Comprehensive analysis of Wireless Power Transfer in Electric Vehicles

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Abstract

Comprehensive analysis of wireless transmission (WPT) approaches for the short and mid-range propagation. The technology and science behind WPT and the scope of the future are detailed. Although a lot of research has been done on this subject during the last decade, much of it still needs to be studied. Themes discussed further are roadway electric vehicles (RPEVs) and electric vehicles (OTVs). The following topics are covered. These cars can transform the transportation system. Nonetheless, they need major initial investments. An additional debate is being conducted on the SPS, the purpose of which is to transfer solar energy and to use it for wireless energy transmission. Attempts to sell cars using WPTs are being carried out aggressively, with the gain and drawbacks being debated.

Keywords: Inductive Power transfer (IPT), Wireless Power transmission (WPT), Online Electric Vehicle (OLEVs),

INTRODUCTION

The most popular wireless technology is the Nikola Tesla bridge, where he attempted to relay wireless electricity. He fell because of both aspects of the principle of diffusion. The Japanese scientists at the Tokyo Tower would be researching a similar phenomenon.

Early experiments in the WPT region include a 2 m transmitter room space suspension from the light bulb. When the business advances, a tram uses digital retransmission and fees to support visitors across the city of Seoul.

Fig. 1 shows the Seoul city tour tram[4]

Fig. 2 shows the transmitting coil[4]

Resonant coupling is necessary to draw electric power for automobiles. A comparison with an opera singer may clarify the resonance 's strength. If the pitch of the singer exceeds the normal pitch of the bottle, the bottle splits into fragments from the increased sound. A similar mechanism is seen in WPT as a magnetic resonance coupling .

1. BASIC PRINCIPLES FOR WIRELESS POWER TRANSMISSION

Wireless power delivery in the previous decade has been extensively studied. This can be classified on the basis of energy transport pathways into radiative and non-radiative. An antenna in the shape of an electromagnetic wave transmits the radiative force. Just as electric waves go all the way,

Efficiency of energy is weak. The non-radiative energy is based on the magnetic relation of the conducting circuits. Non-radiative power transfer can be divided into short and medium ranges where the mid-range WPT means that the propagation wavelength is greater than the length of the resonating coil.

The three basic aspects of WPT are:

1. Inductive coupling between working and driving circuits.
2. Tuning in of circuits, that is “oscillation transformer”.
3. Capacitance loaded open circuit.

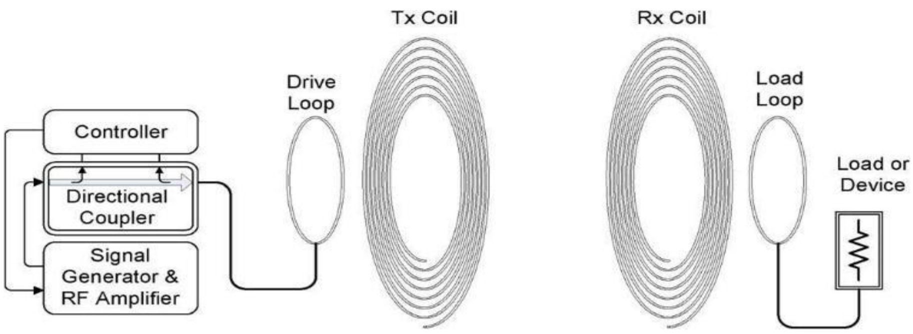

Fig. 3: Magnetically coupled WPT system.

The Tx spiral is excited by the RF-amplifier 's magnetic oscillating field that gives power to the moving coil. The Tx coil is a rotating multiturn next to the spinning control circle. It functions like a transformer step-up. The same design is now used as a transformer on the receiver side because of the single turning load loop attached to the unit. The Tx coil and the Rx coil share a reciprocal inductance based on their distance from the geometry. When the transmitting and the receiving spin are in resonance and have the same resonant frequency, electricity can be transferred through large air gaps.

The following method and definition by which transmissions can be performed are:

Coupling theory:

This method is based on the working theory of reciprocal inductance through the two-piece transformer, in order to cause stress at the ends of the other winding through electromagnetic induction, as seen in the figure. 3. The inductive relation between two drivers.

Winding Structures:

For lack of metal-metal communication the size and position of the magnetic core is important and windings therefore play an significant role in an effective power transmission. The recent development of magnetic circuits to link vehicle pads to ground pads with higher performance has greatly improved. Compared with previous pads, new polarized pads are established and have a higher output.

Inductive WPT:

A variety of EV devices like the GM EV1 have already been able to use inductive power transmission (IPT). The magnetic paddle and the secondary paddle are incorporated into epoxy. In the middle of the secondary coil is the charge paddle inserted that ends the charging of the EV1 without attachment or touch. 6.6 kW or 50 kW, respectively. This device may not have a plug, which is not wireless.

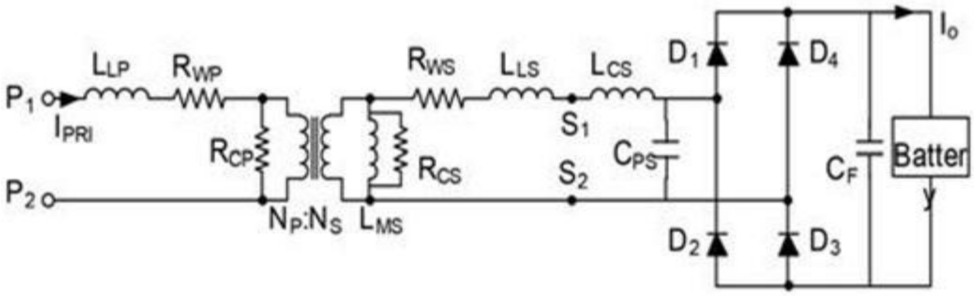

Fig.4: Inductive interface (paddle) equivalent circuit.

The equivalent circuit parameters at the charge coupling interface for an IPT charger are shown in Fig 5

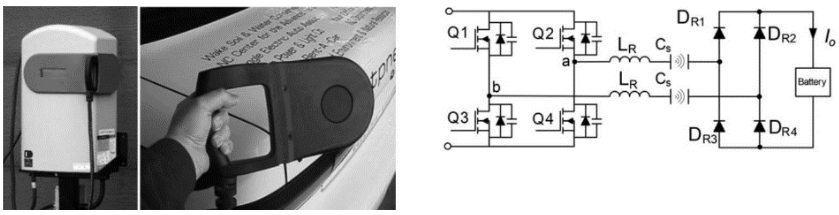

Fig. 5: schematic of a series resonant converter circuit constructed around the coupling capacitor

Figure 5 introduces an IPT universal device with a coaxial converter of ten kVA, a 6.6 kW, 77 kHz, a 200/400 V EV adapter. Through using a coaxial winding transformer, the transformer will transfer the core material off-board and decrease the susceptibility to flux density and frequency of the online EV portion. Through using this approach, transformers require the installation of a single loop that can work over a wide frequency spectrum and the ability to scale up to various power consumptions. The transformer's central architecture involves the effect of non-linear flux propagation, contributing to losses including eddy current and electromagnetic interference. The above losses depend on the core scale, which decreases as the transformer is raised. Capacitive WPT:

As an effective contactless communication method, the latest technical innovation of the efficient wireless power transfer has been suggested. The configuration of the coupling capacitor is the same as the CPT interface. Other sections such as systems for inverters and rectifiers remain similar. Since magnetics do not degrade at any power level as desired. For a capacitive design, the costs and measurements of the galvanic insulation can be minimized. In high-power applications though, this choice is not the favored one. So this makes it easier to extend the bulk of the current CPT technologies to low power applications so handheld electronic devices such as wireless brush loaders or wireless cell phone loaders where a power transfer interface and capacitive matrix pads are introduced.

Low frequency permanent magnet coupling power transfer (PMPT):

Low-frequency PMPT is a mixture of magnetic devices and synchronous electrical magnet permanent machines. There are two major physical elements and they are highlighted in the figure:

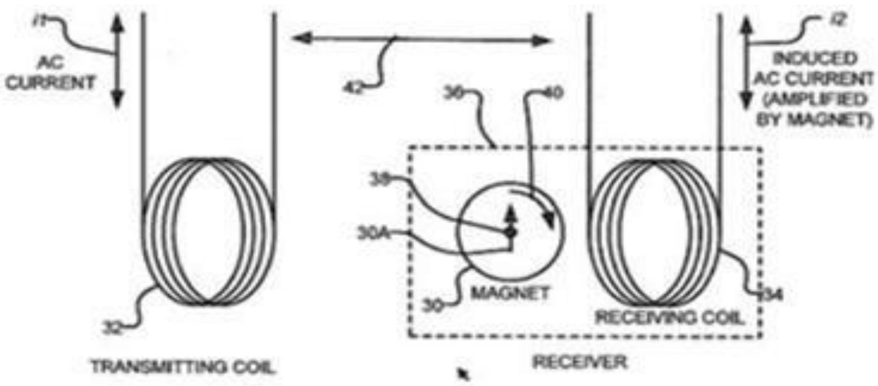

Fig. 6: Use of a rotating magnet to enhance inductive power transfer between two coils.

PMPT transmitter:

An out-of-the-box, self-including motor or directly by static windings are either driven by a cylinder rotor that is permanently magnetized around the circumference of the rotor, separated by air gaps and either positioned outside the rotor or inside the rotor, where it is hollow.

PMPT Receiver:

A similar rotor is located on the vehicle within 150 mm and parallel to the power supply side during testing. The vehicle rotor appears to spin at the same speed as the utility-side rotor due to the interaction of the magnetic fields of the two rotors. This is the magnetic transmission effect.

Table 1: Comparison of strengths and weaknesses along with examples

WPT technologies		Strengths	Weaknesses	Example applications
Inductive Coupling		Simple, high power transfer efficiency in centimeter range	Short charging distance, requiring accurate alignment in charging direction	Electric toothbrush, charging pad for cell phones and laptops
EM radiation	Omnidirectional	Tiny receiver size	Rapid drop of power transfer efficiency over distance, ultra- low-power reception	Charging a WSN for environmental monitoring (temperature, moisture, light, etc.)
	Unidirectional (microwave/ laser)	Effective power transmission over long distance (kilometer range)	Requiring LOS and complicated tracking mechanisms, inherently large scale of devices	SHARP unmanned plane
Magnetic resonant coupling		High efficiency over several meters under Omni-direction, not requiring LOS, and insensitive to weather conditions	High efficiency only within several-meter rang	Charging mobile devices, electric vehicles, implantable devices and WSNs

MID Range Wireless Power Transmission

Attempts have been made to pass power to distances greater than the resonator size several times larger. The transmission is mid-range. Using electronic circuit theory, you can build the mathematical middle range WPT model. Amount of resonators that are magnetically connected.

$$\begin{bmatrix} R_1 + j(\omega L_1 - \frac{1}{\omega C_1}) & j\omega M_{12} & j\omega M_{13} & \cdots & j\omega M_{1n} \\ j\omega M_{12} & R_2 + j(\omega L_2 - \frac{1}{\omega C_2}) & j\omega M_{23} & \cdots & j\omega M_{2n} \\ \vdots & & \ddots & & \vdots \\ j\omega M_{1(n-1)} & \cdots & R_{n-1} + j(\omega L_{n-1} - \frac{1}{\omega C_{n-1}}) & & j\omega M_{(n-1)n} \\ j\omega M_{1n} & \cdots & j\omega M_{(n-1)n} & & R_n + R_L + j(\omega L_n - \frac{1}{\omega C_n}) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_{n-1} \\ I_n \end{bmatrix} = \begin{bmatrix} V_1 \\ 0 \\ \vdots \\ 0 \\ 0 \end{bmatrix} \quad (1)$$

where:

$M_{ij} = k_{ij}\sqrt{L_i L_j}$ $(i, j = 1, 2, \ldots, n; i \neq j)$ is the mutual inductance between winding-i and winding-j;

R_L is the load resistance which is connected to winding-n;

I_i: Current in winding-i

L_i: Self-inductance of winding-i

C_i: Compensating capacitance of winding-i

R_i: Resistance in resonator -i (including the resistance of winding-i and the equivalent series resistance of the capacitor C_i)

ω: Angular frequency

2. ADVANCEMENT IN WPT TECHNOLOGY:

Kurs et al. received the first demo of WPT in 2007, and since that time, several advances in magnetic resonant communication have taken place for commercial use. In 2008, the Intel magnetic resonant attachment was changed by using flat bobbs that fitted more easily into a mobile device than the helix bobbles.

Kurs et al. introduced Witricity Corp. along with the 2009 TED Global Conference to jointly present WPT for cell phones. Kurs et al. created an advanced technology through the proper tuning of linked resonators, which can lead to a simultaneous transfer of energy to several spools used for home and office applications such as computers, tablets, cell phones.

Haier, the maker of home appliances revealed a full HDTV wireless without power cords and signal cables in 2010. Many automotive companies such as Rolls-King, Volkswagen, Nissan, Toyota and Mitsubishi have recently been working on the wireless power-power or hybrid plug-in of electric vehicles.

In 2011 Rolls-Royce developed its Phantom car in electrical form. When such electric cars are stowed in a street or garage, the advancement of WPT technology permits the charging of electric vehicles without any power cords. When fully developed, this WPT technology could enable the electric car industry to improve.

Wireless electricity is a tightly integrated magnetic resonance technology. A 60-watt bulb with 40% power transfer capacity, using two similar resonating coils, was illuminated at a distance of seven meters from the power source.

Fig. 7: a) Magnetic Resonant Coupling was first demonstrated by Kurs et al
b) Intel developed wireless power system by using flat coils
c) Witricity demonstrated this power transfer technology for cell phones

The future of technology is considered to be the Solar Power Satellite (SAS). Wireless power transfer is therefore very critical to the geo-stationary orbit transfer to the earth. Microwave power transmission has been seen for over 40 years, but needs more study. In order to select a frequency of 2.45 GHz in the medical and science band (ISM), but 5.8 GHz is now considered more suitable because C-band RF technologies have recently progressed.

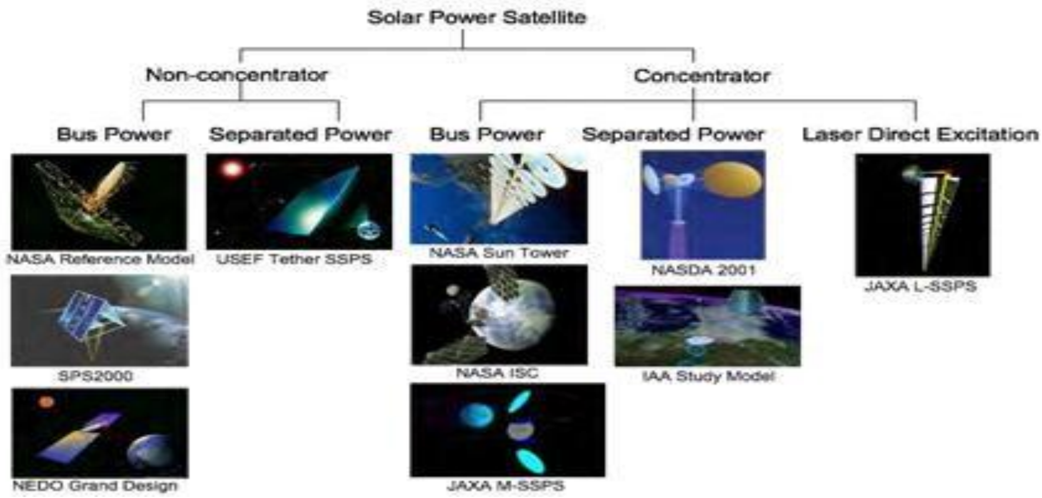

Fig. 8: Various types of SPS

Sasaki and his team will determine for themselves the most suitable medium between the microwaves or laser and conduct a 100-kW class-experiment before 2020 with the chosen medium. 2 MW and 200 MW will be measured before 2030, depending on projected power costs. This scenario would mean that in the 2030s, 1 GW commercial SPS will be built.

3. COMMERCIALLY AVAILABLE SYSTEMS:

Just a handful of the wireless charging solutions are currently available. Such devices are used only in pre-commercial trials and none is mass-produced. The WiTricity Corp. works and cooperates with Mitsubishi Motor Corporation, Delphi Electronics, Audi Motor Company and Toyota. Plug-less power (produced by Evatran) in partnership with Nissan and GM is another strong player for promoting Nissan Leaf and Chevy Volt products. A wireless charge research project is underway between Mercedes Daimler and Conducix- Wampfler. In partnership with the UK Government and the London Transportation Corporation, Qualcomm (acquired by HaloIPT) recently announced a wireless EV charge check.

4. CHALLENGES:

- The most important drawback of WPT systems is the transmission of low performance energy. During the energy conversion of the bobbin, the bulk of losses arise.

- However, due to several factors which include but are not limited to increased infrastructure, device and security / shielding requirements, the installation cost of WPT charging would be more than the plug-in charge methods. WPT can also be disadvantageous because it is not cost-effective for EV users.
- The industrial WPT devices pose complex safety risks related to RF radiation. The association agrees in different countries to restrict human access to the level of RF. The Canadian Health Code 6 lays out these guidelines. In Canada. In the US IEEE standard C95.1 is regulated, while the company using WPT technologies in Europe needs to conform with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) standard legislation. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is doing the same thing in Australia on RF radiation.
- The International Non-Ionizing Radiation Protection Committee (ICNIRP) is limiting magnetic field radiation. ICNIRP also regulates the sensitivity to EM fields to people depending on time. The radiation level for the maximum flow densities does not surpass the human organ in compliance with ICNRP regulations 6.25 μT within the 0.8–150 kHz band.

5. CONCLUSION

In this essay we discussed various technical approaches, drawbacks and implementations for WPT. It also requires development in the fields RPEV, OLEV and SPS. RPEV and OLEV remain in the lower tier, with SPS entirely operating by 2040. Work into short-range power transmission has been carried out widely, but work continues to reduce losses in intermediate data transmission. WPT would then guide the way to a future that is mature, greener and prosperous.

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