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Wireless Power Transfer for Electrical Vehicle

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Abstract— *The non-conventional energy resources are the need of time to maintain energy balance. Nowadays, the transportation system also increases its dependency on electrical energy because it is clean energy easily transmitted from one place to another through wires. Using different technologies, we can transmit electrical power from one place to another short distance place wireless. Wireless power transfer work on the principle of magnetic resonance technology. Using this technology, we transfer electrical power without an electrical conductor; with the help of this technology, the kilowatts power level transferred from several millimetres to hundred millimetres with a grid to load efficiency above 90%. Wire power transfers are used for EV stationary and dynamic charging scenarios. This paper represents technology in the WPT area applicable to EV charging.*

Keyword — Wireless power transfer, EV, Static and Dynamic Charging

I. Introduction

Due to the limited availability of resources, developing alternative methods to generate energy has become essential. Wireless Power Transmission (WPT) is thus an approach to noiseless, cost-efficient and convenient charging. It is estimated that losses incurred due to wires are about 20-30%.[1] Hence WPT attempts to minimise these losses along with the reduction in pollution levels caused due to resources used presently. Wireless Power Transmission can be used to charge portable electronic devices. The Solar Power Satellites (SPS), which are expected to operate in 2025-2030, are manufactured on the concept of capturing solar energy in space for utilisation on Earth. The SPS designs are largely based on WPT.[1] However, the current major application is charging electric cars, fuel-less rockets, fuel-less planes. The basic working principle of inductive WPT Charging is that there are two parts of the inductor. One part of the inductor acts as a primary winding, and the other half acts as a secondary winding of the transformer. The role of the charger is to convert the low-frequency AC power to high-frequency AC power. The high-frequency AC is transmitted from the charger to the secondary side and then is converted to DC power and is supplied to the battery pack.[2].

II. Basic Principles For Wireless Power Transmission

There has been widespread research on wireless power transmission in the previous decade, and it can be categorised into radiative and non-radiative based on energy transfer mechanisms. Radiative power is transmitted through an antenna in the form of an electromagnetic wave. But since electromagnetic waves travel in all directions. the energy efficiency is low.[5,6] Non-radiative power is based on the magnetic coupling of the conducting loops. Non-radiative power transmission can be further divided into short-range and mid-range WPT, where the transmission distance is greater than the resonating coil's dimensions. The three basic aspects of WPT are:

- Inductive coupling between working and driving circuits.
- Tuning in of circuits, that is "oscillation transformer".
- Capacitance loaded open circuit.

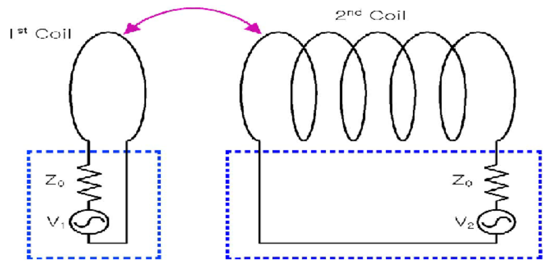

Fig. 1 Schematic of a transformer where Zo is the characteristic impedance and V1 and V2 are the voltages as shown

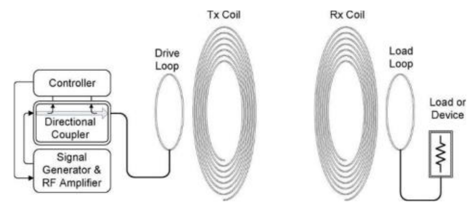

Fig. 2: Magnetically coupled WPT system

The Transformer coil gets excited due to the oscillating magnetic field produced by the RF amplifier, which gives power to the drive loop. The transformer coil is a multi-turn spiral coil next to the single turn drive loop. This system acts as a step-up transformer. A similar arrangement now acts as a step-down transformer on the receiving side due to the single turn load loop connected to the device. The Tx coil and the Rx coil share mutual inductance, which is a function of the distance between them and their geometry. Power can be transmitted through large air gaps when the transmitting and the receiving coil is in resonance and have the same resonant frequency[6-7]. The further approach and description through which transmissions can take place are

2.1 Coupling Theory:

This technology is based on the working principle of mutual inductance via a two-part transformer such that change in current flow through one winding induces a voltage across the ends of the other winding through electromagnetic induction, as shown in Fig. 2. The inductive coupling between two conductors.

2.2 Inductive WPT:

Inductive power transfer (IPT) has been used successfully in several EV systems, such as the GM EV1. The mangaka, the primary is the charging paddle and the secondary are embedded in epoxy. The charging paddle is inserted in the centre of the secondary coil, which begins charging to EV1 without contacts or connectors at either 6.6 kW or 50 kW. This system is connector-less but is not wireless.

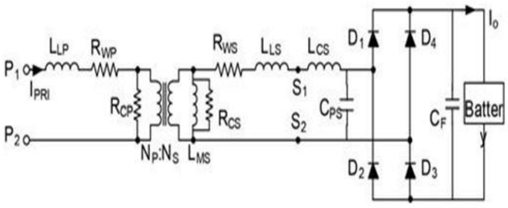

Fig. 3: Inductive interface (paddle) equivalent circuit

2.3 Capacitive WPT:

Use Recent technological venture of capacitive wireless power transfer has been proposed as an alternate contactless power transfer solution. The structure is the same as fig(4), with the CPT interface between a pair of coupling capacitors. Other parts, such as the inverter and rectifier structures, remain the same. Since magnetic does not scale down as desired with decreasing power, at some power level. The cost and size of the galvanic isolation components can be minimised with a capacitive interface.[8] However, this solution is not preferred in High Power applications. And because of this, most of the existing CPT solutions are applied in low power applications and portable electronic devices such as wireless toothbrush chargers or wireless cellular phone chargers where the power transfer interface is implemented with capacitively coupled matrix pads.

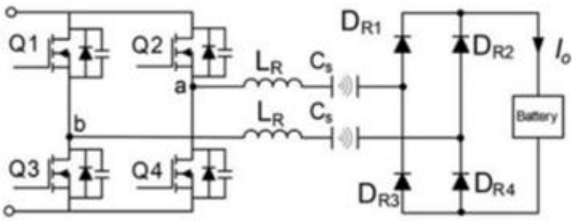

Fig. 4: schematic of a series resonant converter circuit constructed around the coupling capacitor.

2.4 Low-frequency permanent magnet coupling power transfer (PMPT):

Low-frequency PMPT is a combination of elements such as magnetic gears and synchronous permanent magnet electric machines. It consists of two main physical components, and they are shown in the figure

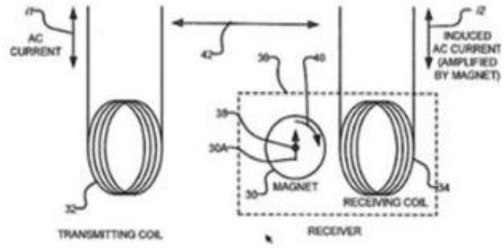

Fig. 5: Use of a rotating magnet to enhance inductive power transfer between two coils.

2.4.1 PMPT Transmitter :

A cylindrical, permanently magnetised rotor is either driven by an external, self-contained motor or directly using static windings positioned around the rotor's circumference, separated by an air gap and located either outside the rotor or inside if the rotor is hollow. Wireless Power Transfer in Electric Vehicles

2.4.2 PMPT Receiver:

A similar rotor on the vehicle is positioned within 150 mm and parallel to the utility-side installation during charging. Due to the coupling of the magnetic fields of the two rotors, the vehicle rotor rotates at the same speed as the utility-side rotor, which is called the magnetic gear effect. [8]

2.5 Comparison Between Different WPT Technologies:

A comparison of the WPT technologies is discussed and is presented in Table 1. IPC (Inductive Power Coupling) is a mature and proven technology. Its only drawback is that it is only a contactless solution and not a wireless solution.

TABLE 1 Comparison of Wireless charger Technologies

Technology	Performance			Cost	Size/Volume
	Efficiency	EMI	Frequency		
IPT	Medium	Medium	10-50kHz	Medium	Medium
CPT	Low	Medium	100-500kHz	Low	Low
PMPT	Low	High	100-500kHz	High	High
RIPT	Medium	Low	10-50kHz	Medium	Medium

3. Application of WEVCS :

Depending on their applications, wireless electric vehicle charging systems can be separated into the following two important scenarios to transfer power from the source to the battery bank and into the car.

3.1. Static Wireless Electric Vehicle Charging System (S-WEVCS):

WEVCS unlocks another door to provide a user-friendly environment for consumers (and avoid any safety-related issues with the plug-in chargers). Static WEVCS can easily replace the plug-in charger with minimal driver participation, and it solves associated safety issues such as trip hazards and electric shock. Fig. 6 shows the basic arrangement of static WEVCS. The primary coil is installed underneath in the road or ground with additional power converters and circuitry. The receiver or secondary coil is normally installed underneath the EVs front, back, or centre. The receiving energy is converted from AC to DC using the power converter and is transferred to the battery bank. Power control and battery management systems are fitted with a wireless communication network to receive feedback from the primary side to avoid safety issues. The charging time depends on the source power level, charging pad sizes, and air-gap distance between the two windings. The average distance between lightweight duty vehicles is approximately 150–300 mm. Static WEVCS can be installed in parking areas, car parks, homes, commercial buildings, shopping centres, and park 'n' ride facilities.[9-11] The Oak Ridge National Laboratory (ORNL) is mostly focusing on improving power transfer efficiency by coil designing, while the University of Auckland has proposed some hardware and software (including charging pad development) to improve plug-in efficiency. Overall, prototypes or lab experiments of stationary WCS for EVs have been developed from power ranges 1–20 kW, air-gap distance 100–300 mm with efficiency from 71 to 95%.

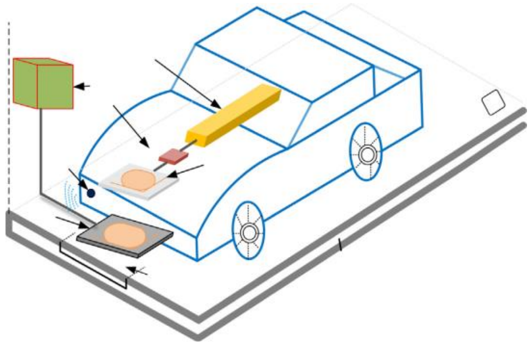

Fig.6. Basic diagram of Static wireless electric vehicle charging system.

3.2. Dynamic Wireless Electric Vehicle Charging System (D-WEVCS)

Plug-in or BEVs are suffering due to two major obstacles-cost and range. To increase range, EVs must charge frequently or install a larger battery pack (which results in additional problems such as cost and weight). In addition, it is not economical to charge a vehicle frequently. The dynamic wireless electric vehicle charging system (D-WEVCS) is a promising technology, which can reduce the problems associated with the range and cost of EVs. It is the only solution for future automation EV. It is also known as a "roadway powered" [14, 17], "on-line" or "in motion" [13] WEVCS. As shown in Fig.7, the primary coils are embedded into the road concrete at a certain distance with high voltage, high-frequency AC source and compensation circuits to the microgrid and RES. Like static-WEVCS, the secondary coil is mounted underneath the vehicles. When the EVs pass over the transmitter, it receives a magnetic field through a receiver coil and converts it to DC to charge the battery bank by utilising the power converter and BMS. EVs' frequent charging facilities reduce the overall battery requirement by approximately 20% compared to current ones [15]. For dynamic-WEVCS, transmitter pads and power supply segments must be installed on specific locations and pre-defined routes [15, 16]. The power supply segments are mostly divided into centralised and individual power frequency schemes, as shown in Fig.7(a) and (b). A large coil (around 5–10 m) is installed on the road surface in the centralised power supply scheme, where multiple small charging pads are utilised. Compared with the segmented scheme, the centralised scheme has higher losses, lower efficiency, high installation and maintenance costs. Overall, the installation of initial infrastructure for this technology would be costly. With the help of a self-driving car in the future, it helps create the perfect alignment between the transmitter and receiver coils, which can significantly improve the overall power transfer efficiency. Dynamic-WEVCS can be easily incorporated in many EV transportation applications, such as light-duty vehicles, buses, rail, and rapid transport.

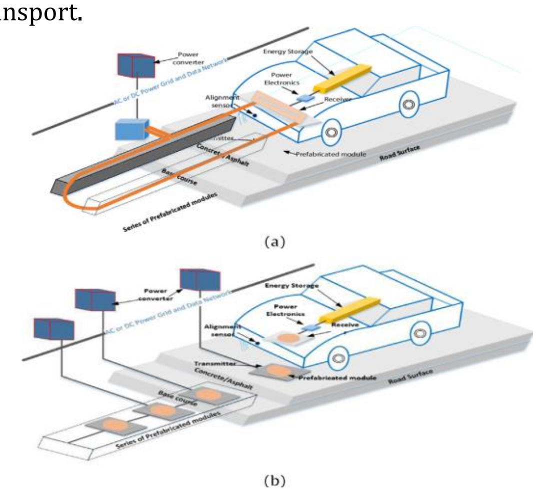

Fig.7. Basic diagram of dynamic wireless electric vehicle charging system.

4. Conclusion:

This paper presents a basic concept for stationary and dynamic wireless electric vehicle charging applications with current researched technology. By using wireless power charging, we can reduce power loss and improve the charging capacity of the plant. In addition, a variety of core and ferrite shapes have been demonstrated, which have been utilised in the current wireless charging pad design. Health and safety issues have been raised, and current developments in international standards are tabled for WEVCS.

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