of the battery pack using a diode rectifier bridge. The traction inverter functions as a boost converter with three-phase power factor correction in this setup while the battery is being charged. The charger architecture is one of the commercially available integrated charging technologies, for instance Renault. It is a system that links the power train to the utility grid through a current-source converter front-end. One such cutting-edge design makes use of a drive structure with

two inverters and an active front-end converter made of silicon carbide. The setup can reach the best efficiency rate of up to 97% and can charge in both directions up to 19.2kW AC. While conductive charging remains the dominant charging method, the many benefits of wireless inductive charging, including its portability, operational safety, and ability to work with autonomous and harsh-environment applications, are rapidly making it an increasingly popular way for electric vehicles to be charged.

Wireless charging offers a number of advantages to driverless vehicles, public transport and other non highly-interactive applications, but these technologies are not as efficient as conductive charging. Efficient and reliable wireless power transmission systems, especially when the coils are misaligned, have been subjected to several studies. Some methods employ advanced control algorithms based on the field that recalibrate the magnetic field to the receiver coil to reduce transmission losses due to misalignment. Building on the previously proposed single-phase integrated chargers, the more complex topologies for integrated wireless charging also connected the wireless receiver coil to the neutral terminal of the motor and negative terminal of the battery through a diode bridge.

These methods did permit wireless currents to flow through the drivetrain components, but they still required additional diode rectifiers and control systems on the transmitter side that caused additional losses and reduced efficiency, unless expensive optimization methods were implemented. Other solutions were available which served for all three functions, but were more complex, costly and bulkier because of the requirement for several multipole high-current contactors. Moreover, these designs required high frequency charging currents and therefore expensive wide-bandgap semiconductor devices were required for the inverter. The wireless charging system in this study is a new completely integrated wireless charging system as illustrated in Figure 1.2 to improve the efficiency, size, and cost of EVs wireless charging systems. The proposed design consists of a compensated wireless receiver coil, an open-winding electric machine, two battery packs and two traction inverters based on a dual-inverter drive topology. A recently developed arrangement for connecting the receiver coil necessitates only two tiny capacitors and four diodes.

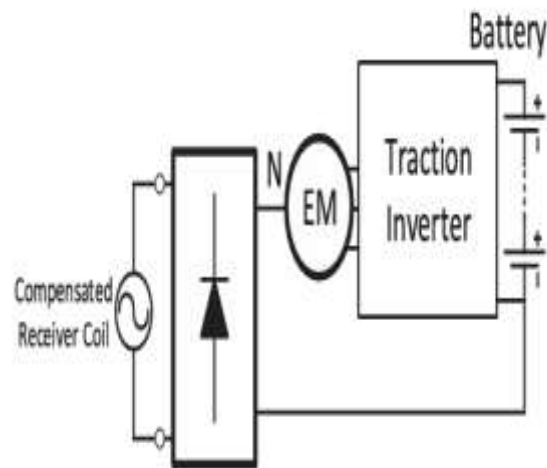


Fig. 1. Integrated wireless charger proposed in which utilizes the drive train

The proposed solution drastically cuts the need for specific on-board charging equipment and utilizes the existing equipment of the drivetrain for operation of wireless charging. The final design is a power electronic system that is simpler, lighter and less costly. The number of converter components and the auxiliary equipment such as cooling systems, control boards, current and voltage sensors, protection circuits, contactors, and exterior enclosures can be reduced with the proposed architecture.

The system's overall compactness and durability are enhanced by this high degree of integration, all while retaining effective wireless charging performance. The suggested integrated wireless charging system is ideal for contemporary electric car applications that need efficient, lightweight, and high-performance charging solutions since the decreased hardware required helps to cut manufacturing and maintenance costs.

The four diodes that are used in a wireless charging system can also be used in an integrated single-phase AC charging system as demonstrated in the previous research, which is an added advantage of the proposed integrated charging system. This significantly simplifies and cuts down on the space, available cost, and complexity of the charging system, and also allows for maximum use of the components in the system by eliminating the need for a special offboard charger.

2. Existing System & Proposed System

Traditional ways of charging electric vehicles mostly rely on conductive (wired) charging or more conventional wireless inductive charging techniques. Conductive charging systems require special on-board converters, control circuits, cooling systems and protective gear, which adds to vehicle size, weight and cost. The traditional wireless charging system does have an improved operating safety and convenience, but it still requires an additional power electrical converter on the receiving end and a communication network between the transmitting and receiving units.

These auxiliary components increase the cost of implementation, decrease system efficiency and limit the number of charging power that can be achieved. There are a number of proposed strategies for partially integrated charging to reduce the amount of on-board equipment. One of them is to connect the receiver coil with the neutral point of the motor; another is to use the components of the charging system of the car. Still, these techniques put delicate drivetrain parts at risk of increased switching losses, heat stress, and electromagnetic interference via high-frequency charging currents. Further complicating it and reducing reliability for high power charging applications, these systems continue to utilize complex control methods and communication protocols.

2.1. Proposed System

By integrating wireless power transfer capabilities with the electric vehicle's current powertrain, the suggested charging design integrates a dual-inverter drive structure with an open-winding motor arrangement. In order to rectify the wireless charging currents and efficiently charge the battery system, only two small capacitors and four diodes are required in addition to the other parts of the system; this allows for the elimination of separate charging converters on the device and the specific receiver-side circuits. Since the drivetrain controls the charging function of the batteries, the suggested setup does away with the need for complicated external charging control and transmitter-side communication. In addition, the hardware components of the system can support single-phase AC charging, improve the efficiency of the components and make the system easier to operate. Further, the design allows for effective isolation of critical components of the drivetrain from the high frequency wireless charging currents, effectively preventing electromagnetic interference,

thermal stress and switching losses. In addition to supporting the charging of two battery packs at once, the suggested solution makes use of the drivetrain's high-power capabilities to provide quicker charging performance. The method suggested was proved successful in the modelling and experimental tests performed for charging power of 6.6 kW over a distance of 200 mm, with the highest efficiency of 94.3%. The results confirm the feasibility, reliability and efficiency of the proposed integrated wireless charging system in the context of modern electric vehicles.

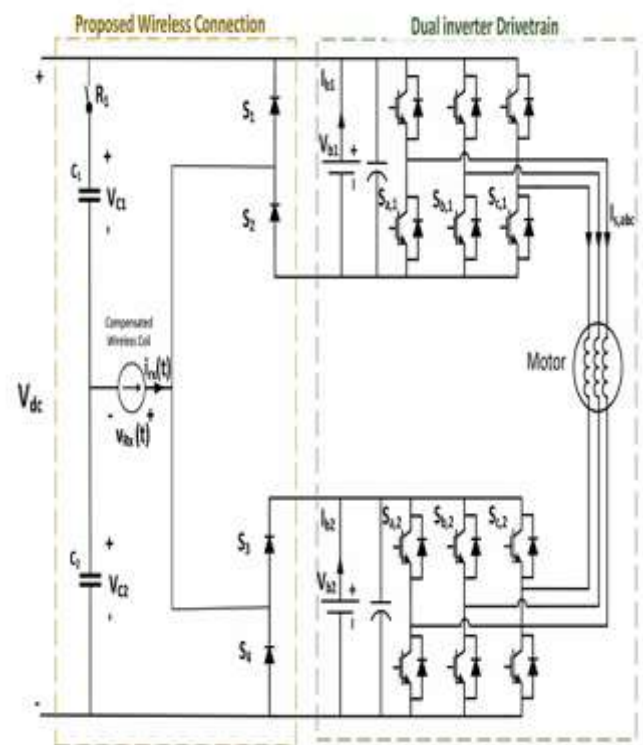


Fig.2. Proposed integrated wireless charger

2.2. Wireless Coil Topology

The actual application of the compensated receiver coil, modeled as a current source a wireless power transmission system that is depicted. The transmitter and receiver coils are designed in a rectangular shape, which improves the transmission performance and magnetic coupling in the proposed configuration. The magnetic field is created between a 200 mm air gap using a high frequency alternating current, and the high frequency alternating current is supplied to the transmitter coil.

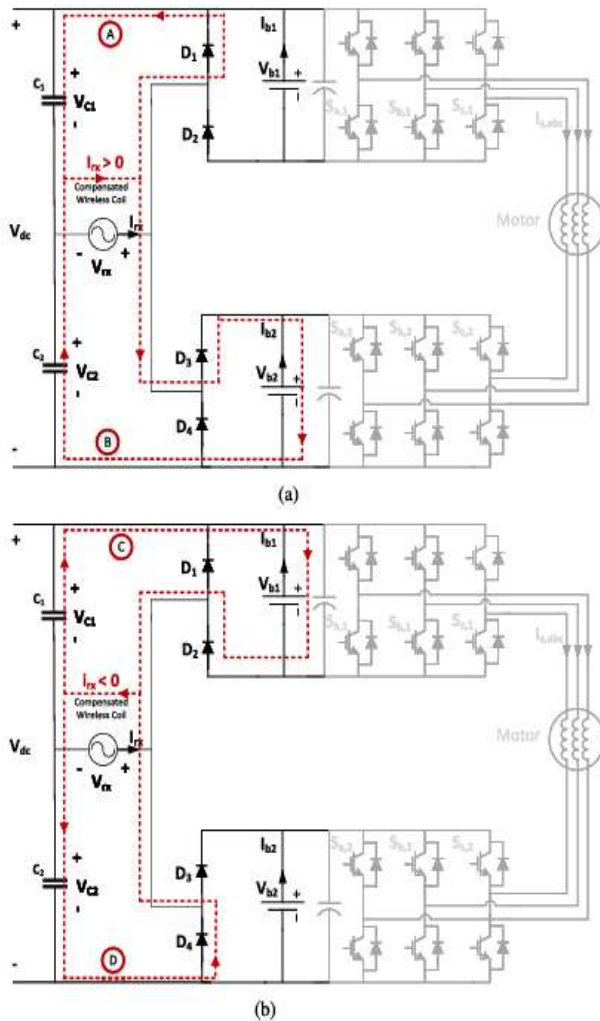


Fig.3. Dual inverter integrated charging circuit during passive operating mode, where the traction inverters and the motor are not involved in the charging operation.

3. Control Scheme

With the proposed integrated wireless charging system, the electric vehicle (EV) would be entirely in charge of the charging process. The wireless receiver power electronics contain the same current drivetrain components and the charging control operation uses the same digital signal processor (DSP), sensors, and control hardware as the traction drive. This integrated approach improves the charging system's robustness and reliability compared to traditional wireless charging methods, as it no longer requires wireless transmission of crucial information from the vehicle's controllers to the outside transmitter. Making the charging process more universal and easier to implement across different charging platforms is achieved by eliminating continuous wireless communication for charging control. This also simplifies system complexity, lower cyber security worries, and lower reliance on specific communication protocols.

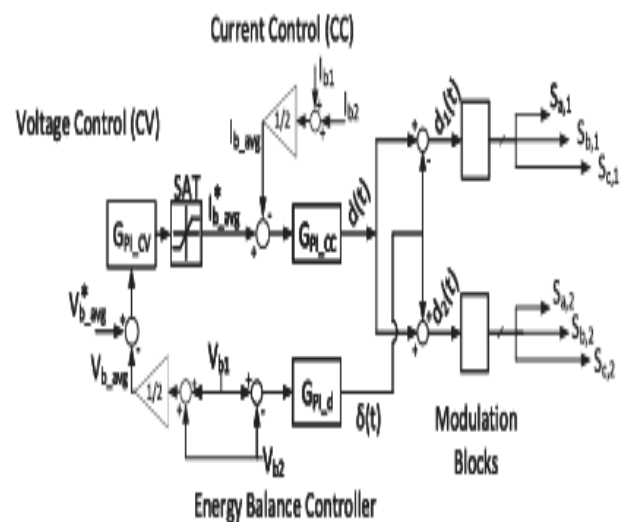


Fig. 4. Control scheme of the integrated charger.

4. Simulation Results

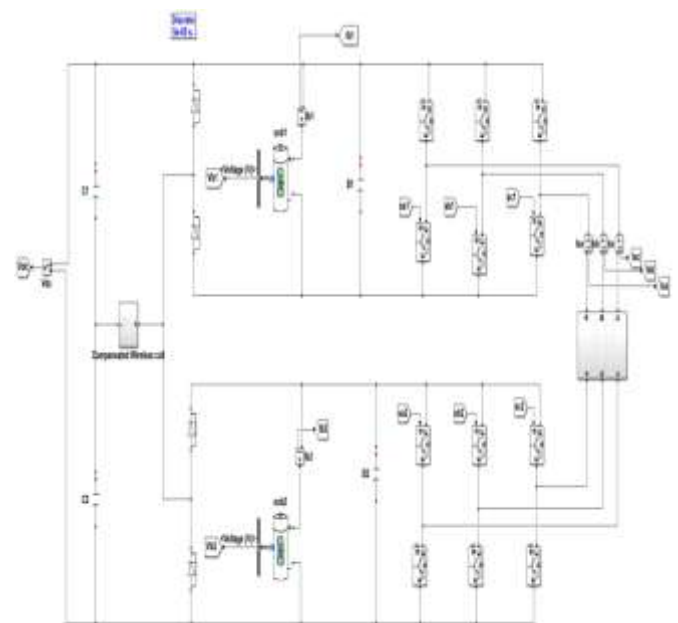


Fig.5. MATLAB/SIMULINK circuit diagram of Proposed integrated wireless charger

The proposed integrated wireless charging system was simulated to demonstrate its operation and to validate its ability to charge., the full switched model of the system is created and simulations are performed in MATLAB. This system's constructed full-scale prototype yielded these parameters. Mutual inductance of the wireless transmitter/receiver coils was measured for the two conditions of perfect alignment and worst-case misalignment as defined by the SAE J2954 standard. In the former case, ($\Delta x = 0$, $\Delta y = 0$), and in the latter, ($\Delta x = 75$ mm) and ($\Delta y = 100$ mm) respectively. The vertical distance between the coils of the transmitter and receiver was kept

constant at ($z = 200 \text{ mm}$) in the system that was suggested. Typically, bigger electric cars and vans with a need for more ground clearance choose for dual-inverter drive systems, which is why this rather wide air-gap distance was chosen.

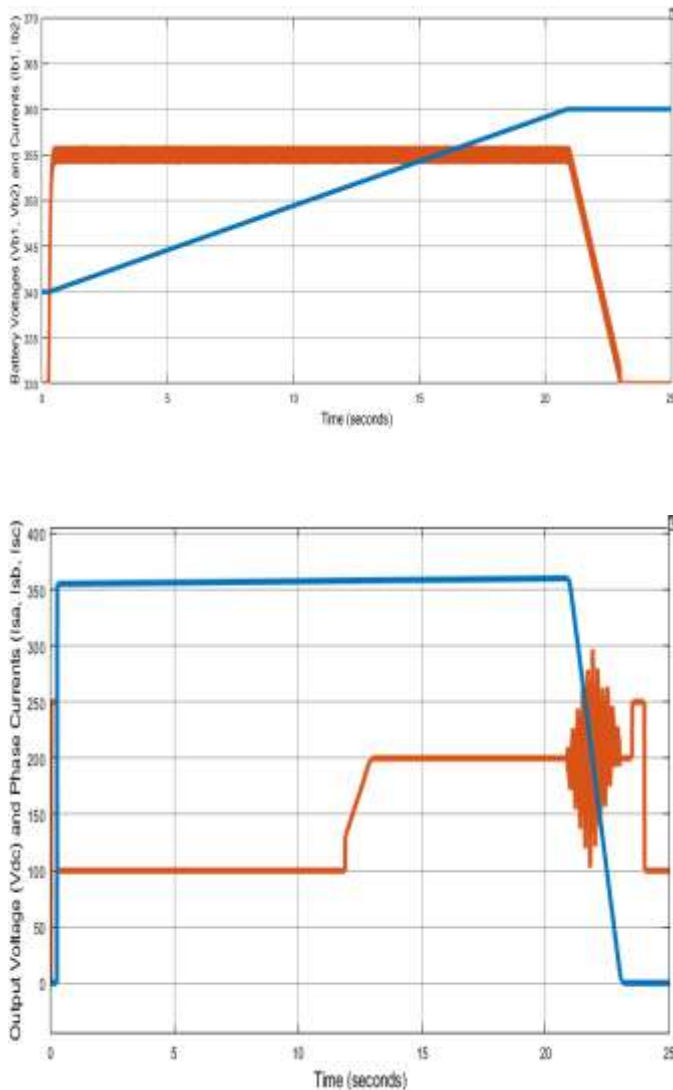


Fig. 6. Simulation of complete charging cycle, where $V_{b_avg} = 360V$ and the coils are well-aligned.

The previous graphic shows the simulation results that highlight the whole charging cycle of the proposed integrated wireless charging system. Since it is difficult to clearly record all the charging stages and system transitions empirically, the charging sequence is presented by simulation analysis, and then deeply studied by the experimental setup. The wireless charging method is illustrated in the picture running with the transmitter on at time 0.05 and off at time 24.5. At this time, the wireless power transmission system is designed to perform at the peak efficiency, as the transmitter current is low and the ohmic loss in the coil is low. The EMF voltage at the receiver side will be

smaller than 200 V and the battery will be charged to roughly 700 V according to equation (28). It needs less magnetic flux and hence less transmitter current. Lower conduction losses.

4. CONCLUSION

This project aims to develop the design of a wireless charging system that will be combined with the already existing engine of an electric car. This will enable the vehicle to wirelessly charge. The proposed solution employs a dual-inverter drive structure and some auxiliary hardware components to achieve the wireless charging current regulation and the battery charge regulation. The new parts will allow you to charge your device more efficiently, remove hardware redundancy and use it as a combined single phase AC system.

The proposed structure does not have to be continuously connected from the transmitter to the charging system as the dual-inverter drive system may charge two battery packs concurrently. The drivetrain has high power capability so extra charging power levels can be added with little additional complexity or cost. A replica of the motor and drive train of an electric automobile was used in simulated trials to demonstrate the ability to do 6.6 kW of Constant Current/Constant Voltage (CC/CV) charging. The practicality, dependability, and efficacy of the integrated wireless charging technique are demonstrated by the proposed system to charge an electric vehicle with a wireless transmission air gap of 200 mm and an excellent total efficiency of 94.3%.

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