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Article Title: Wireless Charging System Coupled for Electric Cars

Wireless Charging System Coupled for Electric Cars

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ABSTRACT

Electric vehicles (EVs) have steadily developed over the last decade as more energy-efficient alternatives to internal combustion engine cars. With increased range and performance, EVs are growing more reliable. Expanding the availability of electric vehicles can be facilitated via wireless charging. Wireless charging (WC) is an interesting remodelling makes electric cars to charge more convenient. Wireless Power Transfer (WPT) enables power to be transmitted from a power source without a trouble of connections, and this charging option increases the use of electric cars. This paper examines the most effective wireless power transmission techniques Magnetic Resonance Coupling (MRC), and its real-world application in EVs. It also examined how wireless power transfer efficiency declines with distance.

Keywords: Electric vehicles, gearbox efficiency, coupling coefficient, impedance matching, WC, MRC, WPT.

1 Introduction

Electric automobiles are among the more ecologically friendly solutions that the auto industry has adopted. An electric vehicle is propelled and managed by one or more traction motors. Electricity from remote power sources is send into an electric vehicle via a collector system. A large traction battery powers the car, and it needs to be charged by plugging it into a charging port [1]. The main issue of EVs is that the batteries are not as efficient or dense as those found in motors that run on gasoline. The benefit of WPT over wired power transfer is the removal of wires, infrastructure, and mobility within transmission range. Additionally, Compatibility with power plugs may also be removed. This paper suggests a methodology for implementing wireless charging techniques for an efficient electric car.

There are various methods for WPT, including Inductive Coupling (IC), laser, and Microwave Power Transmission (MPT), along with MRC and other transmission techniques [2, 3]. Of these, magnetic resonance coupling stands out as the most effective and successful method. This technique involves creating resonance to transmit power without generating electromagnetic wave radiation. As a result, while designing a circuit the resonance frequency becomes crucial [4, 5].

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The main objective of this method is to determine the most practical and efficient approach for wirelessly charging EVs, focusing on variations in coefficients during PT. The primary and secondary impedances of the WPT system is matched in order to optimize PT efficiency [6]. Changing the distance between coils has an impact on the transmitter and receiver's resonance frequencies. Furthermore, since the technology operates in the megahertz range, usable frequencies fall within the Industrial Scientific and Medical (ISM) band. Therefore, it is crucial to set the Resonance Frequency within this ISM band [7].

ANSYS Maxwell and ANSYS Twin are utilized to quicken various stages of power transfer and also influencing the efficiency of MRC. The simulation results indicate that several variables, such as the coil shape, coil space, resonant frequency, and Q factor affect the efficiency of MRC. Power transfer coils come in a variety of shapes and sizes, such as square, rectangular, solenoid, and planar circular designs here the most efficient coils are planar. Moreover, angular displacement has a minimal impact on the performance of planar coils [9].

2 Wireless Charging System for EVS

WCs consist of various components that work together seamlessly. Figure 1 depicts the different phases of wireless power transmission (WPT). A full-bridge rectifier is used to transform the alternating current (AC) electricity coming from the source into direct current (DC).To create a high-frequency AC source, the rectifier's output is sent to an inverter. After passing through a signal conditioning circuit that protects against high-voltage AC, the inverter sends this high-frequency AC output to the transmitting side of the system. [2].

A transmitting coil, a resistor, and a capacitor are the three primary parts of the transmitting circuit. Both the transmitting and receiving sides employ a circular, planar copper coil. The electricity generated by the transmitting coil is absorbed by the receiving coil. On the receiving side, however, a resistor and a capacitor are connected in parallel to the receiving coil. Finally, the AC power is converted back to DC for storage on the load side. [9].

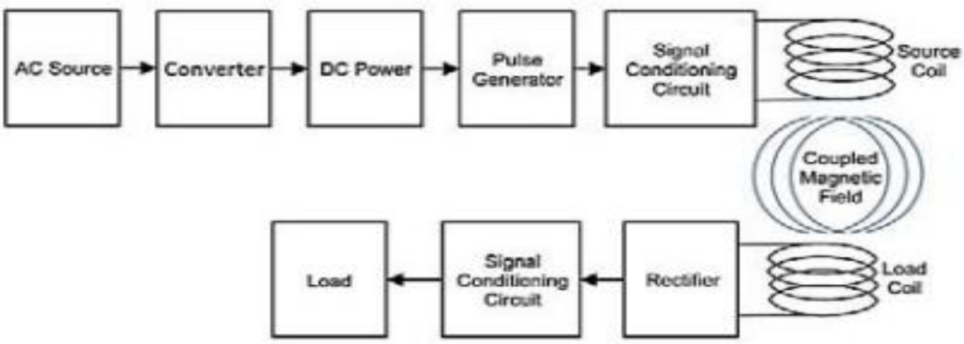

Figure 1: *Block Diagram for the Suggested System*

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2.1 A Modeling Converter

A circuit for a full-wave rectifier is created using filter capacitors and diodes. The purpose of the rectifier is to convert 120 volts of AC to DC. The rectifier circuit's output voltage is 76V DC, while its input voltage is 120V AC. Since Vp = 120 V, VDC = (2Vp)/π = 76 V. The filter capacitor has a capacitance of 6800 μf. The inverter is connected to the rectifier's output. The transmitting coil is connected to the square wave produced by the inverter. The output frequency of the inverter is 13.56 MHz.

2.2 Dimensional Modeling of Power Transfer Coils

The ANSYS Maxwell software is employed to speed the transmitter and receiving coils in a three-dimensional environment. A translucent rectangular plate is positioned between the two coils to collect the magnetic fields generated during their operation [7, 8]. Since both coils have the same diameter, a higher coupling coefficient is achieved. Figure 2 uses ANSYS Maxwell to show the transmitting and receiving coils design.

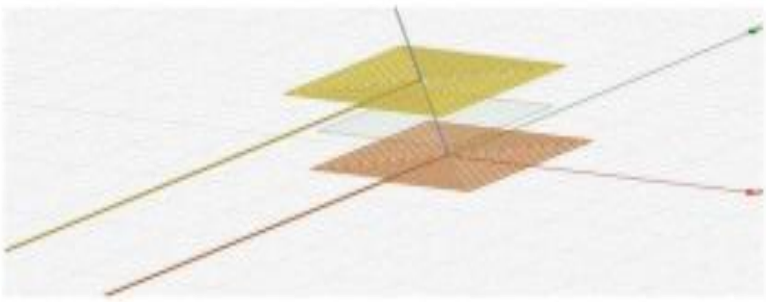

Figure 2: *Design of coil*

2.3 The Coils Design Parameter

Table 1: *Features of the Developed Coil*

Name	Value	Unit	Evaluated...	Description
Xpos	0	mm	0mm	X Position of start point
Ypos	0	mm	0mm	Y Position of start point
Dist	6	mm	6mm	Distance between turns
Turns	10			Number of turns
Width	3	mm	3mm	Width of the spiral
Thickness	3	mil	3mil	Thickness/height of the spiral

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2.4 Rectangular Plate with Dimensions

Table 2: *Characteristics of the Rectangular Plate Design*

Name	Value	Unit	Evaluated Value
Command	CreateRectangle		
Coordinate System	Global		
Position	-50 ,-50 ,25	mm	-50mm , -50mm , 25mm
Axis	Z		
XSize	100	mm	100mm
YSize	100	mm	100mm

2.5. A Magnetic Field across the Two Coils That Transfer Power

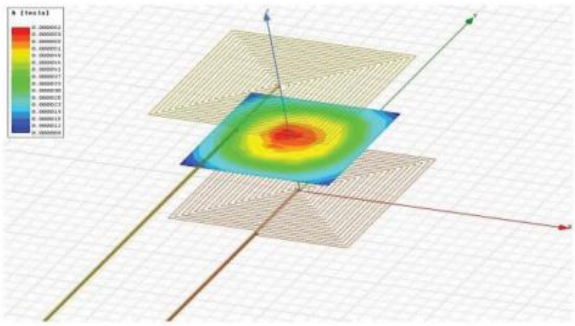

Figure 3: *Magnetic field across the coils of the transmitter and receiver*

The distance between the two coils has an inverse relationship with the magnetic field that is produced between them, as can be shown in Figure 3 [11].

2.6 Coupling Coefficient Vs Coil Spacing

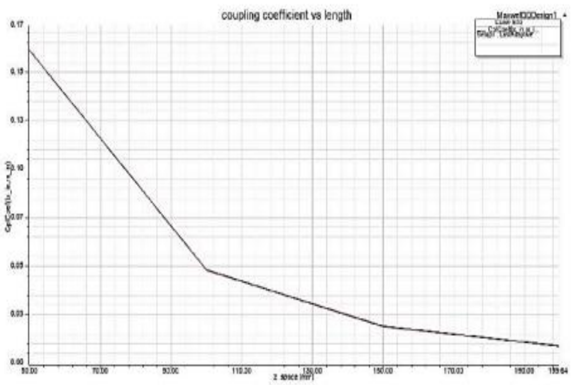

Figure 4: *Coil Spacing versus Coupling Coefficient*

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Figure 4 makes it abundantly evident that the air gap between the coils and the coupling between them is inversely related and the coupling coefficient falls with increasing distance. [12].

2.7 Mutual Inductance Over the Coils That Transmit and Receive

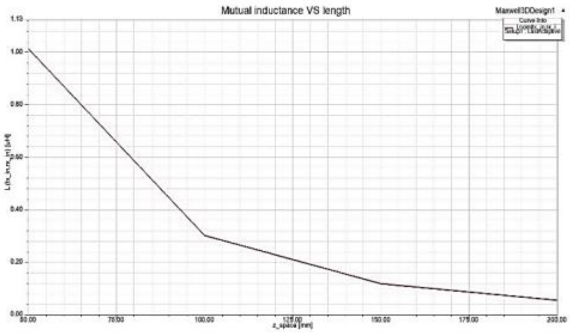

Figure 5: *Mutual inductance in relation to length*

Figure 5 demonstrates that because mutual inductance is inversely proportional to the distance between coils, it decreases as coil distance increases.

3 3d Modelling Of Coil

The 3Dimension modelling of the coils shown in Figure 6 was developed using ANSYS Maxwell software, featuring a circular planar coil design. Copper was selected as the material for the coils. The specifications for both the receiving and transmitting coils are identical [15] [16]. In this simulation, there is a 10 cm gap between the coils.

3.1 The Ansys Maxwell Designed Coil

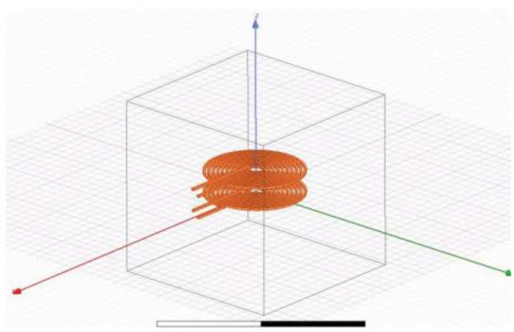

Figure 6: *Coil for the transmitter and receiver*

The overall inductance of the proposed coils is determined using ANSYS Maxwell's magneto static simulation. After importing the two coils into ANSYS Twin Builder, the capacitor values at a frequency of 13.56 MHz are computed. Figure 7 presents the results of this simulation. The

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inductance of the transmitter coil is measured at 0.9001 μH, while the receiving coil also has an inductance of 0.9001 μH. The coils are positioned 10 cm apart.

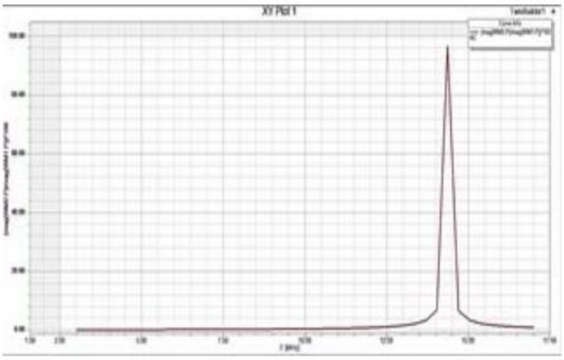

Figure 7: *Efficiency against Frequency*

It is evident from the plot that the frequency at which the capacitor values were designed, 13.556 MHz, achieves the highest efficiency, exceeding 95%.

3.2 The Calculation of Equivalent Circuit and Efficiency

Figure 11 shows the fundamental equivalent circuit of a system for WPT. The circuit includes a voltage source (Vs), coils (Lp, Ls), capacitors (Cp, Cs), a load resistor (R), and their respective internal resistances (Rp, Rs).To achieve optimal effectiveness,

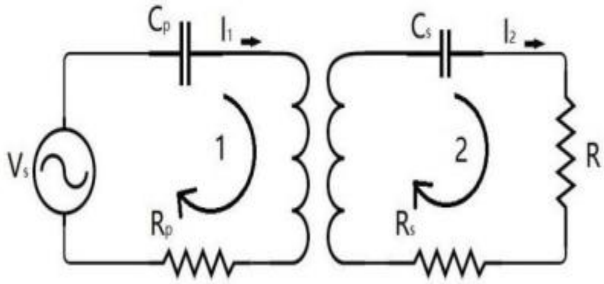

Figure 8: *Circuit Equivalency*

From Loop 1,

$$V_s = I_1[R_P + JL_p\omega + \frac{1}{j_\omega c_P}] - I_2(jL_M\omega) \tag{1}$$

From Loop 2,

$$0{=}I_2\left[jLs\omega + \frac{1}{j\omega c_s} + z_0 + R_s\right] - I_1(j_{L_m\omega}) \tag{2}$$

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$$c_P = cs = c$$
$$L_P = Ls = L$$
$$R_P = R_s = R \tag{3}$$

$$I_2[jL\omega + \frac{1}{j\omega c} + z_0 + R] = I_1(j_{L_m}(\frac{1}{j\omega c}) + z_0\omega) \tag{4}$$

$$I_2 = I_1 \frac{j_{L_m}\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R]} \tag{5}$$

$$v_S = I_1[R + j_L\omega + (\frac{1}{j\omega c}) \text{-} I_1[\frac{(j_{L_m}\omega)^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}] \tag{6}$$

$$z_i = R + j_L\omega + \frac{1}{j\omega c} + [\frac{L_m^2\omega^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}] \tag{7}$$

$$z_i = R + jL\omega + \frac{1}{j\omega c} + [\frac{L_m^2\omega^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}] + j_{L_m\omega} - j_{L_m\omega} \tag{8}$$

$$z_i = R + \frac{1}{j\omega c} + j(L - L_m)\omega + \frac{-jL_m^2\omega^2 + j^2 L_m L\omega^2 + jL_m\omega(z_0 + R) + jL_m(\frac{1}{j\omega c})\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R} \tag{9}$$

$$z_i = R + \frac{1}{j\omega c} + j(L - L_m)\omega + \frac{(j\omega L_m)(j(L - L_m)\omega) + \frac{1}{j\omega c} + z_0 + R}{jL\omega + \frac{1}{j\omega c} + z_0 + R} \tag{10}$$

$$z_i = R + \frac{1}{j\omega c} + j(L - L_m)\omega + \frac{1}{\frac{1}{jL_m\omega} + \frac{1}{j(L - L_m)\omega + \frac{1}{j\omega c} + z_0 + R}} \tag{11}$$

$$z_i = R + jL\omega + \frac{1}{j\omega c} + \left[\frac{L_m^2\omega^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}\right] \tag{12}$$

Efficiency of the equation,

$$\eta = \frac{p_0}{p_i} = \frac{I_2^2 z_0}{I_1{}^2 z_i} \tag{13}$$

From eqn [4],

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$$\frac{I_2}{I_1} = \frac{jL_m\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R} \tag{14}$$

From eqn [11] and [12],

$$\eta = \left[\frac{jL_m\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R}\right]^2 \frac{z_0}{\left[R + jL\omega + \frac{1}{j\omega c} + \left[\frac{L_m^2\omega^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}\right]\right]} \tag{15}$$

To transfer power as much as possible,

$$L_m^2 = \frac{z_0^2 - R^2}{\omega_0^2} \tag{16}$$

4 Result and Discussion

Simulation of Equivalent Circuits with MATLAB. The effectiveness of WPT is analyzed using the MATLAB simulation program. The previous section provided the values for the circuit parameters. It is believed that 3.3 kW of input power, delivered by 132.5 V sinusoidal waves, is used for electric vehicles (EVs). The power and efficiency measurements are explained using established techniques from the literature.

Using MATLAB Simulink's transient analysis, the wireless power transfer system's overall effectiveness is evaluated. The parameters for simulation include a coil resistance of 50 mΩ, a load resistance of 5 Ω, an inductance value of 0.9001 µH, a mutual inductance of 0.1159 µH, and a capacitance of 0.1375 NF.

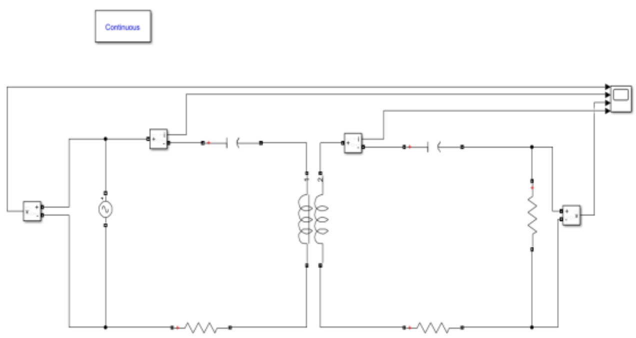

Figure 9: *Equivalent Circuit in MATLAB*

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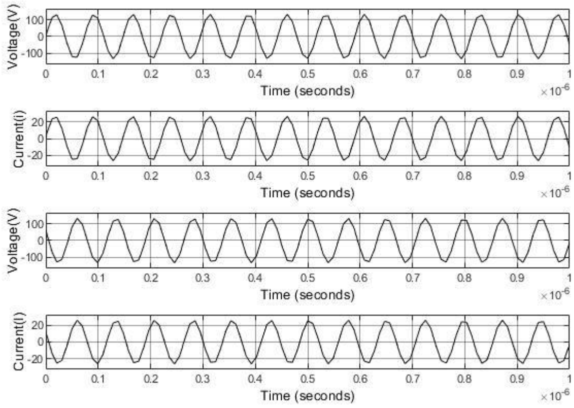

Figure 10: *Output wave form*

We obtained an output of 125.87V and 25.16A for an input of 131.5V and 24.67A. 3.2 kW of power were obtained in the load when 3.3 kW of input power was used. Power of about 100W faded away as a loss.

5 Conclusion

The focus of this study is on charging electric vehicle batteries through wireless technology. The coil and overall circuit model were developed using ANSYS Twin Builder and ANSYS Maxwell, along with MATLAB for the computation of the equivalent circuit and efficiency. Simulation results demonstrate that wireless EV charging via magnetic resonance can achieve an efficiency of 97.1% at a distance of 10 cm, comparable to traditional wired charging systems. This is largely due to the WPT approach, which eliminates the isolation transformer, a major source of losses in wired systems.

The study also highlights that factors such as resonance, coil spacing, and circuit impedance significantly influence the optimal efficiency of wireless charging. The system is designed for a 3.3 kW input, producing 3.2 kW output. As the climate change and fossil fuel depletion make vehicle electrification essential, wireless technology presents several advantages over conventional charging methods. While the initial costs may be higher, maintenance costs are generally lower. However, WPT does have limitations; it is not suitable for long-distance applications and generates more heat than cable charging when using magnetic resonance coupling.

This technique can help mitigate power outages and energy crises, and it offers the possibility of charging EVs while they are in motion with minimal adjustments. In our quickly changing world, wireless technology is set to play a big part in EV charging in the future.

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