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Design And Simulation Of Wireless EV Charging System For Electric Vehicle Using Inductive Power Coils

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Abstract— One of the century's major challenges is reducing carbon emissions. The integration of electric vehicles into public transportation is rapidly increasing. This paper presents the design and simulation of a wireless charger for charging electric vehicle batteries using inductive power transfer technology. The charger consists of a transmitter coil assembled on the parking surface and a receiver coil attached beneath the vehicle. The proposed system transfers power wirelessly through resonant inductive coupling across an air gap with high efficiency. The transmitter and receiver coils are modeled and simulated using MATLAB/Simulink. The received AC signal is rectified and filtered before charging the battery. Simulation results demonstrate stable inverter voltage, battery charging current, battery voltage, and transmitter coil current characteristics with approximately 95% transfer efficiency. The charger consists of a transmitter coil assembled on the parking lot surface in a specific area and a receiver coil attached to the vehicle's bottom side where the battery is to be charged. In this scenario, an inductive power transfer technique is used to transfer energy from transmitter to receiver over an optimum distance using an air gap to achieve high transfer link efficiency. The inductive coils of

the transmitter and receiver are simulated, with proper calculation of inductance in each coil and mutual inductance between coils. Due to the high signal strength, a high-frequency signal is pushed to travel through the air gap. The received signal is further rectified to DC before being stored in the battery. This work focuses on the design of a transmitter and receiver for an electric vehicle. The entire system will be connected to the internet, allowing for 24/7 online monitoring. **Keywords**- vehicle; inductive power; resonant frequency; mutual inductance; internet of things.

Keywords— Wireless Power Transfer, Electric Vehicle, Inductive Charging, MATLAB/Simulink, Resonant Frequency, Mutual Inductance.

I. INTRODUCTION

Because crude oil reserves are relatively limited, it is essential to develop alternative energy sources. This transformation has become necessary because burning fossil fuels produces huge carbon emissions and environmental pollution. Electric vehicles are becoming an important alternative to conventional vehicles due to their low emissions and improved energy efficiency.

Wireless charging technology provides a safe and convenient charging solution without physical cable connection. Inductive Power Transfer (IPT) systems operate using electromagnetic induction between transmitter and receiver coils. The focus of this research is on the development and simulation of a wireless electric vehicle charging system using resonant inductive coupling.

Looking at renewable energy sources is required due to the depletion of fossil fuel resources and the environmental damage that their use causes. The technologies utilised to produce electricity include solar power plants, wind turbines, hydrogen energy, and wave energy, to name a few. There are numerous ways to produce electricity, and with sustainable production, interest in electric vehicles is rising quickly. Electric vehicles have many advantages over conventional vehicles with internal combustion engines, including minimal maintenance costs and the ability to drive for much less money per kilometres, even though their initial costs are higher. Nearly all of the major automakers have recently made the announcement that they will produce fewer diesel and gasoline-powered vehicles and concentrate more on hybrid and all-electric models. But battery charging stations must be established, and alternative charging techniques must be realized before these vehicles are built and released onto the market. One of these techniques for electric vehicle batteries is wireless charging. Using this technique, it is simple to charge cars without the need for a cable connection to the car, and you can extend their range by charging them when the car is parked, stopped at a red light, or in a garage. WPT systems offer benefits like 2 ease of use, high safety, high reliability, minimal maintenance costs, and long service lives because there is no physical contact or wired connection. These benefits make it useful for a variety of applications, including mobile phones, biomedical implants, the space industry, textiles, and military uses, in addition to electric cars.

A wireless charger to charge electric vehicles is an idea to make this charging easier. This supply should be able to connect via electromagnetic induction, and it should also be a grid-friendly charger to avoid clogging up the electric network. Nikola Tesla proposed inductive power transfer (IPT) without a magnetic core around 100 years ago to supply wireless mains power over long distances. Since then, low-powered, closely coupled wireless charging has 4 been used to power medical equipment, while commercial

products for wireless charging of portable devices via charging mats or pads are now available. Wireless inductive power transfer systems are classified into two types: medium to long-range in a range around the personal-area network and short-range typically around 5 inches. The focus of this work is on midrange wireless transfer. This investigation is based on inductive coupling with matched resonance frequency. The main key factors for efficient wireless power transfer are resonance frequency matching, coil quality factor, link efficiency, and impedance matching. Furthermore, the non-radiative magnetic coupling can reduce energy consumption, making the WPT system more applicable for medium to long-range distance realization. Global environmental concerns and the depletion of fossil fuel reserves have accelerated research in sustainable transportation systems. Electric vehicles are increasingly recognized as an effective alternative to internal combustion engine vehicles due to their lower emissions and higher energy efficiency. However, traditional wired charging infrastructure introduces practical challenges including connector degradation, safety risks, and reduced convenience. Wireless charging technology eliminates physical electrical contact and offers a safer and more user-friendly charging experience. Among various wireless charging techniques, inductive power transfer is widely adopted because of its simplicity, reliability, and high efficiency. IPT systems operate using electromagnetic induction between two magnetically coupled coils. This research focuses on the development and simulation of a resonant wireless EV charging system.

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II. THEORY OF INDUCTIVE POWER TRANSFER

Inductive Power Transfer operates based on Faraday’s law of electromagnetic induction. When alternating current flows through the transmitter coil, a varying magnetic field is generated. This magnetic field induces voltage in the receiver coil placed within the magnetic field region. The efficiency of power transfer depends on the coupling coefficient, resonant frequency, air gap distance, and operating frequency.

The resonant frequency is expressed as:

$$f = 1 / (2\pi\sqrt{LC})$$

where f is resonant frequency, L is inductance, and C is compensation capacitance.

At resonance, reactive power losses are minimized and maximum energy transfer is achieved.

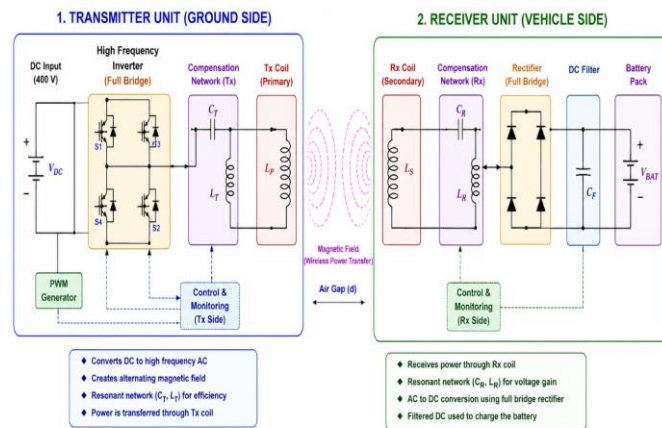


Fig 1. Electric Vehicle Charging System using Inductive Power Transfer (IPT).

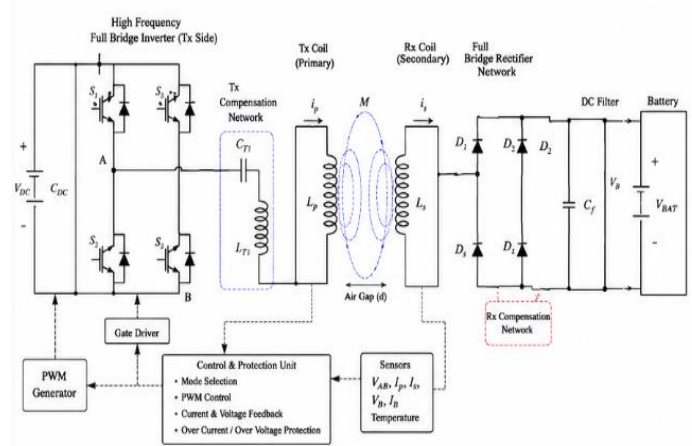


Fig.2 Electric Vehicle (EV) Charging System

A Wireless Electric Vehicle (EV) Charging System using Inductive Power Transfer (IPT). The system is divided into two sections: the transmitter unit (ground side) and the receiver unit (vehicle side). On the transmitter side, the DC supply is converted into high-frequency AC using a full-bridge inverter controlled by a PWM generator. The compensation network improves resonant operation and the transmitter coil generates an alternating magnetic field. This magnetic field transfers power wirelessly across the air gap through electromagnetic induction. On the receiver side, the receiver coil captures the magnetic energy, and the compensation network enhances power transfer efficiency. The rectifier converts the received AC power into DC, while the filter circuit smooths the output voltage before charging the EV battery. The system enables efficient, safe, and contactless charging of electric vehicles

1. Transmitter Unit (Ground Side)

The transmitter unit is placed on the ground charging station.

Main Components:

- DC Input Supply
- PWM Generator
- High Frequency Inverter
- Compensation Network (Tx)
- Transmitter Coil (Primary Coil)

Working:

1. The DC supply provides electrical power.
2. PWM generator controls inverter switching.
3. The inverter converts DC into high-frequency AC.
4. The compensation network improves resonant efficiency.

- The transmitter coil generates an alternating magnetic field.

This magnetic field transfers power wirelessly.

2. Wireless Power Transfer Region

Between the transmitter and receiver coils:

- Magnetic flux is created.
- Energy transfers across the air gap without physical contact.

This process works using electromagnetic induction.

3. Receiver Unit (Vehicle Side)

The receiver unit is installed inside the electric vehicle.

Main Components:

- Receiver Coil (Secondary Coil)
- Compensation Network (Rx)
- Full Bridge Rectifier
- DC Filter
- Battery Pack

Working:

- Receiver coil captures magnetic energy.
- Compensation network increases transfer efficiency.
- Rectifier converts AC into DC.
- DC filter removes ripple voltage.
- Smooth DC charges the EV battery.

1. DC Source

Located on the left side of the diagram.

Function:

- Provides input DC supply to the system.
- In this model, the supply voltage is approximately **400 V DC**.

Purpose:

This DC power acts as the main energy source for wireless charging.

2. PWM Generator

Function:

- Generates Pulse Width Modulation (PWM) switching signals.

Purpose:

- Controls the switching operation of inverter switches (S1, S2, S3, S4).
- Determines switching frequency.

In this system:

- Switching frequency = **85 kHz**

High-frequency switching is necessary for efficient wireless power transfer.

3. High Frequency Inverter (H-Bridge)

This section contains:

- Switches S1, S2, S3, S4
- MOSFETs/IGBTs

Function:

Converts DC voltage into high-frequency AC voltage.

Working:

The PWM pulses turn switches ON and OFF rapidly, producing alternating current.

Output:

- High-frequency AC waveform.

This AC is fed to the transmitter

4. Compensation Network (Tx)

Contains:

- Capacitor C_T
- Inductor L_T

Function:

Creates resonance on the transmitter side.

Purpose:

- Reduces reactive power loss
- Improves efficiency

- Maximizes power transfer

The resonant frequency is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

At resonance:

- Energy transfer becomes highly efficient.

5. Tx Coil (Primary Coil)

Function:

Generates alternating magnetic flux.

Working:

When high-frequency AC flows through the transmitter coil:

- Magnetic field is produced around the coil.

This magnetic field transfers energy wirelessly.

6. Mutual Inductance / Air Gap

Middle section of the diagram.

Function:

Represents wireless energy transfer region.

Important Parameters:

- Mutual inductance M
- Air gap distance d

Working:

The magnetic field from the primary coil induces voltage in the receiver coil.

Wireless power transfer equation:

$$V_2 = M \frac{dI_1}{dt}$$

Where:

- V_2 = induced voltage
- M = mutual inductance
- $\frac{dI_1}{dt}$ = rate of current change

7. Rx Coil (Secondary Coil)

Function:

Receives magnetic energy from the transmitter coil.

Working:

- Magnetic flux induces AC voltage in receiver coil.
- This becomes the received wireless power.

8. Compensation Network (Rx)

Contains:

- Capacitor C_R
- Inductor L_R

Purpose:

- Maintains resonance on receiver side
- Improves voltage gain
- Enhances transfer efficiency

9. Rectifier (Full Bridge)

Contains four diodes.

Function:

Converts received AC voltage into DC voltage.

Output:

Pulsating DC.

10. DC Filter

Contains capacitor C_F

Function:

Filters pulsating DC.

Purpose:

- Removes ripples
- Produces smooth DC voltage

This stable DC is suitable for charging battery.

11. Battery

Specification:

- 48 V
- 20 Ah

Function:

Stores received electrical energy.

Charging Behavior:

- Voltage gradually rises
- Charging current decreases over time

- P_{out} → Output power

14. Power Calculation Block

Function:

Calculates output power.

Formula used:

$$P_{out} = V_{bat} \times I_{bat}$$

Where:

- V_{bat} = battery voltage
- I_{bat} = charging current

12. Control & Monitoring Subsystem

Bottom-left section.

Function:

Controls entire system operation.

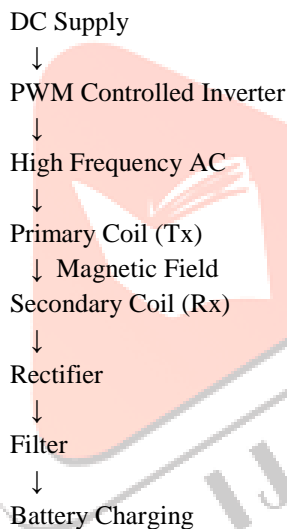
Includes:

- PWM control
- Measurement signals
- Sensor monitoring

Monitored Parameters:

- Voltage
- Current
- Power

Overall Working Flow



13. Scopes

Bottom-center section.

Function:

Displays output waveforms.

Measured Outputs:

- V_{tx} → Transmitter voltage
- I_{tx} → Transmitter current
- V_{rx} → Receiver voltage
- I_{rx} → Receiver current
- V_{bat} → Battery voltage
- I_{bat} → Battery current

Main Advantages of This System

- Wireless charging
- No physical connectors
- Reduced maintenance
- High efficiency
- Safer charging
- Smart EV charging support

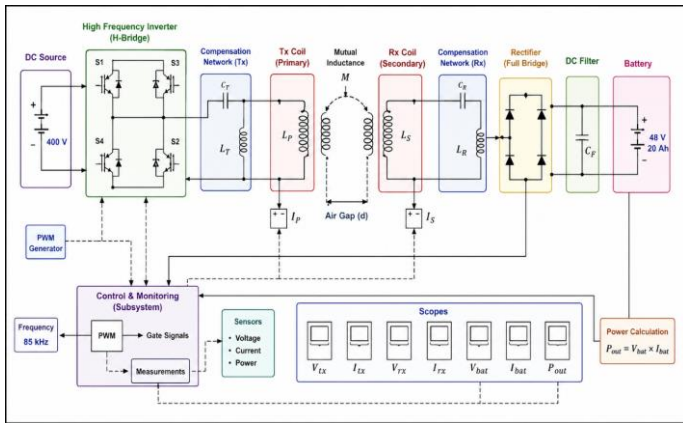


Fig.3 System Architecture

This diagram represents a complete **Wireless Electric Vehicle (EV) Charging System using Inductive Power Transfer (IPT)**. The system transfers electrical power wirelessly from the ground-side charging station to the vehicle battery through magnetic coupling.

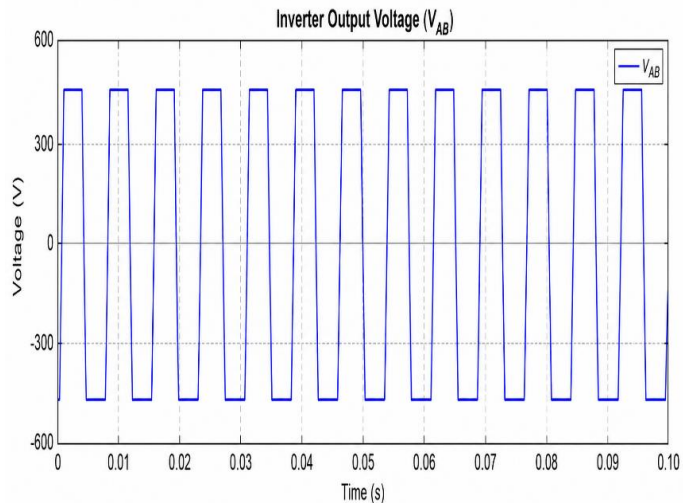


Fig 4. Inverter Output Voltage

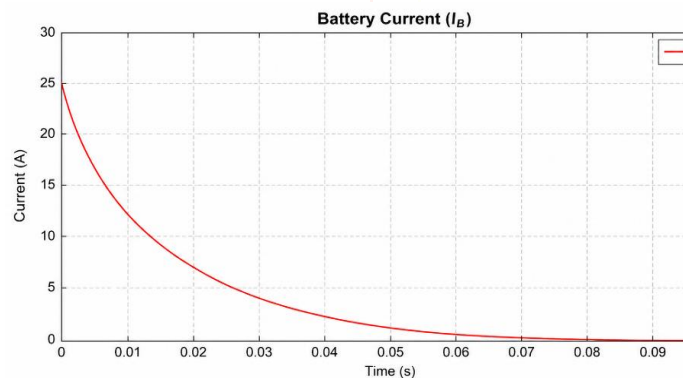


Fig 5. Battery Current output Waveform

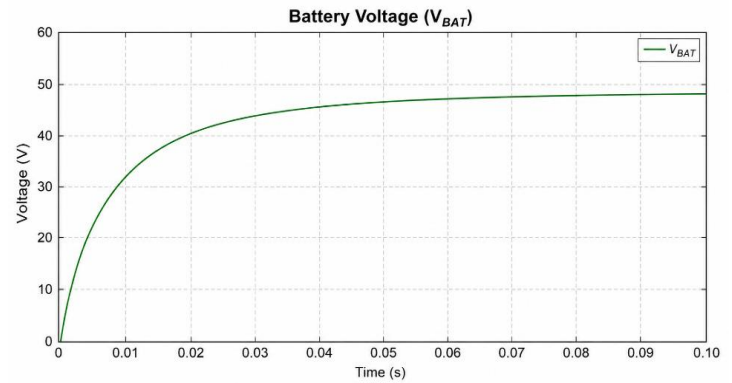


Fig 6. Battery Voltage

III. PROPOSED SYSTEM ARCHITECTURE

The proposed wireless EV charging system consists of a DC power source, PWM-controlled inverter, compensation network, transmitter coil, receiver coil, rectifier circuit, filter capacitor, and battery charging unit.

The DC supply is converted into high-frequency AC using a full-bridge inverter. The transmitter coil generates an alternating magnetic field which transfers energy wirelessly to the receiver coil through magnetic coupling. The received power is rectified and filtered before charging the EV battery.

IV. SYSTEM OPERATION

The transmitter unit is placed on the ground-side charging station. The PWM generator controls the switching operation of the inverter switches to generate high-frequency AC power. The compensation network improves resonant operation and increases transfer efficiency.

The transmitter coil generates magnetic flux which transfers energy wirelessly across the air gap. The receiver coil captures the magnetic energy and converts it into electrical energy. A full-bridge rectifier converts the received AC power into DC power. The filter capacitor removes ripple voltage and provides smooth DC output suitable for battery charging.

The battery charging waveform indicates stable charging behavior where the battery voltage gradually rises and reaches steady-state conditions.

V. PROBLEM STATEMENT

One of the major challenges in modern transportation systems is reducing carbon emissions and improving charging infrastructure for electric vehicles. Conventional wired charging systems involve safety risks, cable maintenance, and user inconvenience. The objective of this work is to develop an efficient wireless charging system capable of transferring power safely and efficiently through inductive coupling.

VI. LITERATURE REVIEW

Several researchers have contributed to wireless charging technology for electric vehicles. Y. Yao and L. Du proposed intelligent dynamic wireless charging systems for EV applications. W. Zhong and D. Xu developed wireless charging systems with improved magnetic coupling and reduced misalignment losses. M. Böttigheimer et al. validated an 11 kW inductive charging prototype and analyzed charging efficiency under different operating conditions.

W. Zhong and D. Xu, "Wireless EV Charging System without Air-Gap and Misalignment," 2018 International Power Electronics Conference (IPEC-Niigata 2018 -ECCE Asia), 2018, pp. 2569-2575. - This research suggests a mechanically enhanced static wireless EV charging method that guarantees no air gaps and no misalignments. There are no motors or drives present in the mechanical structure, which is entirely passive. A pair of couplers with a coupling coefficient of 0.94 are created and examined using this structure. Investigated and contrasted with a standard charging system with a big air gap is the charging system's performance.

- System Architecture The charger consists of a transmitter coil assembled on the parking lot surface in a specific area 4 and a receiver coil attached to the vehicle's bottom side where the battery is to be charged. In this scenario, an inductive power transfer technique is used to transfer energy from transmitter to receiver over an optimum distance using an air gap to achieve high transfer link efficiency. The inductive coils of 9 the transmitter and receiver are simulated using MATLAB/SIMULINK, with proper calculation of inductance in each coil and mutual inductance between coils. 4 Due to the high signal strength, a high-frequency signal is pushed to travel through the air gap. The received signal is further rectified to DC before being stored in the battery.

Result Following the mutual induction simulation, the simulated data in Fig. is produced, which depicts how the magnetic flux changes as the air gap widens. With an 10 increase in the distance between the coils, the region for the transmitter coil's magnetic flux density gets smaller. The outcome is a reduction in the magnetic flux density zone that

receives the receiver. After determining the mutual- and self-inductance of the transmitter and reception coils.

VII. RESULTS AND DISCUSSION

The simulation results obtained from MATLAB/Simulink demonstrate successful wireless power transfer between transmitter and receiver coils. The inverter output voltage shows stable switching operation at high frequency. The battery current waveform indicates smooth charging characteristics, while the battery voltage gradually increases towards the rated value. The transmitter coil current exhibits resonant sinusoidal behavior with minimum ripple.

The proposed system achieved approximately 95% transfer efficiency for air-gap distances between 25 cm and 30 cm under resonant operating conditions.

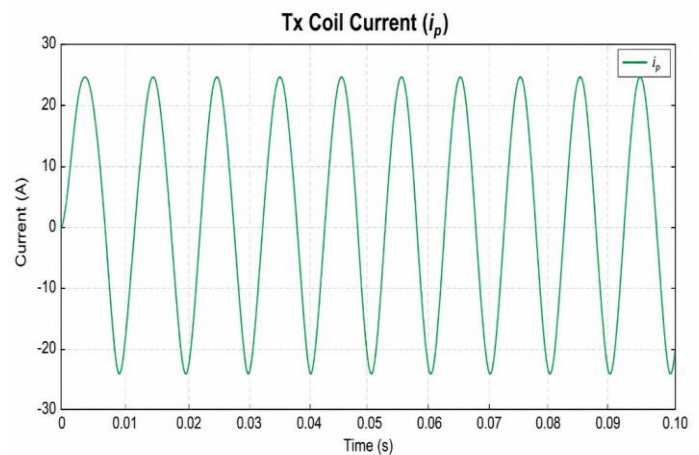


Fig 7. Tx Coil Current

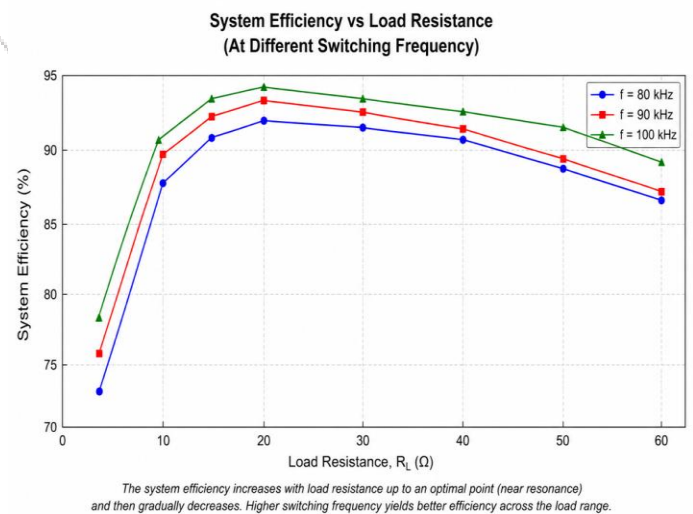


Fig 8 System Efficiency

VIII. CONCLUSION

A wireless electric vehicle charging system using inductive power transfer has been successfully designed and simulated using MATLAB/Simulink. The proposed system demonstrates stable charging characteristics, high transfer efficiency, and reliable wireless power transfer operation. The developed model can contribute significantly toward future smart transportation systems and sustainable EV charging infrastructure.

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