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Wireless Power Transfer for Moving Electric Vehicle

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***Abstract* - As the world faces depletion of resources, electric cars have emerged as a viable alternative. To address the challenge of powering electric vehicles (EVs) in everyday life WPT is being explored as a practical and reliable solution for charging EVs. In this project, we have developed a prototype WPT system that operates at 60 kHz frequency and put it into practice. Compared to plug-in electric vehicles (PEVs), which require cable and plug chargers, galvanic separation of onboard electronics, and ESS packs, wireless charging offers a more convenient option for customers. The WPT system eliminates the need for cables, offers built-in electrical isolation, regulates on the grid side, and allows for dynamic on-road charging, reducing the required size of onboard ESS. Our project's primary objective is to build an antenna system suitable for vehicles that employ resonant magnetic-coupled wireless power transfer technology for electric car charging systems. The use of WPT in EVs provides a cleaner, more practical, and safer means of charging. The WPT system's primary and secondary coils form the heart of the technology, with a coupling coefficient ranging from 0.1 to 0.5. Both sides must be adjusted with resonant capacitors to transmit the rated power. The operating frequency is a critical selection factor that affects the power electronic circuit's component choices and coil size. Ultimately, our project aims to create a wireless resonant transfer system for vehicle charging that is both efficient and reliable.**

Keywords: WPT, dynamic on-road charging, resonant magnetic-coupled wireless power transfer technology, resonant capacitors.

I. INTRODUCTION

Wireless power supply systems have become increasingly popular in recent years, allowing electrical power to be delivered to devices without the need for physical connections. There are three core ideas that enable wireless electric power transmission:

1) Electromagnetic induction type
2) Radio reception type
3) Resonance type

Electromagnetic induction type utilizes the phenomenon in which an electric current applied to one coil induces an electromotive force in the other coil using magnetic flux as the medium. This technique is commonly used for non-contact power transmission. Unlike communication systems, WPT focuses on efficiency in transmitting energy wirelessly using all electromagnetic frequencies. While the electromagnetic field and its strength spread in all directions, the efficiency from transmitter to receiver is quite poor. This makes WPT ideal for transportation infrastructure using electric vehicles (EVs), which are gaining interest due to concerns about the environmental effects of the petroleum-based transportation infrastructure and the threat of peak oil. EVs utilize electricity from a variety of sources, including fossil fuels, nuclear power, renewable sources such as tidal, solar, and wind power, or a combination of these sources. This sets them apart from fossil fuel-powered automobiles. The electricity is delivered to the car through overhead power lines, wireless energy transfer methods, or a direct connection via an electrical cable. Once received, the electricity is used to power a battery, flywheel, or super capacitors within the car to store it. Regenerative braking and suspension allow for the recovery of energy lost during braking, which is then returned to the on-board battery. Overall, EVs rely heavily on outside energy sources, but they offer a promising solution to the energy problem and global warming. With the age of inexpensive oil coming to an end, the demand for alternatives is rising, and the price rivalry between alternatives and oil is increasing.

1.1 Literature Review

This literature review explores the current state of research and development in wireless power transmission, covering various applications and technologies. The paper by T.U. Blackwell et al. (2003) [1] focuses on laser power beaming for space propulsion and power transmission, while G. Chattopadhyay et al. (2010) [2] investigate millimeter-wave wireless power transfer for space applications. In the field of inductive power transfer, H.H. Wu et al. (2011) [3] propose a novel series-tuned IPT pickup system for efficient AC-voltage output, while S.P. Kamat (2009) [4] addresses energy management for multimedia applications in battery-powered devices. M. Kato and C.-T.D. Lo (2007) [5] explores memory compression for reducing power consumption in

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Java-enabled handheld devices. Karalis et al. (2010) [6] present a novel method for non-radiative mid-range energy transfer, while J. Sallan et al. (2009) [7] explore the optimal design of ICPT systems for electric vehicle battery charging. The safety implications of radio frequency electromagnetic fields are addressed by the IEEE Std. C95.1-1999 [8], while the historical significance of Nikola Tesla's work on wireless power transmission is highlighted by his 1905 paper [9]. Finally, J.A.C. Theeuwes et al. (2007) [10] present an efficient, compact wireless battery design, and the contributions of the IEEE-SA Standards Board to wireless power transmission technologies are acknowledged [11]. This diverse range of research demonstrates the ongoing advancements and potential applications of wireless power transmission across various domains.

1.2 Objectives

1) The main objective of our project is to design and develop a wireless power transfer system suitable for electric vehicles using resonant magnetic coupling technology.
2) The main aim of our project is to design and develop an antenna system suitable for vehicles using resonant magnetic coupled wireless power transfer technology to electric vehicle charging systems.
3) At the core of the wireless power charging systems are primary and secondary coils. In order to transfer the rated power, both sides have to be tuned by resonant capacitors.

1.3 Problem Statement

The current dependence of electric vehicles (EVs) on wired charging infrastructure presents significant limitations, hindering their widespread adoption. These limitations include limited charging availability, long charging times, and the inconvenience of physically connecting a charging cable. Wireless power transfer (WPT) technology offers a promising solution to these challenges by enabling EVs to be charged automatically and seamlessly while parked or even in motion. However, further research and development are needed to overcome technical challenges such as efficiency losses, safety concerns, and cost reduction to make WPT systems universally available and economically viable for mass EV adoption. By addressing these challenges, WPT can revolutionize the EV industry, leading to a more convenient, efficient, and sustainable transportation future.

II. PROPOSED SYSTEMS

In the proposed system aims to develop an antenna and wireless power transfer system suitable for electric vehicles (EVs).Using resonant magnetic coupling principle, the wireless power transfer technology to the electric vehicle is designed. When the vehicle's power receiver's frequency is tuned in exact with the resonance frequency of the transmitter unit below the road, the electrical power will flow from the transmitter coil inside the platform to the receiving coil inside the bottom of the electric vehicle. This project describes the design and implementation of a wireless power transfer system for moving electric vehicles of any type like e-cars or e-bikes.

III. METHODOLOGY

The idea of electric vehicles that are powered by the roads has been put up in an effort to solve battery issues. This technique enables wireless power charging while the electric vehicle is in motion, allowing for battery downsizing and the elimination of waiting periods for charging. Designing and developing an antenna and WPT system suited for moving vehicles is the primary goal of our research (EVs). The technology for wireless power transmission to electric vehicles is created using the resonant magnetic coupling concept. When the resonant frequency of the emitter unit below the road is correctly synchronized with the automobile's power receiver, electricity will be transmitted between the coil that transmits inside the base to the receiver coil inside the bottom. When the frequency of the electric vehicle's power receiver is exactly matched to the resonance frequency of its transmitter unit below the road, current will be transmitted from the coil that transmits below the road's surface to the receiving coil within the lowest part of the electric car. In this project, the design and execution of a wireless power transfer system for moving electric automobiles utilizing the model EV system is addressed.

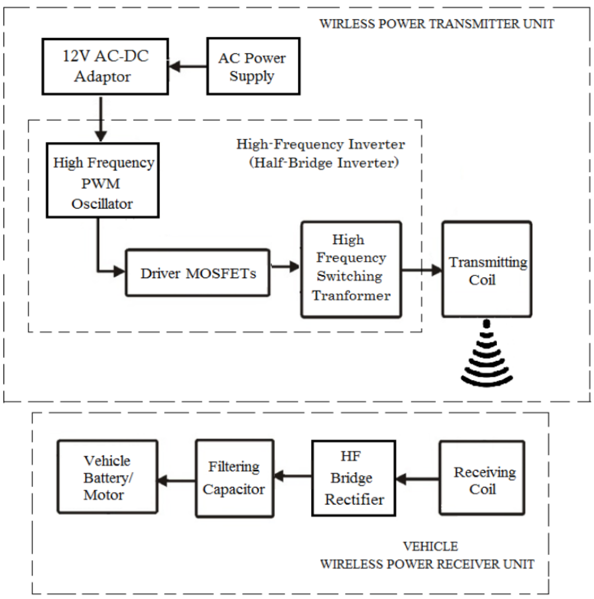

Figure 1: Block Diagram of Transmitter and Receiver

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3.1 Block Diagram Explanation

3.1.1 AC Power Supply

The wireless power transmitter requires an AC power supply, which is obtained from an AC220v source.

3.1.2 AC-DC Adapter (SMPS)

To convert the AC power supply to DC, a Switching Mode Power Supply (SMPS) is used. The input of the SMPS is 220v AC, and the output is 12v DC.

3.1.3 High Frequency PWM Oscillator

The KA3525 IC circuit is used for building Very High Frequency PWM Oscillators. This oscillating device creates a pulse width modulation (PWM) wavelength in the range of 65 KHz and generates PWM switching pulses for controlling the MOSFETs. The two MOSFET gates receive PWM1 and PWM2, two distinct PWM pulses produced by the oscillator. Because of the 90-degree phase difference between each PWM pulse, each MOSFET turns on and off alternatively.

3.1.4 Driver MOSFETs

Here, an extremely high frequency transformer is switched by two driver MOSFETs. The "Drain" pins of the two MOSFETs are joined by both ends of the transformer's primary. Current passes through the transformer's primary winding when a MOSFET is switched ON. One MOSFET turns on half of the primary, while another MOSFET turns on the other half. A square AC wave is created in the transformer primary as a result of the alternate switching of both MOSFETs.

3.1.5 High Frequency Transformer

Two driver MOSFETs are used to switch a very high frequency transformer in this instance. The primary terminals of the transformer's transformer connect the "Drain" pins of each of the MOSFETs. When a MOSFET is turned ON, current flows via the primary winding of the transformer. A half of the core is illuminated by one MOSFET, and the other half is illuminated by a different MOSFET. The alternating switching of the two MOSFETs results in a square AC wave in the transformer primary.

3.1.6 Half bridge Inverter

An HF flipping transformer and a couple MOSFETs make up the Half Bridge Inverters circuit driver. Two MOSFETs are linked to the switching transformer's primary, and the transmitting coil is connected to the secondary. The higher frequencies AC voltage is produced by the 1⁄2 Bridge Inverter from a DC input voltage.

3.1.7 Transmitting Coil

The copper coil windings of the source coil are intended to transform the higher-frequency oscillating power supply into electromagnetic signals that echo at a certain frequency.

3.1.8 Receiving Coil

From the sender's antenna, the receiver coil receives electromagnetic frequencies and transforms them into high-energy electrical power.

3.1.9 HF Bridge Rectifier

Rapidly switching with the objective to transform the HF current from the coil of copper in which it is received into a DC (direct current) source voltage, rectifying diodes are employed in HF bridge rectifiers.

3.1.10 Filtering Capacitor

The filtering effect of the capacitor eliminates ripple that is created at the rectifier & generates a steady and smooth DC voltage output that may be utilized to power a vehicle's motor or charge batteries.

3.2 Circuit Diagram

For designing and developing an antenna for WPT system the circuit diagram is made:

- Transmitter circuit diagram
- Vehicle receiver circuit diagram

3.2.1 Transmitter circuit diagram

AC-DC Converter or Switching Mode Power Supply (SMPS) converts 220V 50Hz AC supply into 24V DC output. The converted DC is then converted into a High frequency AC using a high frequency resonant half- bridge PWM inverter. The HF inverter used here is a half bridge push-pull type inverter. It is operated using a PWM switching controller which produces 45 to 120KHzoscillator Frequency. The HF converter converts Dc to HF ac. The HF ac current is fed to a switching transformer, which drives the HF Ac power to the transmitting coil. Transmitting coils convert HF electrical current into electromagnetic waves. The transmitting coil is operated at its resonant frequency so that maximum power will be transmitted with higher output efficiency.

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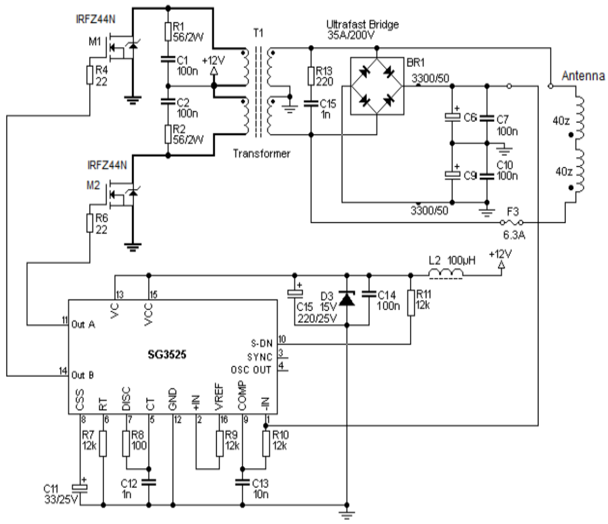

Figure 2: Transmitting circuit diagram

3.2.2 Vehicle receiver circuit diagram

The receiver consists of a receiving coil which is tuned to the frequency of the transmitting coil. So when coils are within the coupling range, the power is received in the receiving coil. The receiving coil converts the electromagnetic waves back to HF AC output. High frequency AC current is converted into a DC current using a fast switching bridge rectifier. A capacitor filter is used, which stabilizes the Dc voltage and produces a constant Dc output. Then the output of the filtering circuit provides a constant charging current to batteries of the vehicle.

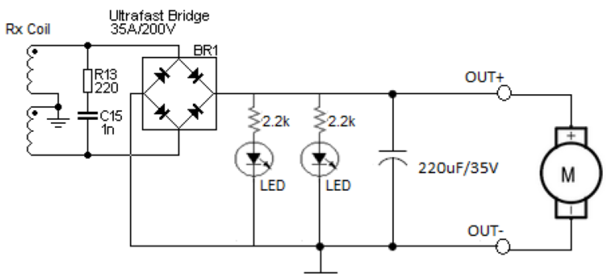

Figure 3: Vehicle Receiver Circuit Diagram

IV. HARDWARE DETAILS

4.1 MOSFET

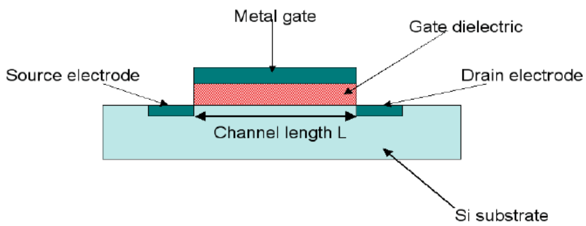

Figure 4: MOSFET

MOSFET stands for Metal-Oxide-Semiconductor Field-Effect Transistor. There are two main types of MOSFETs: n-channel and p-channel. In an n-channel MOSFET, the source and drain are doped with n-type material (which has an excess of electrons), and the gate is separated from the channel by an insulating layer of oxide. When a voltage is applied to the gate, it creates an electric field that allows current to flow between the source and drain. In a p-channel MOSFET, the source and drain are doped with p-type material (which has a deficiency of electrons), and the gate is negatively biased with respect to the source and drain.

4.2 KA3525 Pulse Width Modulator

The KA3525 is a pulse width modulation (PWM) controller integrated circuit (IC) that is commonly used in switch-mode power supplies (SMPS) and DC-DC converters. It is designed to control the output voltage of a power supply by adjusting the duty cycle of a square wave signal that is fed to a power switch such as a MOSFET or a bipolar transistor. The KA3525 features a voltage reference, an oscillator, a programmable feedback comparator, a pulse steering flip-flop, and a high current totem pole output stage. The oscillator frequency can be adjusted with external resistors and capacitors, while the feedback comparator can be programmed with external components to set the desired output voltage level. The pulse steering flip-flop and totem pole output stage work together to produce a PWM signal with a duty cycle that is proportional to the difference between the output voltage and the programmed reference voltage. The KA3525 can be used in a wide range of applications, including battery chargers, LED drivers, motor controllers, and voltage regulators. It is a popular choice for SMPS designs due to its ease of use, low cost, and high efficiency

4.3 Vertical Ferrite Core Transformer

Figure 5: Vertical Ferrite Core Transformer

A vertical ferrite core transformer is a type of transformer that uses a ferrite core that is oriented in a vertical direction. Ferrite is a type of ceramic material that has high magnetic permeability and low electrical conductivity, making it ideal for use in transformers. In a vertical ferrite core transformer, the primary and secondary windings are wound around a

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ferrite core that is oriented in a vertical direction. The advantage of using a vertical ferrite core is that it allows for a shorter path length for the magnetic flux, which can result in a more efficient transformer. Vertical ferrite core transformers are commonly used in high-frequency applications, such as in power supplies for computers and other electronic devices. They are also used in audio equipment, such as amplifiers and speakers. Overall, the use of ferrite cores in transformers has revolutionized the field of electronics, allowing for smaller and more efficient devices. The use of vertical ferrite cores is just one of the many innovations that have contributed to this progress.

V. MERITS AND DEMERITS

5.1 Merits

No line of sight required: Wireless power transmission does not require a clear line of sight between the transmitter and receiver. Even if there are physical barriers like wood, metal, or other devices between the source and the load, electricity transmission is still possible.

Interference-free: Unlike radio waves, wireless power transmission does not interfere with other electromagnetic waves, making it suitable for sensitive applications.

Safe: Wireless power transmission using resonant coupling produces significantly reduced wavelengths, making it safe for human use.

More efficient: Compared to electromagnetic induction, wireless power transfer through resonance induction is more effective in transferring energy over greater distances.

5.2 Demerits

Limited range: Wireless power transfer is only practical over short distances, typically a few meters.

Efficiency: The efficiency of wireless power transfer decreases with increasing distance, with efficiency rates of around 40% for long distances and up to 85% for short distances.

Development stage: While wireless power technology is rapidly evolving, it is still in the early stages of development. Further research and development are needed to improve its effectiveness and distance capabilities.

VI. CONCLUSION

Wireless Power Transfer (WPT) technology is a promising solution to address the challenges associated with EV charging. The WPT system's components include a power transmitter and power receiver, with various modules such as inverter, energy lines, regulators, rectifying devices, and pickup modules. The resonating frequencies used in the WPT system affect the constant voltage and constant current management. The electricity lines are set up alongside and below the road, with the transmitted energy powering the EV motors and recharging the batteries. WPT technology has the potential to offer a more convenient, efficient, and safe charging solution for EVs, and further research is required to improve its performance and reduce its cost.

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