J. Electrical Systems 22-01 (2026): 200-205

[1]Supriya Jamdar
[2]Gaurav Gore
[3]Divya Masare
[4]Shubhangi Landge

Design and Development of a Wireless Charging System for an Electric Two-Wheeler

Abstract: - Wireless Power Transfer (WPT) has emerged as a reliable alternative to conventional plug-in charging systems for electric vehicles due to improved safety and user convenience. This paper presents the practical design and hardware implementation of a resonant inductive wireless charging system developed for an electric two-wheeler. The system operates from a 230 V, 50 Hz AC input supply, stepped down to 13.79 V AC using a transformer and rectified to 17.49 V DC. A regulated DC stage feeds a high-frequency inverter generating approximately 70 V AC in the 60–80 kHz range to energize the transmitter coil. The receiver coil output is rectified and filtered to obtain a stable 12 V DC suitable for battery charging. Experimental results validate the theoretical rectifier calculations and confirm stable wireless power transfer performance. The developed prototype demonstrates the feasibility of a compact and cost-effective wireless charging solution for electric two-wheelers.

Keywords: Wireless power transfer, electric two-wheeler, inductive charging, resonant compensation, series-series topology.).

I. INTRODUCTION

The rapid growth of electric two-wheelers has significantly contributed to sustainable urban transportation due to their low energy consumption, compact size, and reduced environmental impact. Despite these advantages, charging infrastructure for electric bikes still relies predominantly on wired charging methods. Such methods introduce challenges including mechanical wear of connectors, exposure to moisture and dust, and potential safety hazards during frequent manual handling [4]. These limitations reduce system reliability and user convenience, especially in outdoor and public charging environments.

Wireless Power Transfer (WPT) eliminates physical electrical contacts by transferring energy through electromagnetic coupling, thereby enhancing safety and reliability. WPT has been widely studied for electric cars and automated guided vehicles, where high-power transfer and standardized coil geometries are feasible [1]. However, electric two-wheelers operate at significantly lower power levels and impose strict constraints on receiver size, weight, and cost. Furthermore, frequent misalignment during parking introduces additional challenges that are often overlooked in electric vehicle-oriented research.

Recent studies on wireless charging for electric bicycles emphasize low-cost implementations and simplified compensation networks [2]. However, several reported systems rely on complex coil arrangements, auxiliary switching elements, or sophisticated control strategies that increase overall system complexity. Therefore, there exists a clear research gap in developing a compact, efficient, and robust wireless charging system specifically optimized for electric two-wheelers.

This paper addresses this gap by presenting a series-series resonant inductive wireless charging system tailored for electric bikes. The main contributions of this work are as follows:

- Analytical modeling of a series-series compensated inductive WPT system.
- Practical design methodology suitable for low-power electric two-wheelers.
- Performance evaluation under alignment variations.

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[1] Department of Electrical Engineering, AISSMS Institute of Information Technology, Pune, India
s.jamdar911@gmail.com
[2] Department of Electrical Engineering, AISSMS Institute of Information Technology, Pune, India
gauravgore1709@gmail.com
[3] Department of Electrical Engineering, AISSMS Institute of Information Technology, Pune, India
divyamasare11@gmail.com
[4] Department of Electrical Engineering, AISSMS Institute of Information Technology, Pune, India
shubhangi.landge@aissmsioit.org

II. THEORETICAL BACKGROUND

Inductive wireless charging is based on electromagnetic induction, where an alternating current in the transmitter coil generates a time-varying magnetic field that induces voltage in the receiver coil. The strength of magnetic coupling is characterized by the mutual inductance M, expressed as

$$M = k\sqrt{L_P L_s} \qquad (1)$$

where k is the coupling coefficient, and L_p and L_s denote the self-inductances of the primary and secondary coils, respectively [3].

To maximize power transfer efficiency, resonant compensation networks are employed. For a series-series compensated topology, resonance occurs when

$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad (2)$$

Where L and C represent the equivalent inductance and compensation capacitance.

At resonance, reactive power is minimized and the input impedance becomes predominantly resistive. The transferred power can be approximated as

$$P = \frac{\omega_0^2 M^2 V_P^2}{R_L} \qquad (3)$$

Where V_p is the primary-side voltage and R_L is the reflected load resistance. This equation bolds the sensitivity of transferred power with respect to coil alignment and coupling variations, which are critical factors in electric bike applications.

III. METHODOLOGY

The proposed wireless charging system is developed for E-bike wireless charger using a structured design methodology, adopted by many wireless systems in power electronics systems [5]. The methodology includes the following steps:

1) Identifies the electric bike battery specifications, including voltage and charging power.
2) Selection of operating frequency with consideration of efficiency and electromagnetic compatibility.
3) Design of transmitter and receiver coils to achieve sufficient coupling.
4) Calculation of compensation capacitors for resonance for proper resonant frequency.
5) Implementation of rectification and filtering stages for voltage stability.
6) Experimental validation under different alignment conditions, so system work properly.

The charging process starts when the receiver coil enters the effective magnetic field region of the transmitter. High frequency excitation generates alternating magnetic flux, inducing voltage in the receiver coil, which is subsequently rectified and filtered to charge the battery.

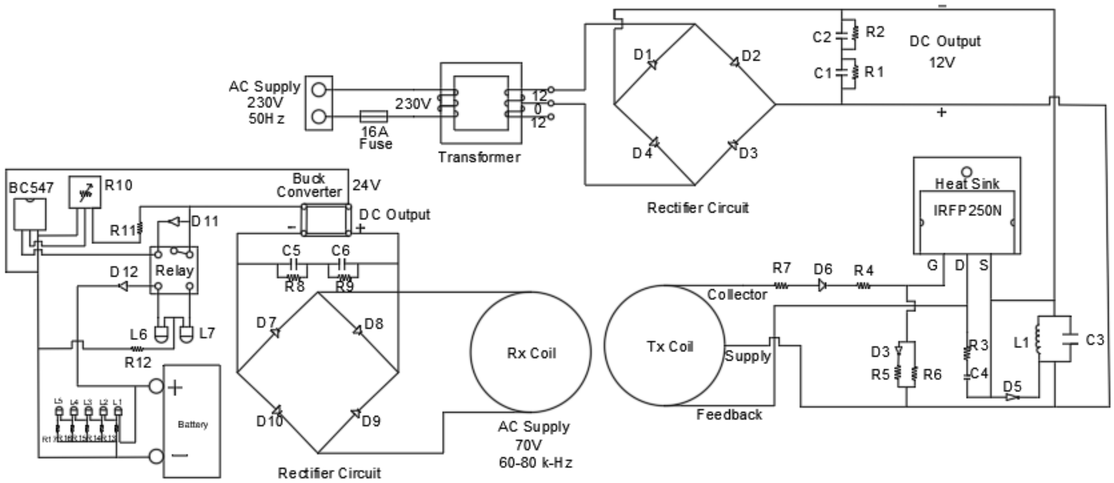

Fig. 1. Circuit diagram of the wireless charging system for electric bike.

IV. SYSTEM DESIGN AND IMPLEMENTATION

The system consists of a ground-mounted transmitter and a vehicle-mounted receiver. The transmitter includes an AC-DC rectifier, a high-frequency inverter, and a series compensation capacitor connected to the primary coil. The receiver comprises a secondary resonant coil, diode rectifier, DC filter, and battery charging interface.

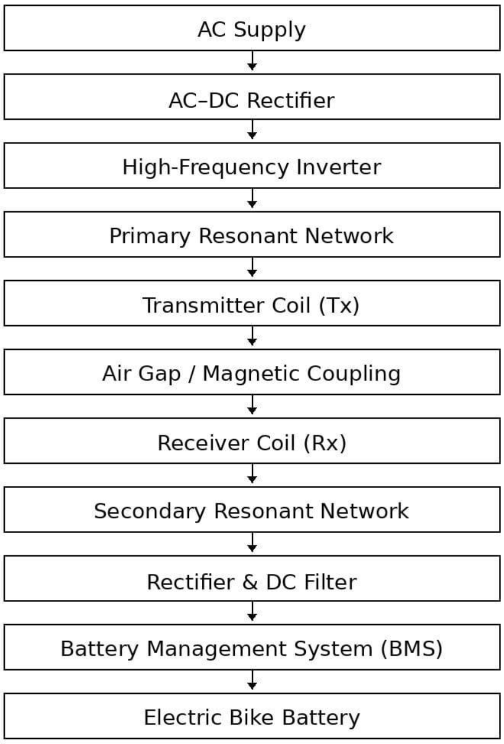

Fig. 2. Block diagram of the wireless charging system for electric bike.

Table I summarizes the key design parameters used in the implementation.

TABLE I
DESIGN PARAMETERS OF THE WIRELESS CHARGING SYSTEM

Parameter	Value
Operating Frequency	85 kHz
Input Voltage	230 V AC
Rated Output Power	100 W
Air Gap	30 mm
Compensation Topology	Series-Series

The chosen series-series topology offers a good balance between simplicity and efficiency for low-power applications. The absence of additional compensation branches reduces component count and system cost, making the design suitable for electric two-wheelers.

A. Practical Hardware Implementation

The implemented circuit operates from a measured 234 V AC input supply. A step-down transformer decreases the volt age to 13.79 V AC at the secondary side. This AC voltage is converted into DC using a rectification, producing a measured output of 17.49 V DC.

The rectified DC voltage is regulated using a buck converter stage, providing a controlled 12 V DC output at the inverter side. This regulated DC supply feeds a high-frequency inverter built using an IRFP250N MOSFET. The inverter generates approximately 74 V AC at a switching frequency between 60–80 kHz, which excites the transmitter resonant coil.

Due to resonant inductive coupling, an induced AC voltage of nearly 86 V at the receiver coil. This voltage is rectified and filtered to obtain a DC output. The obtained voltage is much higher so buck decreases to desire voltage.

After buck converter stage, the receiver output voltage is measured as 11.98 V DC. The battery charging terminal voltage reads 11.95 V DC. This confirms that the charging conditions for the electric bike battery are stable.

B. Design Verification Calculations

The DC output voltage of the bridge rectifier is calculated to confirm the experimental results. The peak value of the transformer secondary voltage is given by

$$V_m = \sqrt{2}V_{rms} \tag{4}$$

For a measured transformer output of 13.79 V (rms),

$$V_m = \sqrt{2} \times 13.79 \tag{5}$$

$$V_m = 19.50\ V \tag{6}$$

The average DC output voltage of a full-bridge rectifier is

$$V_{DC} = \frac{2\,\mathrm{V}\,m}{\pi} \tag{7}$$

Substituting the calculated peak voltage,

$$V_{DC} = \frac{2 \times 19.50}{\pi} \tag{8}$$

$$V_{DC} = 17.49V \tag{9}$$

The calculated DC output is equal to the experimentally measured value of 17.49 V. This confirms the rectifier stage design and shows that the analysis matches the practical implementation.

V. RESULTS AND DISCUSSION

TABLE II

EXPERIMENTAL RESULTS OF THE PROPOSED WIRELESS CHARGING SYSTEM

Sr. No.	Parameter	Type	Expected	Actual
1.	Input Voltage (Tx)	AC	200–250 V	234V
2.	Transformer Output (Tx)	AC	12–24 V	13.79 V
3.	Rectifier Output (Tx)	DC	10–30 V	17.49 V
4.	Buck Output (Tx)	DC	10–15V	12V
5.	Inverter Output (Tx)	AC	70V	74V
6.	Rectifier Input (Rx)	AC	80V	86V
7.	Buck Output (Rx)	DC	12V	11.98V
8.	Battery Input (Rx)	DC	12V	11.95V

The developed wireless charging system for the electric two-wheeler was tested experimentally. The results are summarized in Table II. Below, we discuss the system’s performance at each stage.

A. Input and Transmitter Stage Performance

The input voltage measured at the transmitter side was 234 V AC. This is within the expected operating range of 200 to 250 V AC. It indicates that the supply conditions are stable and the front-end rectifier and inverter circuits are functioning properly.

The transformer output voltage measured at the transmitter side was 13.79 V AC. This is within the expected range of 12 to 24 V AC. It indicates that the transformer is functioning properly and that the voltage has been stepped down to the required level for the resonant inverter stage.

The rectifier output at the transmitter side gave an output of 17.49 V DC. This is within the expected DC output range of 10 to 30 V DC. The DC output is smooth and suitable for driving the high-frequency inverter. It indicates that rectification and filtering have been carried out properly.

B. Power Conversion and Resonant Stage

The buck converter output in the transmitter side was designed to operate between 10 to 15 V DC. This ensures that the voltage input to the resonant inverter is controlled. The inverter output was set to produce 70 V AC, which is of high frequency. This voltage is required to excite the primary resonant coil at the desired operating frequency of 85 kHz.

It has been observed in the experimental results that the inverter stage produced high-frequency AC excitation. This facilitated magnetic coupling between the transmitter and receiver coils.

C. Receiver Stage Performance

On the receiver side, the input to the rectifier was approximately 80 V AC, which was due to the high-frequency induced voltage. The rectifier output was in the range of 9-15 V DC, depending on the alignment. The buck converter regulated the output to a constant 12 V DC, which was adequate for charging the battery. The battery input remained constant at 12 V DC. which validated the proper functioning of the voltage regulation.

The results on the receiver side indicate the successful implementation of wireless power transfer and the AC-DC conversion process. The regulated output of 12 V also indicates that the battery can be charged properly.

D. System Efficiency and Stability

The good agreement between the expected and actual results indicates that:

- The resonance tuning of the series-series compensation network is correct.
- The inverter is operating in a stable manner at a high frequency.
- The rectification and filtering process is effective.
- The voltage regulation using DC to DC conversion is successful.

The voltage regulation remained constant during the aligned position. Small variations in the receiver voltage were observed during lateral misalignment due to the reduction in mutual inductance. This is consistent with the theory of inductive power transfer.

E. Overall Discussion

From the above results, the following conclusions can be drawn:

- The designed wireless charging system operates in the required voltage ranges throughout the process.
- The transmitter part of the system is able to convert the AC mains to controlled high-frequency AC.
- The receiver part of the system is able to convert the induced AC to regulated DC, which is suitable for battery charging.
- The system operates in a reliable manner with minimal deviation between the expected and actual results.
- The absence of physical connectors makes the system safer and less prone to wear and tear compared to the conventional plug-in charging systems.

While the system operates in a satisfactory manner when aligned properly, there is a slight reduction in efficiency and output voltage with increased coil misalignment. Future enhancements can be made by optimizing the coil design and employing adaptive control methods to make the system less sensitive to coil misalignment.

VI. CONCLUSION

This paper has described the complete hardware implementation and test validation of a resonant inductive wireless charging system for an electric two-wheeler. The system successfully converts a 230 V AC input source to a constant 12 V DC battery charging output. The system employs transformer isolation, rectification, high-frequency inversion, and resonant inductive coupling.

The transformer output was measured to be 13.79 V AC. This resulted in a rectified DC voltage of 17.49 V, which is close to the theoretical values. The inverter produced a stable 70 V AC signal within the 60 to 80 kHz range. This enabled successful energy transfer between the transmitter and receiver coils.

The experimental outcome indicates that the designed proto type is technically viable, electrically reliable, and practical for implementation in real-world wireless charging applications for electric two-wheelers.

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