

A Half-Bridge-Based Inverter Topology for Multi-Transmitter Coil Wireless Power Transfer System

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Received: 3/3/26, Revised: 9/4/26, Accepted: 16/4/26

Abstract

This paper presents a half-bridge-based inverter topology for multi-transmitter wireless power transfer (WPT) systems. The proposed topology reduces the number of power switches compared with conventional full-bridge multi-transmitter systems while allowing independent control of each transmitter coil using a shared DC power source. An analytical model of the multi-transmitter WPT system is developed and simplified into an equivalent two-coil model to analyze output power and transfer efficiency. The operating modes of the inverter and a hierarchical transmitter-side control scheme with outer voltage and inner current control loops are presented to regulate output voltage and control individual transmitter coil currents. The proposed system is experimentally validated using a prototype operating at 67 kHz. Experimental results demonstrate stable inverter operation, effective voltage regulation under load variation, good dynamic response under step load changes, and improved transfer efficiency under receiver coil displacement compared with a conventional single-transmitter system. The results confirm that the proposed inverter topology reduces system complexity while improving misalignment tolerance and extending the effective operating area of multi-transmitter wireless power transfer systems.

Keywords: Inverter topology, Half bridge configuration, Multi transmitter coil, Wireless Power Transfer

1. Introduction

Wireless power transfer (WPT) systems offer several advantages, including improved safety, user convenience, high reliability, resistance to environmental conditions, and low maintenance requirements, which clearly distinguish them from conventional wired power transfer methods [1]. WPT technology has been widely applied in various applications such as biomedical implants, consumer electronics, and electric vehicle charging systems [2]–[4]. With the increasing demand for WPT across diverse applications, designing systems that achieve high performance while maintaining cost-effectiveness has become an important research objective.

Magnetically coupled coils are essential components in inductive wireless power transfer systems, as they form the electromagnetic coupling across the air gap that enables power transfer between the transmitter and

receiver. Conventional single-transmitter WPT systems, however, often encounter limitations, especially under coil misalignment, load variations, or when a wider charging area is required. These issues can result in reduced transfer efficiency and unstable system performance.

In static wireless charging systems for electric vehicles (EVs), a single transmitter (Tx) coil and a single receiver (Rx) coil are commonly used [5]. High power transfer efficiency requires proper coil alignment; however, misalignment is unavoidable in practical operation. Such misalignment causes variations in magnetic coupling, leading to changes in output voltage and power, as well as a reduction in overall efficiency. As a result, many studies have focused on addressing these challenges.

Previous studies have attempted to overcome these limitations using several approaches. Frequency tuning and impedance matching techniques have been widely investigated [6]–[9], while reactive power compensation topologies have been explored in [10]–[13]. In addition, maximum power point tracking methods based on adjusting the equivalent load resistance have been studied in [14]–[15], and magnetically coupled coil structures designed to produce a more uniform magnetic field have been proposed in [16]–[17]. However, most of these methods are primarily designed for two-coil wireless power transfer systems and provide limited tolerance to coil misalignment.

Multi-transmitter wireless power transfer systems have been proposed to address these challenges and offer several important advantages. These include improved misalignment tolerance by maintaining acceptable performance even when the receiver is not aligned with a single transmitter [18]–[19], enhanced power transfer efficiency through optimal transmitter selection or excitation strategies expanded coverage area for charging multiple devices or supplying larger loads [15], and improved adaptability to load variations, ensuring stable power delivery under changing load conditions [20]–[21].

In wireless charging systems, the inverter circuit is essential for converting DC power into high-frequency AC power. This process increases the variation of magnetic flux generated by the transmitter coil, which subsequently produces an induced voltage in the receiver coil. In a typical multi-coil wireless power transfer (WPT) system, multiple power converters are used, with

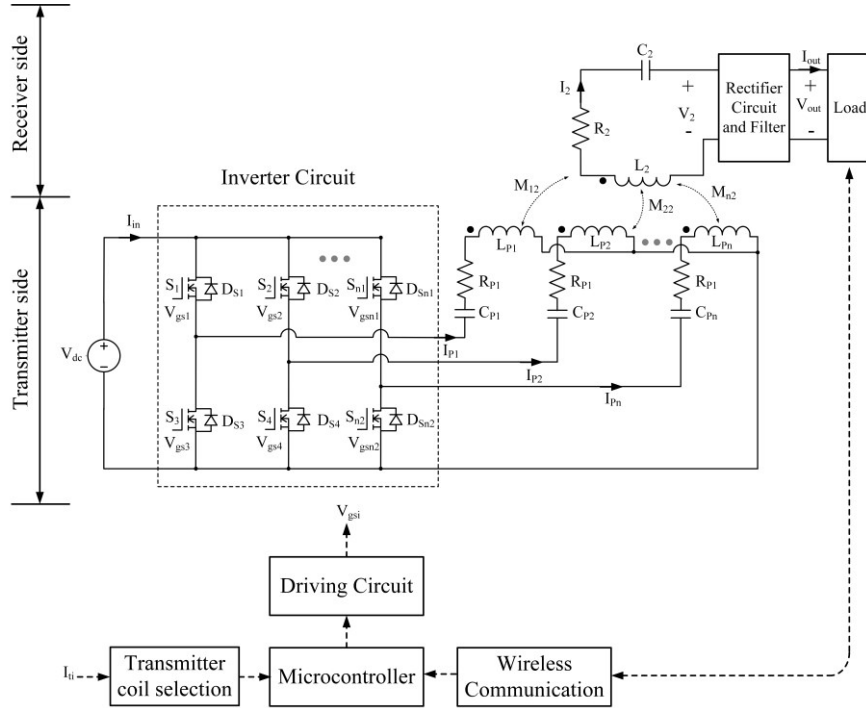


Fig. 1 Overall configuration of the proposed multi-transmitter wireless power transfer (WPT) system based on a half-bridge inverter topology

one converter assigned to each transmitter coil. A key limitation of this approach is that the number of power circuits increases as more transmitter coils are added. This results in higher component count, increased system cost, and larger physical size, and often leads to more complex control strategies.

Previous studies on inverter design for multi-transmitter wireless power transfer systems have proposed various inverter topologies with a focus on reducing the number of power switches, as reported in [22]–[23]. power switches, where n represents the number of transmitter coils. Compared with conventional full-bridge inverters, which require $4n$ switches, the proposed approach significantly reduces the number of power switches. In addition, each transmitter coil can be controlled independently, allowing flexible power regulation and improved system adaptability.

The paper is organized as follows. Section 2 describes the proposed system. Section 3 presents the analysis of the proposed circuit. The timing diagram and modes of operation of the proposed inverter topology are detailed in Section 4. The transmitter-side controller is described in Section 5. Experimental validation of the proposed system is presented in Section 6. Finally, Section 7 concludes this paper.

Therefore, this research presents an alternative inverter design approach for multi-transmitter wireless power transfer systems by applying a half-bridge inverter structure. The proposed design requires $2n$

2. System Description

The proposed system comprises a transmitter side and a receiver side. On the transmitter side, a DC power source feeds a half-bridge-based inverter with multiple switch pairs. Each half-bridge leg is connected to an individual transmitter coil through a resonant compensation network, enabling independent coil excitation while sharing a common DC supply. The resonant network shapes the high-frequency current to generate an alternating magnetic field for wireless power transfer. The inverter is controlled by a driving circuit governed by a microcontroller unit (MCU), which manages coil selection and power regulation. Wireless communication is employed to exchange control or feedback information between the transmitter and receiver sides, enabling adaptive operation. On the receiver side, the receiver coil is magnetically coupled to the active transmitter coil. The induced high-frequency AC voltage is converted into a regulated DC output through a rectifier and filter circuit to supply the load. Overall, the system enables flexible multi-coil operation, independent control, and reliable power transfer under misalignment and load variations.

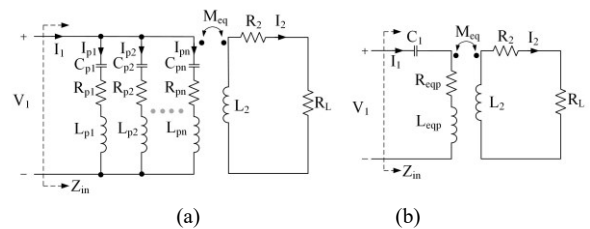


Fig. 2 Equivalent circuit of the WPT system: (a) multi-transmitter configuration, (b) equivalent simplified two-coil configuration

3. Analytical modeling of the multi-transmitter coil WPT system

Figure 2(a) illustrates the equivalent circuit of the multi-transmitter coil wireless power transfer (WPT) system. The model includes the self-resistance (R_{p1} – R_{pn}) and self-inductance (L_{p1} – L_{pn}) of the transmitter coils, the self-resistance (R_2) and self-inductance (L_2) of the receiver coil, and the load resistance (R_L). Capacitive compensation is applied on the transmitter side (C_{p1} – C_{pn}) and the receiver side (C_2). The circuit also accounts for the transmitter coil currents (I_{p1} – I_{pn}), input current (I_1), input voltage (V_1), and output voltage (V_2). The mutual inductance between coupled coils is represented by M_{eq} , and the input impedance is denoted as Z_{in} . Under normal operating conditions, the circuit in Fig. 2(a) can be simplified into an equivalent two-coil WPT model, as shown in Fig. 2(b). To simplify the analysis of the multi-transmitter wireless power transfer system, the transmitter coils are represented by an equivalent transmitter coil model. Since multiple transmitter coils are connected to the inverter and operate at the same frequency, the equivalent resistance (R_{eqp}) and inductance (L_{eqp}) of the transmitter side can be obtained from the parallel combination of the individual transmitter coil parameters. Therefore, the equivalent resistance and equivalent inductance of the transmitter side are defined in Equations (1) and (2).

$$\frac{1}{R_{eqp}} = \sum_{i=1}^n \frac{1}{R_{pi}} \quad (1)$$

$$\frac{1}{L_{eqp}} = \sum_{i=1}^n \frac{1}{L_{pi}} \quad (2)$$

where R_{pi} and L_{pi} are the resistance and inductance of the i -th transmitter coil, respectively. The equivalent mutual inductance between the equivalent transmitter coil and the receiver coil is defined in Equations (3).

$$M_{eq} = k\sqrt{L_{eqp}L_2} \quad (3)$$

Using Kirchhoff's Voltage Law (KVL) applied to the equivalent circuit shown in Fig. 2(a), the input current I_1 and output current I_2 can be derived based on the reflected impedance model of the wireless power transfer system. The input impedance of the system can be expressed in Equations (4).

$$Z_{in} = (R_{eqp} + jX_1) + \frac{(\omega M_{eq})^2}{(R_2 + R_L) + jX_2} \quad (4)$$

Therefore, the input current can be expressed as shown in Equation (5).

$$I_1 = \frac{V_1}{(R_{eqp} + jX_1) + \frac{(\omega M_{eq})^2}{(R_2 + R_L) + jX_2}} \quad (5)$$

and output current can be expressed as shown in Equation (6).

$$I_2 = \frac{\omega M_{eq} V_1}{\sqrt{[R_{eqp}(R_2 + R_L) - X_1X_2 + (\omega M_{eq})^2]^2 + [R_{eqp}X_2 + (R_2 + R_L)X_1]^2}} \quad (6)$$

Using the derived output current, the output power and transfer efficiency can be obtained, resulting in Equations (7) and (8).

$$P_{out} = \frac{(\omega M_{eq})^2 R_L V_2^2}{[R_{eqp}(R_2 + R_L) - X_1X_2 + (\omega M_{eq})^2]^2 + [R_{eqp}X_2 + (R_2 + R_L)X_1]^2} \quad (7)$$

$$\eta = \frac{(\omega M_{eq})^2 R_L}{R_{eqp}[(R_2 + R_L)^2 + X_2^2] + (\omega M_{eq})^2 (R_2 + R_L)} \quad (8)$$

$X_1 = \omega L_{eqp} - (1/\omega C_1)$, $X_2 = \omega L_2 - (1/\omega C_2)$, $\omega = 2\pi f$. Equations (7)–(8) show that output power and efficiency depend on self-resistance, load resistance, inductance, operating frequency, and mutual inductance, making parameter optimization essential for improving the performance of multi-transmitter WPT systems.

4. Mode of Operation

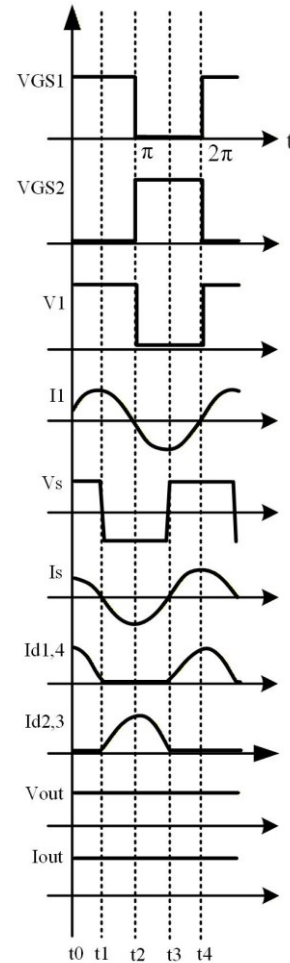


Fig. 3 Timing diagram and corresponding waveforms of the proposed WPT system

One switching period of the proposed inverter can be divided into four operating modes, as illustrated in Figs. 3 and 4.

Mode 1 (t_0-t_1) : During this interval, switches S1 and S4 are turned ON, while S2 and S3 are OFF. The input DC voltage is applied to the resonant network on the transmitter side, causing the transmitter current to increase and generate an alternating magnetic field. On the receiver side, the induced current flows through diode D1, transferring power to the load.

Mode 2 (t_1-t_2) : Switch S1 is turned OFF, and the resonant current continues to flow through the antiparallel diodes of the switches (freewheeling operation). The energy stored in the resonant components is transferred to the receiver side, and diode D2 conducts to maintain load current continuity.

Mode 3 (t_2-t_3) : Switches S2 and S3 are turned ON, while S1 and S4 are OFF. The polarity of the applied voltage across the resonant network is reversed, causing the transmitter current to change direction. Power transfer continues through magnetic coupling, with diode D3 conducting on the receiver side.

Mode 4 (t_3-t_4) : Switch S2 is turned OFF, and the resonant current freewheels through the switch diodes. The remaining energy is delivered to the load through diode D4 until the next switching cycle begins.

5. Transmitter side control

The control structure of the proposed multi-transmitter wireless power transfer system is shown in Fig. 3. The control strategy is designed to regulate the output voltage while independently controlling the current of each transmitter coil using a hierarchical

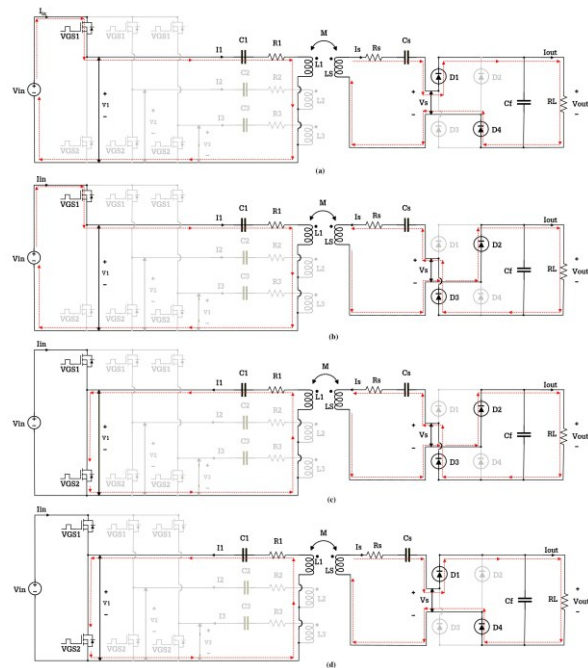


Fig. 4 Switching operation (a) Mode 1 [t_0-t_1] (b) Mode 2 [t_1-t_2] (c) Mode 3 [t_2-t_3] (d) Mode 4 [t_3-t_4]

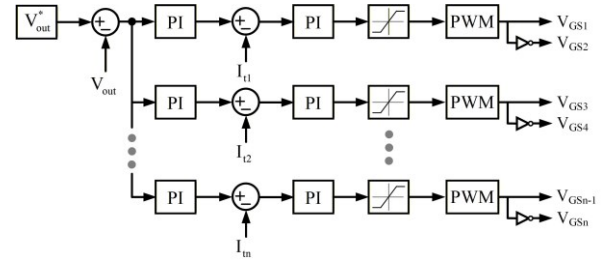


Fig. 3 Block diagram of transmitter side control

control structure consisting of an outer voltage control loop and multiple inner current control loops. In the outer control loop, the reference output voltage is compared with the measured output voltage V_{out} , and the voltage error is processed by a PI controller to generate the reference current for the transmitter coils. This reference current is then distributed to the inner current control loops. For each transmitter coil, the reference current is compared with the measured transmitter coil current (I_{t1} , I_{t2} , ..., I_{tn}). The current error of each coil is regulated by an individual PI current controller to ensure independent current control. The controller outputs are then limited to maintain safe operation and converted into PWM signals to generate the corresponding gate signals (V_{GS1} , V_{GS2} , ..., V_{GSn}) for the inverter switches. As a result, the proposed hierarchical control scheme provides stable output voltage regulation, independent transmitter coil current control, and flexible power distribution among multiple transmitter coils in the multi-transmitter wireless power transfer system.

6. Experimental Results

Figure 3 shows the experimental setup of the proposed multi-transmitter wireless power transfer (WPT) system. The experimental system consists of a transmitter side and a receiver side designed to validate the proposed inverter topology and control strategy. On the transmitter side, a DC power supply feeds the proposed inverter circuit through a gate driver controlled by a microcontroller. Transmitter-side compensation capacitors are connected to each transmitter coil to form resonant networks that generate high-frequency alternating currents and produce an alternating magnetic field for wireless power transfer. Voltage and current sensors are used to monitor system operation and provide feedback signals

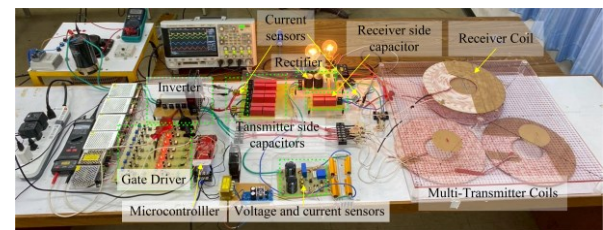


Fig. 3 Experimental setups of the proposed system

for the control system. On the receiver side, the receiver coil is magnetically coupled to the transmitter

coils. The induced high-frequency AC voltage is compensated, rectified, and filtered to produce a regulated DC output voltage for the load. The experimental setup is used to evaluate steady-state operation, voltage regulation performance, and transfer efficiency of the proposed multi-transmitter WPT system under different operating conditions.

An experimental test was conducted for the case of a single transmitter coil transferring power to a single receiver coil. The distance between the transmitter and receiver coils was set to 6 cm. A DC input voltage of 100 V was supplied to the inverter circuit, and the switching frequency was set to 67 kHz. Power was delivered to a 5Ω load. The voltage and current at various points in the circuit were recorded, as shown in Fig. 4.

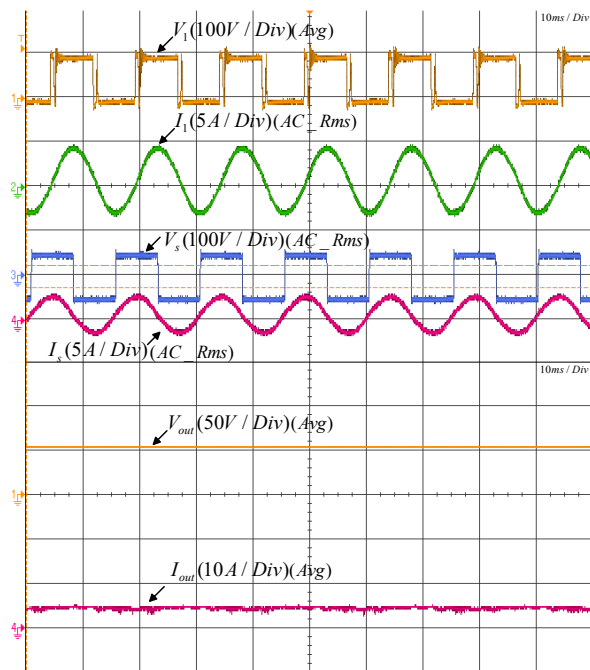


Fig.4 Measured voltage and current waveforms

From the figure, it can be observed that the inverter output voltage (V_1) has a square waveform, while the input current (I_1) is approximately sinusoidal. The secondary-side voltage (V_s) is also a square waveform due to the operation of the rectifier diodes, whereas the induced current (I_s) is sinusoidal. After rectification, the output voltage (V_{out}) and output current (I_{out}) are obtained. The experimental results demonstrate that the system is capable of successfully transferring electrical power to the load.

Figure 5 presents the experimental results of the proposed feedback control system under a step load change condition. When the load resistance is suddenly increased, the output voltage remains well regulated with minimal overshoot and fast settling time, while the output current decreases according to the load condition. The PI controller gains were experimentally tuned to achieve stable operation and

fast dynamic response, with proportional gain K_P approximately in the range of 0.2–0.4 and integral gain K_I approximately in the range of 0.05–0.2. This result demonstrates that the proposed hierarchical control scheme provides stable voltage regulation and robust dynamic response under load variations, confirming the effectiveness of the proposed control strategy for multi-transmitter wireless power transfer systems.

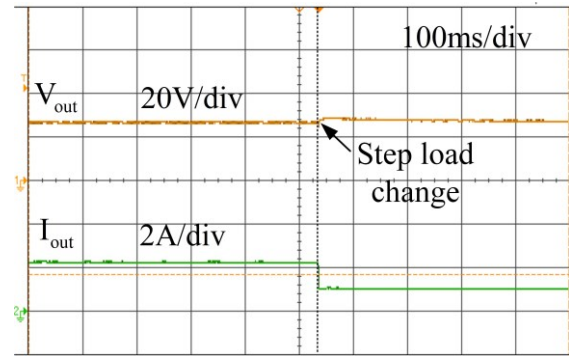


Fig.5 The output voltage regulation under step load change

Figure 6 shows the measured transfer efficiency obtained with an input voltage of 100 V, an operating frequency of 67 kHz, a 24Ω load, and a fixed coil separation of 10 cm. Two cases are evaluated: a single-transmitter–single-receiver configuration and the proposed multi-transmitter system with transmitter coil selection. The results demonstrate an extended effective operating area under receiver coil displacement for the proposed system.

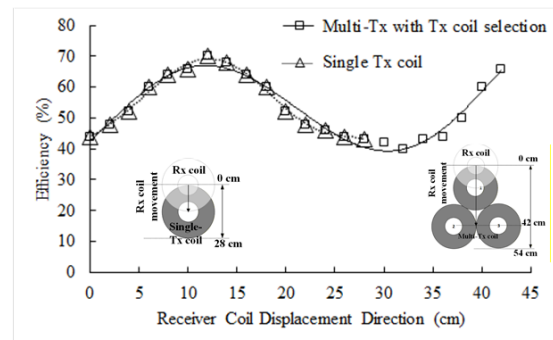


Fig. 6. Measured transfer efficiency under receiver coil displacement for single- and multi-transmitter WPT systems

7. Discussion

The experimental results demonstrate that the proposed half-bridge inverter topology is suitable for multi-transmitter wireless power transfer systems. Compared with conventional multi-transmitter systems that require multiple full-bridge converters, the proposed topology significantly reduces the number of power switches while maintaining independent control of each transmitter coil. This reduction in component count can decrease system cost, circuit complexity, and overall system size.

The hierarchical control structure consisting of an outer voltage control loop and inner current control loops provides stable voltage regulation and flexible power distribution among transmitter coils. The experimental results under step load change conditions show that the output voltage remains well-regulated with small overshoot and fast settling time, indicating good dynamic response of the control system.

In addition, the efficiency comparison between single-transmitter and multi-transmitter configurations shows that the proposed system can extend the effective operating area when the receiver coil is displaced. This characteristic is particularly important for practical wireless charging applications where coil misalignment cannot be avoided. The ability to maintain acceptable efficiency over a wider displacement range demonstrates the advantage of the multi-transmitter approach combined with the proposed inverter topology.

However, the system still depends on proper transmitter coil selection and current control to achieve optimal performance. Future work may focus on automatic transmitter selection algorithms, adaptive power distribution control, and optimization of resonant parameters to further improve system efficiency and dynamic performance.

8. Conclusion

This paper presented a half-bridge-based inverter topology for multi-transmitter wireless power transfer systems. The proposed topology reduces the number of power switches compared with conventional full-bridge multi-transmitter systems while allowing independent control of each transmitter coil using a shared DC power source. An analytical model of the multi-transmitter WPT system was developed, and the operating modes and hierarchical control strategy were described.

Experimental results verified stable inverter operation, successful wireless power transfer, and effective output voltage regulation using the proposed hierarchical control scheme. The PI controller gains were tuned to achieve stable operation and fast dynamic response under load variation. Efficiency measurements under receiver coil displacement showed that the proposed multi-transmitter system extends the effective operating area compared with a single-transmitter configuration.

The results confirm that the proposed inverter topology can reduce system complexity while improving misalignment tolerance and operational flexibility of multi-transmitter wireless power transfer systems. Therefore, the proposed system is suitable for applications requiring wide charging areas and stable power transfer under varying load and alignment conditions.

Acknowledgment

This work was supported in part by the Rajamangala University of Technology Lanna (RMUTL) under the Fundamental Fund 2568 titled “The Development of A Wireless Battery Charging System Laboratory for Practical Instruction in Modern Electric Vehicle” under Grant FF2568P123.

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