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Static Wireless Charging for Electric Vehicles

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Abstract

Electric vehicles have been continuously evolving energy-efficient alternatives to vehicles powered by combustion engines during the last decade. EV's are getting more reliable with increased range and performance. It is more accessible when we give the wireless charging system for electric vehicles. Wireless charging for an electric vehicle is an interesting innovation that makes electric vehicle charging more convenient. This mode of charging improves the usability of Electric vehicles and wireless power transfer allows transferring power from a power source without clutters of wires. This discusses one of the most efficient types of wireless power transfer method **-** *Magnetic Resonant coupling and its simulation will done in MATLAB-Simulink. The efficiency of wireless power transfer and its decrease with separation is also analyzed.*

Keywords: *Wireless power transfer (WPT), Magnetic resonance coupling, Electric vehicles, Transmission efficiency, Impedance matching, Coupling Coefficient, Wireless charging.*

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I. INTRODUCTION

The automobile industry has deviated towards an ecofriendly alternative, i.e., the electric vehicles. An electric vehicle, collectively called as EVs, uses one or more traction motors for propulsion and working. An electric vehicle is powered through a collector system using electricity from distant power sources. It uses a large traction battery to power up the vehicle, which is to be connected to a charging outlet to power the battery up. The main problem associated with EVs is that the electric batteries are not as dense or efficient than the motors working on gasoline. The main advantage of wireless power transfer over wired is that it can eliminate cable and infrastructure and can provide mobility within transmission range it can also eliminate power plug compatibility issues. This paper proposes a system to implement wireless charging methods for an electric vehicle with high efficiency.

There are various methods of wireless power transmission (WPT), namely microwave power transmission, inductive-coupling-power transmission, laser-power transmission methods, magnetic resonance coupling etc. Among them, the most effective and efficient method is Magnetic Resonant Coupling. Magnetic resonance coupling involves the creation of a resonance and transmission of the power without radiation problems due to electromagnetic waves. Hence, the resonance frequency is a crucial factor in the circuit design. The main aim of this paper is to define the most efficient and effective method for wireless charging of the EV according to coefficient variations in wireless power transfer. To obtain maximum power transfer efficiency, impedances of the primary and secondary sides of the WPT system needs to be matched. Resonance frequency of the transmitter and receiver changes along with the changes in coil spacing. However, as the technology is applied to the level of megahertz range, the usable frequency is enclosed by the Industrial Scientific and Medical (ISM) band. Hence, the resonance frequency has to be fixed within the ISM band.

Simulations of various power transferring stages and the factors that affects the efficiency of magnetic resonance coupling are done using Ansys Maxwell and Ansys Twin Builder. From the simulations it is observed that the efficiency of magnetic resonance coupling depends on various factors like the shape of the coil, the distance between the coils, frequency of resonating coils and Q factor. There are different types of coil concepts used for power transfer solenoid, rectangular, square and planar circular among them planar type coils are more efficient. The planar type coils are also less affected by angular displacement.

II. Wireless Charging System For Electric Vehicles

Wireless charging systems consist of different components for its smooth working. The various stages involving WPT. The AC power comes from the source and is converted into DC. A full bridge rectifier is being used to convert AC-DC. The output of the rectifier is supplied to the inverter for getting a high-frequency AC source. This high frequency AC output from the inverter is supplied to the transmitting side of the system. The output from the inverter is fed into a signal conditioning circuit for protecting the circuit from high voltage AC and then into the input of the transmitting circuit.

The transmitting circuit mainly consists of a resistor, a capacitor and the transmitting coil. A circular planar copper coil is used for both transmitting and receiving sides. The receiving coil collects the power transmitted from the transmitting coil. The receiving side has a resistor and a capacitor in parallel with the receiving coil. The load side AC is converted DC for storing purposes.

2.1 Proposed System

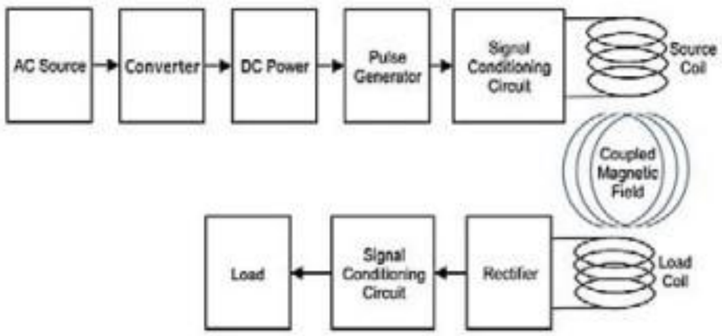


Fig:1 Block diagram of Proposed System

2.2 Converter Modelling

Diodes and filter capacitors are used to design a full-wave rectifier circuit. The rectifier is designed to convert 120V AC into DC. A voltage of 120V AC is supplied to the rectifier circuit, the obtained output voltage of the circuit is 76V DC. VDC= (2Vp)/π =76 V since Vp =120 V.

The output of the rectifier is connected to the inverter. The inverter generates a square wave which is connected to the transmitting coil.

III. Equivalent Circuit And Efficiency Calculation

The basic equivalent circuit of wireless power transfer system is shown below. The following circuit contains voltage source (Vs), Capacitors (Cp, Cs), coils (Lp, Ls), their internal resistance (Rp, Rs) and a load resistor(R). For getting maximum efficiency,

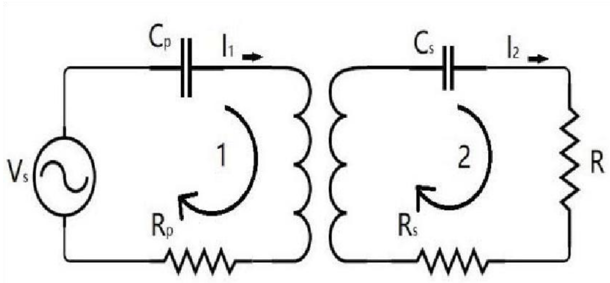


Fig:2 Equivalent Circuit

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,

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

$$c_p = cs = c$$
$$L_p = Ls = L$$

$$R_P = R_s = R$$

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

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

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

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

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

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

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

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

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

Equation for efficiency,

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

From eqn [4],

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

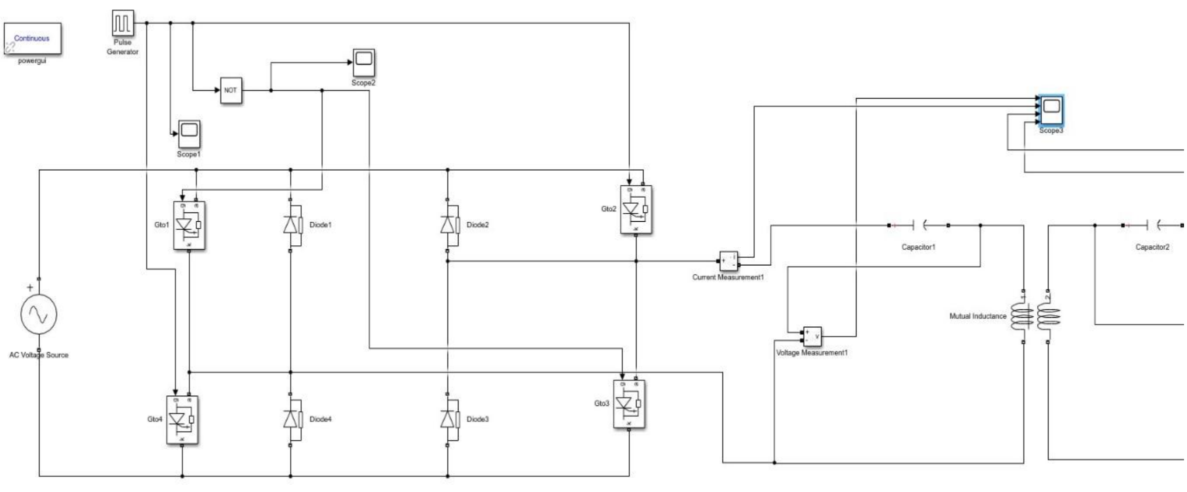
From eqn [11] and [12],

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

For maximum power transfer,

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

IV. Design of Wireless Charging System



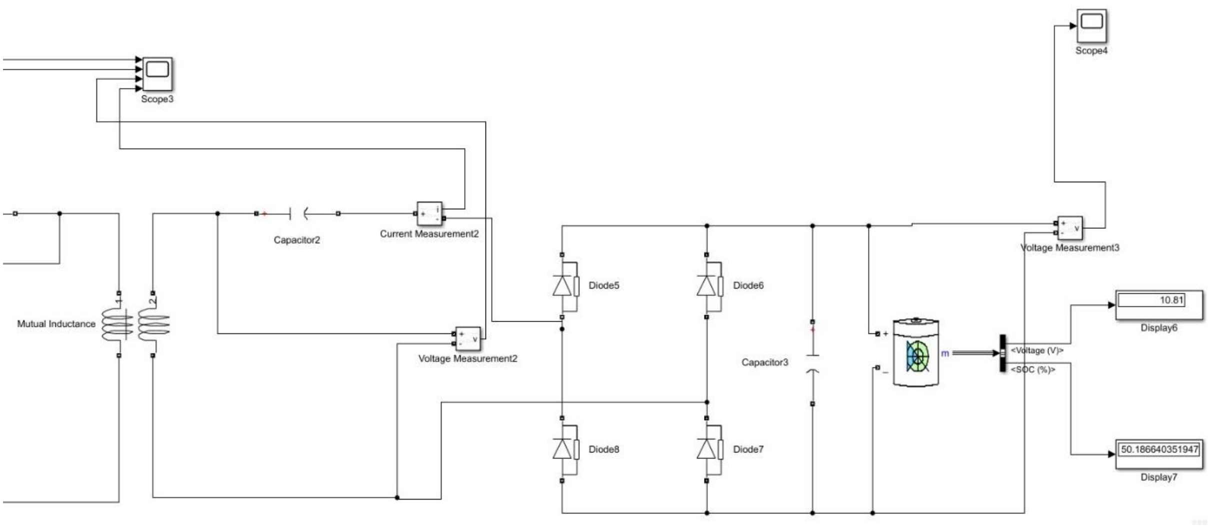


Fig:3 Simulink Model

V. RESULT

To determine the efficiency of WPT, MATLAB simulation software is used. The values of circuit parameters are discussed above. The input power for EV's is taken as 1.67kw. It is driven by sinusoidal waves of 132.5 V, and the determination of power and efficiency, is described using previously described methodology.

The total efficiency of wireless power transfer system is found out using the MATLAB Simulink. The inductance value equals to 1uH, mutual inductance is 1.1uH, Capacitance of 1uF, coil resistance R is 1Ohm and a load resistance of 0.05ohm.

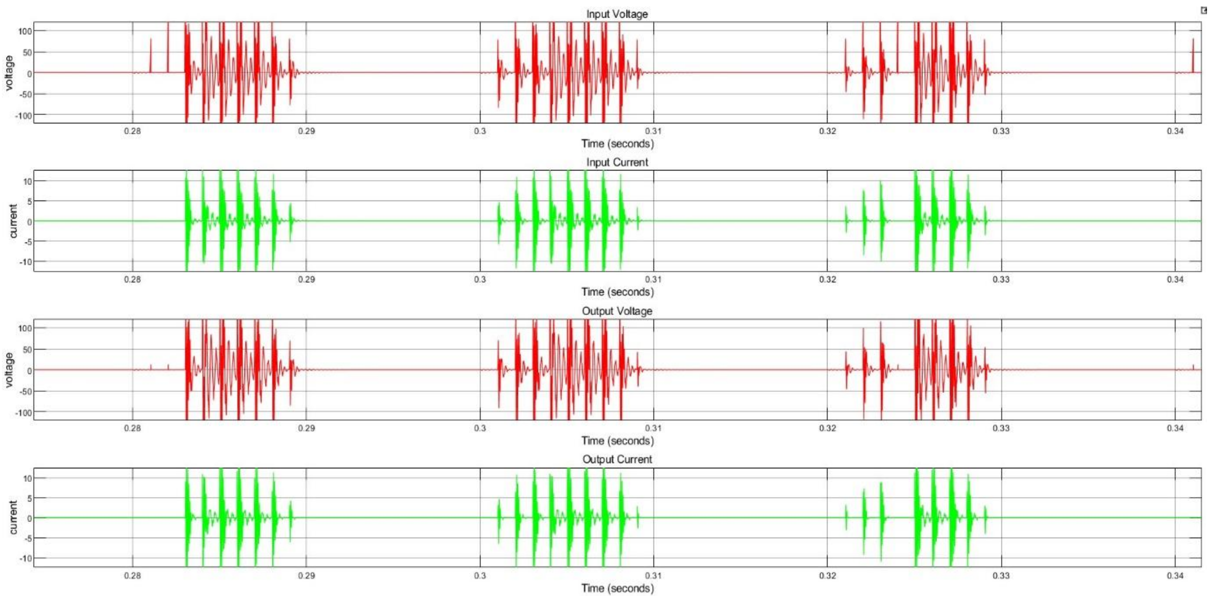


Fig:4 Input, Output-Voltage and Current Waveforms

They are not pure sinusoidal because of variation in frequency but we need to match the input and output, voltage and current waveforms. From the above we can see the input, output-voltage and current waveforms are matched.

For 131.3V and 12.79A input we got 128.4V and 12.8A as output. The amount of power obtained in the load was 1.64kW. When the input power was 1.67kW. Almost 30W power dissipated as loss.

VI. CONCLUSION

This paper deals with wireless battery charging of electric vehicles. Simulation results shows us the efficiency of wireless EV charging by magnetic resonance over long distances, and we found the efficiency to be 97.86% for a distance of 10cm.Which is found to be similar to that of a conventional wired charging system, as the isolation transformer, which is the main lossy component of wired charging system can be eliminated by using WPT method. Also, it was observed that the maximum efficiency of the wireless charging depends on resonance, coil spacing and the impedance of the circuit. In this paper for a 1.67kW input, the output is 1.64kW. The vehicle electrification is inevitable due to environmental and scarcity of fossil fuels. Wireless charging will provide many benefits compared to wired charging. The maintenance cost is less, but the initial cost is very high. There are also some limitations for WPT using magnetic resonance coupling that is increased heating than wired charging and it cannot be used for long distance applications. This method also helps us to reduce energy crisis as well as power loss. Also, with slight modification we can even use this method to charge the EV while running. In this fast-paced world wireless technology plays a major role in the future of electrical vehicle charging.

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