International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

WIRELESS CHARGING SOLUTION FOR CONNECTED ELECTRIC VEHICLES

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Abstract—Over the past ten years, electric vehicles have been steadily improving as more eco-friendly substitutes for combustion engine-powered automobiles. EVs are becoming more dependable as their performance and range improve. Adding wireless charging to electric vehicles can increase their accessibility. The exciting development of wireless charging for electric vehicles makes charging them more practical. The utility of electric vehicles is increased by this charging method, and wireless power transfer enables electricity to be transferred from a power source without messy wires. The use of magnetic resonance coupling, one of the most effective wireless power transmission techniques, and its real-world applications in electric vehicles are covered in this research. Analysis is also done on the effectiveness of wireless power transfer and how it declines with distance.

Key Words: Wireless power transmission (WPT), Magnetic resonance coupling, Wireless charging, Transmission Efficiency, Impedance Matching, Electric Vehicles.

1. INTRO DUCTION

Electric vehicles have become a more popular choice in the automotive business. One or more traction motors are used by an electric vehicle, often known as an EV, for propulsion and working. Electricity from distant power sources is used to power an electric car through a collector system. The car is powered by a sizable traction battery, which must be charged by plugging it into a charging outlet [1]. The fundamental issue with EVs is that their electric batteries are less dense and less effective than those used in gasoline-powered engines. The fundamental benefit of wireless power transfer over wired power transfer is that it can do away with cables and infrastructure, offer mobility within transmission range, and also do away with problems with power plug compatibility. This study suggests a mechanism to efficiently utilize wireless charging techniques for electric vehicles.

There are several ways to transmit power wirelessly (WPT), including microwave transmission, inductive coupling, laser transmission, magnetic resonance coupling, and more [2, 3]. The most successful and efficient technique is magnetic resonance coupling. The process of magnetic resonance coupling entails setting up a resonance and transmitting electricity without encountering any issues with electromagnetic radiation. As a result, resonance frequency plays a key role in circuit design [4, 5]. The primary goal of this study is to identify the best and most efficient way for wirelessly recharging an electric vehicle (EV) in light of wireless power transfer coefficient fluctuations. Impedances on the main and secondary sides of a capacitor must be as low as possible for best power transfer efficiency. t is necessary to match the WPT system [6]. With changes in coil spacing, the resonance frequency of the transmitter and receiver also changes. The Industrial Scientific and Medical (ISM) band, however, encloses the useable frequency when the technology is applied to the megahertz range. It is necessary to establish the resonance frequency inside the ISM band as a result [7].

Ansys Maxwell and Ansys Twin Builder are used to simulate different power transfer stages and the variables that affect magnetic resonance coupling efficiency. From the simulations, it can be shown that the Q factor, the frequency of the resonating coils, the distance between the coils, and the shape of the coil all affect how effectively magnetic resonance coupling occurs. Planar type coils are more effective than other sorts of coil conceptions utilized in power transfer solenoids, including rectangular, square, and circular shapes. The angular displacement has less of an impact on coils of the planar type [9].

2.ELECTRIC VEHICLE WIRELESS CHARGING SYSTEM

Systems for wireless charging are made up of many parts to ensure proper operation. Figure 1 depicts the various phases of WPT. The source's AC power is transformed into DC at the source. To convert AC to DC, a complete bridge rectifier is being employed. The inverter receives the rectifier's output in order to obtain a high-frequency AC source. The transmitting side of the system is given access to this high-frequency AC output from the inverter. In order to protect the circuit from high voltage AC, the inverter's output is passed into a signal conditioning circuit before being supplied into the transmitting circuit's input. [2].

A resistor, a capacitor, and the transmitting coil make up most of the transmitting circuit. Both the transmitting and receiving sides utilize a circular planar copper coil. The power transmitted by the transmitting coil is captured by the receiving coil. Along with the receiving coil, a resistor and capacitor are present on the receiving side. To store energy, the load side AC is transformed to DC. [9].

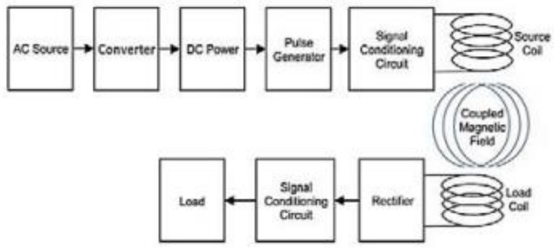

Figure 1 Block Diagram of Proposed System

2.1CONVERTER MODELLING

A full-wave rectifier circuit is created using diodes and filter capacitors.

The rectifier's purpose is to change 120V AC voltage into DC.

The rectifier circuit receives a voltage of 120V AC, and the resultant output voltage is 76V DC.

Vp = 120 V, hence VDC = (2Vp)/ = 76 V.

The filter capacitor's capacitance is 6800 f.

The inverter is connected to the rectifier's output. The transmitting coil is connected to the square wave produced by the inverter. The inverter's output frequency is 13.56 MHz

3 3D COIL MODELLING FOR POWER TRANSFER

SYS Maxwell software is used to simulate the transmitter and receiver coil in three dimensions. To record the magnetic fields that occur between the coils, a transparent rectangular plate is positioned between the transmitting and receiving coils [7, 8]. As both coils have the same size, a greater coupling coefficient is obtained. The design of a transmitting and receiving coil using ANSYS Maxwell is shown in figure 2.

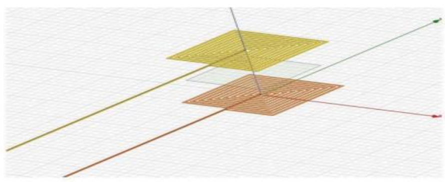

Figure 2 Coil Design

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3.1DESIGN PARAMETERS OF THE COIL

Table 1 Specifications of the designed 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

3.2DIMENSIONS OF THE RECTANGULAR PLATE

Table 2 Design parameters of the rectangular plate

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

3.3 A MAGNETIC FIELD EXISTS BETWEEN THE TWO POWER TRANSFER COILS

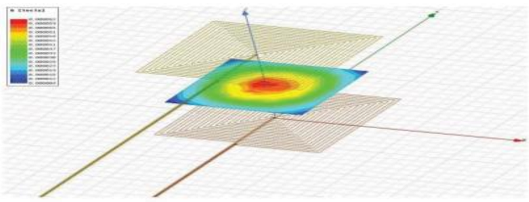

Figure 3 Magnetic field between transmitter and receiver coil.

It can be shown from Figure 3 that the magnetic field generated by the two coils is inversely proportional to their distance [11].

3.4COUPLING COEFFICIENT VS COIL SPACING

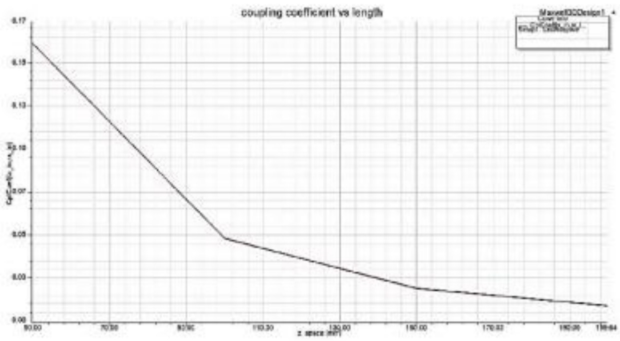

Figure 4 Coupling coefficient vs coil spacing

The coupling coefficient will decrease because, as can be seen from Figure 4, the air gap between the coils is inversely proportional to the coupling between the coils [12].

3.5 Mutual interaction between the sending and receiving coils

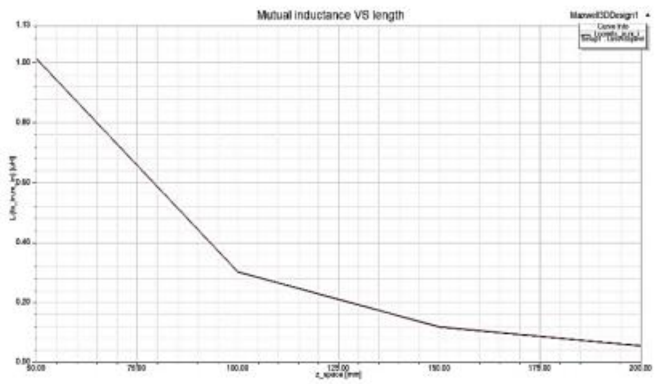

Figure 5 Mutual inductance vs length

Figure 5 shows that the mutual inductance will decrease as the distance between the coils grows, i.e., it is inversely proportional to the distance.

4 3D MODELLING OF COIL

ANSYS The 3D model of the coils in figure 6 was created using Maxwell software. This simulation makes use of a circular planar coil architecture. The coil in use is made of copper. The specifications of the transmitter and receiving coil are identical. [15] [16]. For this simulation, a 10 cm gap exists between the coils.

4.1 THE DESIGNED COIL IN ANSYS MAXWELL

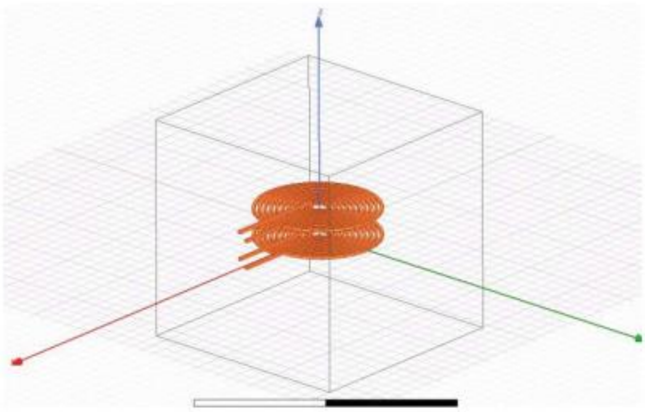

Figure 6 Transmitter and receiver coil

The overall inductance of the planned coil is calculated using ANSYS Maxwell's magneto statics simulation. The capacitor values are then determined for the frequency 13.56 MHz once the two coils are added to Ansys Twin Builder. Figure 7 is the result of conducting the simulation.

The transmitter coil's inductance value is 0.9001uH.

The receiving coil's inductance value is 0.9001uH.

The coils are separated by 10 cm.

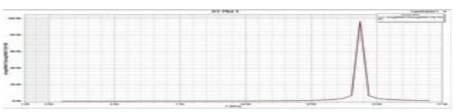

Figure 7 Frequency vs Efficiency

From the plot the maximum efficiency is found at 13.556MHz which is the frequency we designed the capacitor values; the efficiency value is above 95%.

5. EQUIVALENT CIRCUIT AND EFFICIENCY CALCULATION

Figure 11 depicts the fundamental equivalent circuit of a wireless power transfer system. The voltage source (Vs), capacitors (Cp, Cs), coils (Lp, Ls), their internal resistance (Rp, Rs), and a load resistor (R) are all present in the circuit below.

For getting maximum efficiency,

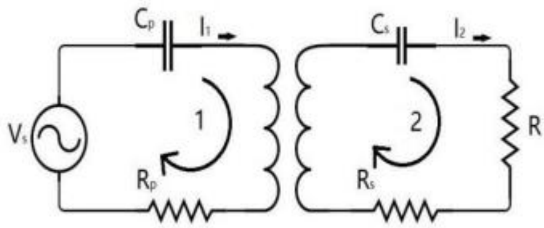

Figure 8 Equivalent circuit

From Loop 1,

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

From Loop 2,

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

$$c_P = cs = c$$
$$L_P = Ls = L$$

$$R_P = R_s = R$$

$$I_2[jL\omega + \frac{1}{j\omega c} + z_0 + R] = I_1(j_{L_m}(\frac{1}{j\omega c}) + z_0\omega) \quad [3]$$

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

$$v_s = I_1[R + j_L\omega + (\frac{1}{j\omega c}) - I_1[\frac{(j_{L_m}\omega)^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}] \quad [5]$$

$$z_i = R + j_L\omega + \frac{1}{j\omega c} + \left[\frac{L_m^2\omega^2}{jL\omega+\frac{1}{j\omega c}+z_0+R}\right] \quad [6]$$

$$z_i = R + jL\omega + \frac{1}{j\omega c} + \left[\frac{L_m^2\omega^2}{jL\omega+\frac{1}{j\omega c}+z_0+R}\right] + j_{L_m\omega} - j_{L_m\omega} \quad [7]$$

$$z_i = R + \frac{1}{j\omega c} + j(L-L_m)\omega + \frac{-jL_m^2\omega^2 + j^2L_mL\omega^2 + jL_m\omega(z_0+R) + jL_m(\frac{1}{j\omega c})\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R} \quad [8]$$

$$z_i = R + \frac{1}{j\omega c} + j(L-L_m)\omega + \frac{(j\omega L_m)(j(L-L_m)\omega) + \frac{1}{j\omega c} + z_0 + R}{jL\omega + \frac{1}{j\omega c} + z_0 + R} \quad [9]$$

$$z_i = R + \frac{1}{j\omega c} + j(L-L_m)\omega + \frac{1}{\frac{1}{jL_m\omega} + \frac{1}{j(L-L_m)\omega + \frac{1}{j\omega c} + z_0 + R}} \quad [10]$$

$$z_i = R + jL\omega + \frac{1}{j\omega c} + \left[\frac{L_m^2\omega^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}\right] \quad [11]$$

Equation for efficiency,

$$\eta = \frac{p_0}{p_i} = \frac{I_2^2 z_0}{I_1{}^2 z_i} \quad [12]$$

From eqn [4],

$$\frac{I_2}{I_1} = \frac{jL_m\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R} \quad [13]$$

From eqn [11] and [12],

$$\eta = \left[\frac{jL_m\omega}{jL\omega + \frac{1}{j\omega c} + z_0 + R}\right]^2 \frac{z_0}{\left[R + jL\omega + \frac{1}{j\omega c} + \left[\frac{L_m^2\omega^2}{jL\omega + \frac{1}{j\omega c} + z_0 + R}\right]\right]} \quad [14]$$

For maximum power transfer,

$$L_m^2 = \frac{z_0^2 - R^2}{\omega_0^2} \quad [15]$$

6. RESULT

Equivalent Circuit Simulation in MATLAB

MATLAB simulation software is used to calculate the effectiveness of WPT.

As was said earlier, circuit parameter values. 3.3kW are used as the input power for EVs. It is powered by 132.5 V of sinusoidal waves, and the methods used to calculate its power and efficiency is given.

Transient analysis in MATLAB Simulink is used to determine the overall effectiveness of the wireless power transmission system. The mutual inductance is 0.1159uH, the capacitance is 0.1375nF, the coil resistance is 50m Ohms, and the load resistance is 5ohm. The inductance value is 0.9001uH.

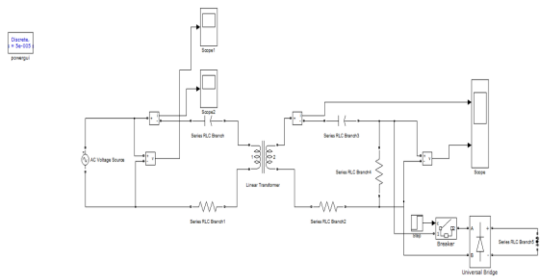

Figure 9 Equivalent circuit in MATLAB

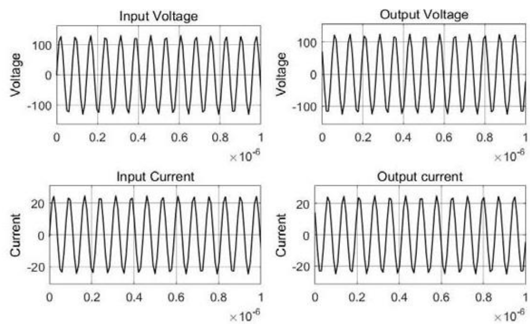

Figure 10 Output wave form

We obtained 125.87V and 25.16A as the output with an input of 131.5V and 24.67A. The power output into the load was 3.2kW. when 3.3 kW of input power was used. A loss of around 100W of electricity occurred.

7. CONCLUSION

The wireless battery charging of electric vehicles is the topic of this study. The coil and whole circuit models were created with ANSYS Twin Builder and ANSYS Maxwell. And MATLAB was used to calculate the equivalent circuit and efficiency. The efficiency of wireless EV charging via magnetic resonance across extended distances is demonstrated by simulation results, and we determined it to be 97.1% for a distance of 10 switch, when the isolation transformer—the principal lossy component of a wired charging system—is deleted using the WPT approach, is found to be comparable to that of a traditional wired charging system. Additionally, it was discovered that resonance, coil spacing, and circuit impedance all affect how efficiently wireless charging operates at its highest level. In this study, the output is 3.2kW for a 3.3kW input. Because fossil fuels are becoming increasingly scarce and the environment, electrification of vehicles is unavoidable. Compared to wired charging, wireless charging will offer a variety of advantages. The original cost is relatively high, but the maintenance cost is lower. Additionally, WPT using magnetic resonance coupling has several restrictions, such as higher heating as compared to cable charging and the inability to be employed for long-distance applications. This approach also aids in lowering power outages and energy crises. We can also use this strategy to charge the EV while jogging with a small adjustment. Wireless technology is crucial to the future of electrical vehicle charging in today's quick-paced society.

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