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CHALLENGES IN WIRELESS CHARGING FOR ELECTRIC VEHICLES

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Abstract

Wireless charger". "Electric vehicles". Two concepts that are much talked about. Putting them together in a single sentence, as in "let me hook up my electric vehicle to my wireless charger Not so much. In wireless charging the current coming from the wall power outlet moves through the wire in the wireless charger, creating a magnetic field. The magnetic field creates a current in the coil inside the device. This coil is connected to the battery and the current charges the battery. The two induction coils in proximity combine to form an electrical transformer. Wireless charging has been around for years in low-power consumer applications – wireless shavers are widely available, and electric toothbrushes have used it since the early 1990s. Even the medical field is using wireless charging for subcutaneous implants

Introduction

Almost all EVs today use conductive charging, but there are lingering concerns. Safety is a potential issue, especially in wet conditions. Home-based 110V or 220V systems take up to 10 hours to fully recharge an EV. Public fast-charging stations have more power available and can charge EVs in much less time, but they take up large amounts of space, and the equipment can be stolen. Also, fast chargers can degrade battery life.. In automotive, wireless charging was a feature of the GM EV1 There were three charging levels. The vehicle itself included a 1.2k Wlevel 1 charger, which ran off a standard 120V outlet. It could provide a full charge, but took as long as 14 hours; it was primarily intended to provide a quick charge to get the vehicle home or to a commercial charging station.

For home installation, a level 2 charger provided 6.6kW but required a 208-240vac supply. Recharging the EV1 to full capacity took as long as eight hours, although it could achieve 80% charge in one to three hours.

Principles of wireless charging**.**

Wireless charging for EVs uses near-field charging (NFC): a transmitting coil produces a magnetic field that transfers energy via induction to a nearby receiving coil. The fraction of the magnetic flux generated by the transmitter coil that penetrates the receiver coil and contributes to the power transfer is a function of the distance between the two coils. The transfer efficiency depends on the coupling (k) between the coils and their quality factor (Q).

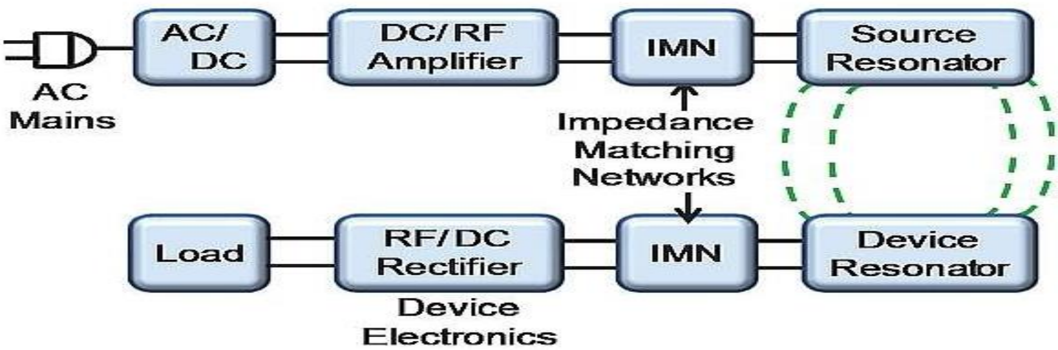

Figure 1- Resonant charging system

A tightly-coupled system gives the most efficient transfer of power but at the cost of high sensitivity to coil misalignment. Such systems are popular for consumer applications such as cell phones where the transmitter and receiver are within a few millimeters. EV wireless charging demands more flexibility in coil alignment and a longer range, so it uses a system with a resonant receive transmitter combination. This allows for looser coupling but is less efficient. Figure 1 shows the block diagram of a resonant charging system. If two high-Q resonators are placed in close proximity such that there is coupling between them, the resonators can exchange energy.

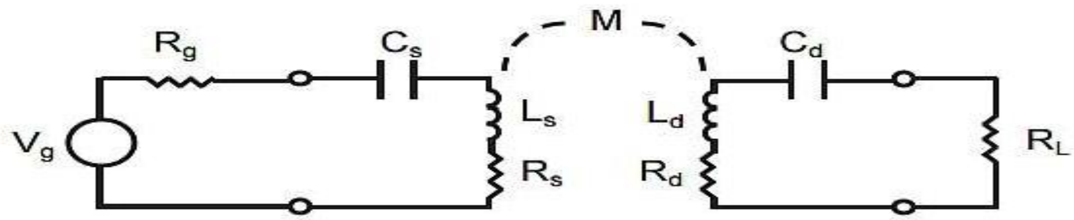

Figure 2: Equivalent circuit for a coupled resonator system (source: Witricity)

The equivalent circuit for such a coupled resonator is shown in Figure 2. The generator outputs a sinusoidal voltage with amplitude Vg and frequency ω with output resistance **Rg**. The source (transmitter) and device (receiver) resonator coils are represented by the inductors **Ls** and **Ld**, coupled through their mutual inductance M, where **M = k √ (LsLd).**

A resonator is formed by a coil and a capacitor in series. Rs and Rd are the parasitic resistances of the coil and resonant capacitor for the respective resonators. The load is represented by an equivalent AC resistance RL. The maximum power transfer efficiency (PTE) occurs at the resonant frequency and is a function of the electromagnetic coupling of the two coils. The power transfer (PT) between them occurs when the source and device impedances are matched. If the two coils are strongly coupled, PT varies with frequency, with twin peaks above and below the resonant frequency.

Coil design

The design and shape of the transmitter and receiver resonator coils have a key effect on system performance. For stationary charging, the transmitter coil is in the form of a flat pad containing the coil to generate the field and a ferrite layer to guide it, plus an aluminium layer for shielding.

Safety concerns

There are two main safety concerns with wireless systems: foreign objects between the coils, and the effects of EMI. A metallic object between the transmitter and receiver coils can be heated by the magnetic field. Above a certain size, the heat generated poses a safety risk, One way to detect its presence is by the disturbance in the magnetic field caused by induced eddy currents, which can be detected by a sensor array. The other concern is EMI. Careful coil design minimizes the amount of EM radiation that emanates outside the vehicle envelope, so even lying on the ground up against the vehicle does not heat tissue or pose an increased risk of cancer. In equipment, there is concern that wireless charging might interfere with the operation of other wireless equipment such as remote keyless entry (RKE) systems **Wireless charging future scope**

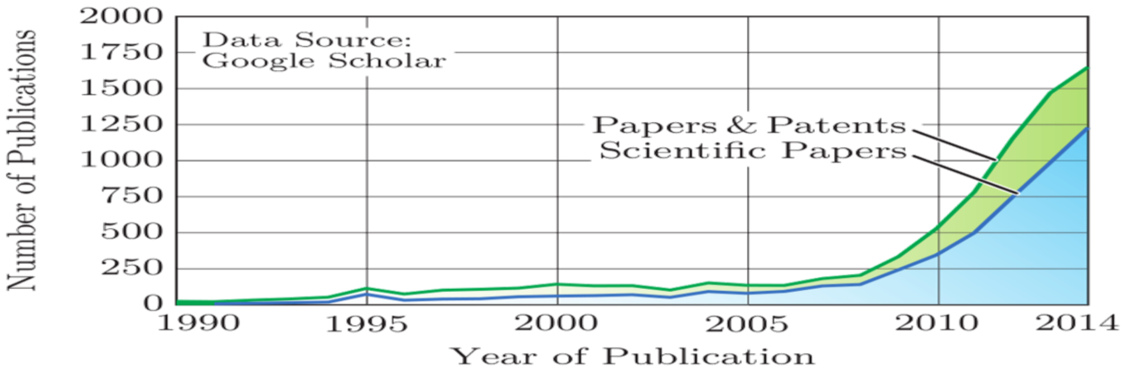

Figure 2- Number of publications

Wireless charging – generic power transfer overview

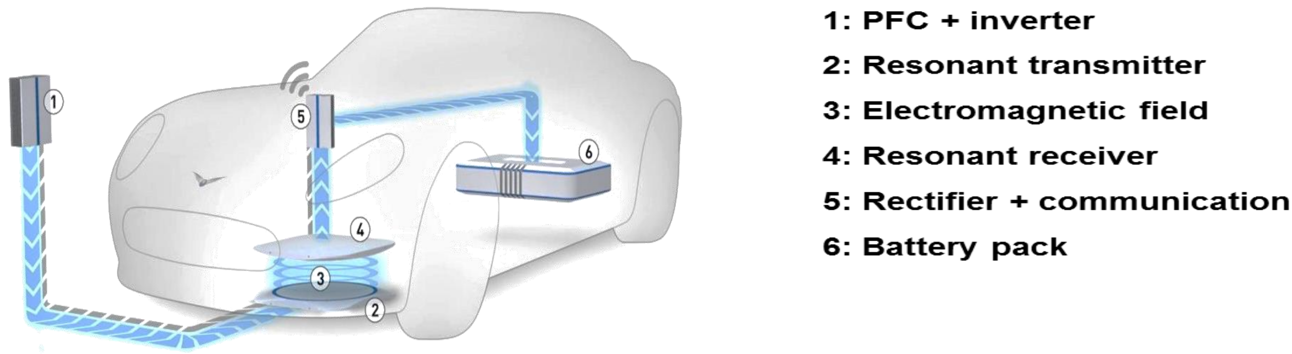

Figure 3- Wireless charging – generic power transfer

Inductive Charging :

Inductive charging is one kind of short distance wireless charging. This method works on the principle of "ELECTROMAGNETIC INDUCTION" where the charger device will create an E.M field with alternating polarity using a coil of insulated copper wire & a similar coil will be placed inside the mobile device which will convert E.M field back to electric current there by charging the battery.

Range versus efficiency

Maximum efficiency heavily depends on: Distance transmitter – receiver, Radii of antennae
Q-factor (resistance in system), Misalignment transmitter – receiver

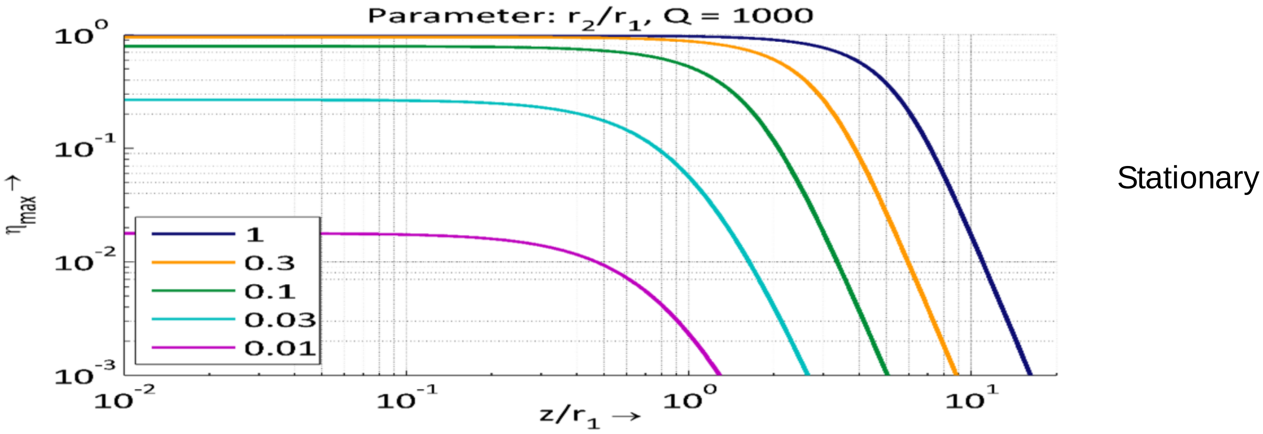

Figure-4 Range versus efficiency

Maximum efficiency heavily depends on: Distance transmitter – receive, Radii of antennae, Q-factor (resistance in system), Misalignment transmitter – receiver.

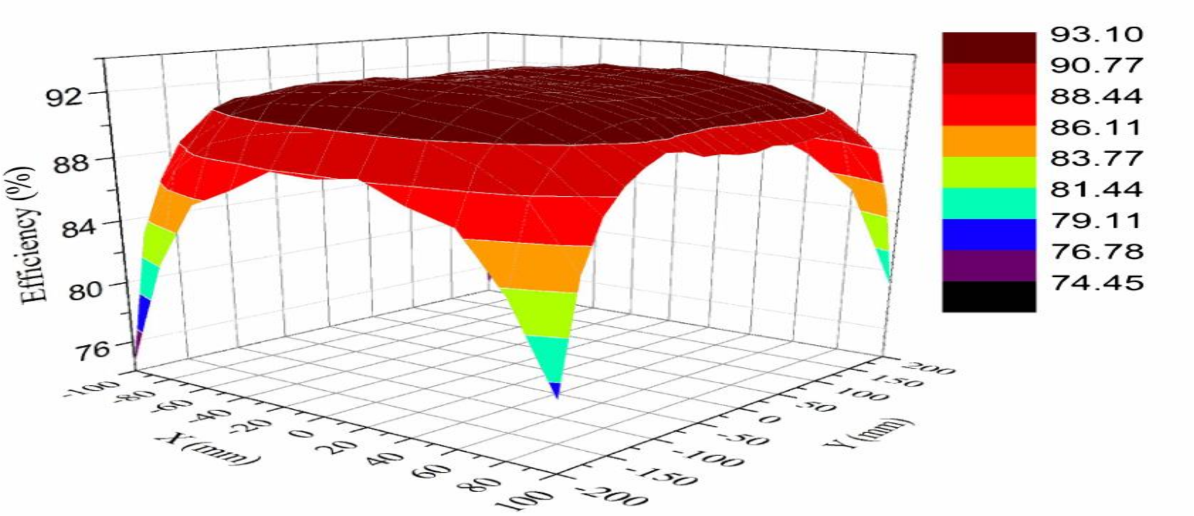

Figure-5 Distance transmitter versus efficiency

Matching resonance frequencies (1)

High efficiency → low resistances → high Q-factor

Ground and vehicle pad resonance frequency must match, Transferred power highly sensitive to frequency and matching, Resonance frequency dependent on component wear, air gap, tolerances.

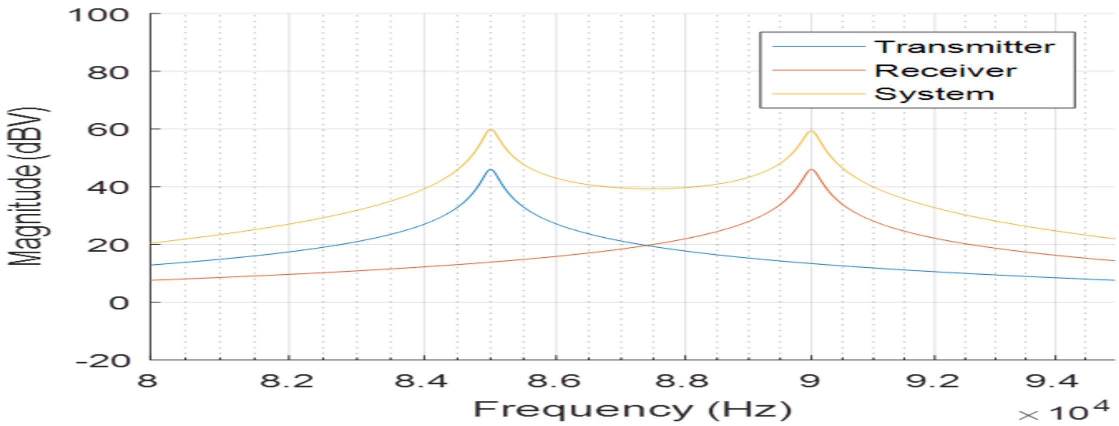

Figure-6 Matched resonance frequency

Matching resonance frequencies

Impedance matching essential for reliable and efficient operation Common method: change resonance capacitor value

$$\omega = \frac{1}{\sqrt{LC}}$$

Wireless charging circuit

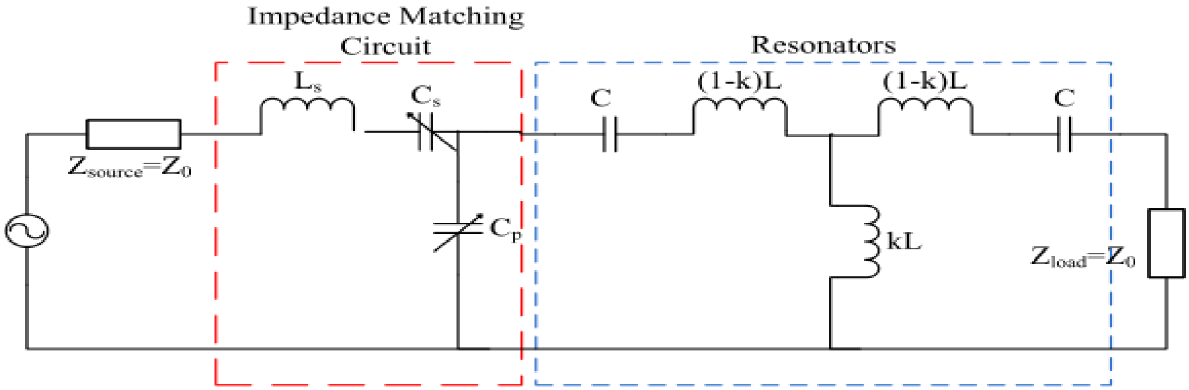

Figure-7 Wireless charging circuit

Wireless charging

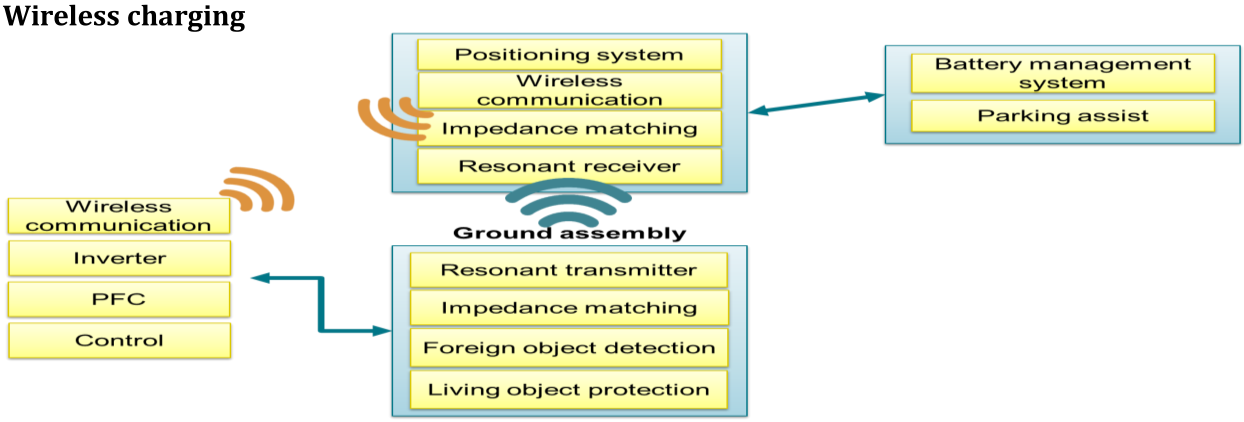

Figure-8 Wireless charging

Conclusions.

in this paper, various WPT technologies are intro-duced and compared in the perspective of EV wireless charging applications. The principles of inductive power transfer and strongly coupled magnetic reso-nance are discussed, focusing on maximum power transfer and maximum efficiency. A summary has been made on current wireless EV charging achieve-ments. High-performance, safe, and cost-effective dynamic electric vehicle charging has the potential to revolutionize road transportation. What combination of capacitive and inductive WPT will enable this revolution is an open question. Both systems offer tremendous opportunities for research, especially in high-frequency power electronics and near-field coupler design.

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