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INDUSTRY DIRECTION™

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Chief Editor

Recent developments of inductive pad for charging of electric vehicles (EV)

EV charging infrastructure

Electric vehicles (EVs) are one of the primary alternatives currently being pursued due to their advantages in terms of performance, emission, and safety. However, EV acceptability is closely related to its driving range, and purchase cost, and the availability and performance of charging infrastructure. Based on the literature, there are three alternatives for EV supply equipment, i.e., charging infrastructure: (1) battery swapping, (2) conductive charging, and (3) wireless charging. In a battery swapping scenario, the battery swapping stations (BSSs) are set up to replace the empty battery of the vehicle with a fully charged one. This strategy offers a speedy recharging process (i.e., battery exchange in less than five minutes), and it allows flexible charging time, which can be shifted to the off-peak period. However, the long-term battery health impacts, associated cost, and practicality of battery swapping stations are still in question. Although conductive charging technology offers a cost-effective and feasible solution, it shows long charging time (20 min–8 h), and some safety concerns in harsh environment due to the heavy-duty cables exposed to the public, such as arcing, and exposed conductor. The third option is the wireless power transfer (WPT) technology, in which an EV can be charged without physical connections, during long-term parking (stationary), driving (dynamic or in-motion), or transient stops (quasi-dynamic or opportunistic). Wireless charging technology offers an ideal solution for EV charging because of being automatic, convenient, reliable in harsh environment, durable against vandalism, and can be implemented on the road, public parking, private parking and bus stops. Furthermore, implementing in-motion wireless charging has the potential to provide unlimited driving range and zero downtime, and dramatically reduce the onboard battery size, which leads to less EV price, size, and weight, with more efficient operation. Wireless charging technology has the potential to speed spreading of EVs, which improves people's lifestyle, and creates a better world for future generations.

WPT technology

WPT technology can be divided into four main categories: far-field, near-field transfers, mechanical force, such as magnetic gear, and acoustic. Magnetic gear technology utilizes mechanical forces in energy conversion. It was first introduced to substitute the traditional connected gear, and later it was demonstrated for different applications, such as EV stationary charging, EV drive, wind power, and low-power medical devices. Acoustic WPT system consists of a transmitter that converts electrical energy into compressed sound waves that propagate through air, and a receiver with a transducer transforms the motion caused by the sound waves into electrical power. Acoustic technology has been used in various applications, such as ultrasonic cleaning, and medical ultrasonography. The other way of transferring electric power wirelessly is by electromagnetic fields (EMFs), which can be either far-field or near-field. In far-field WPT, the power is transferred by electromagnetic radiations within GHz frequency range, such as laser, microwave, and radio-

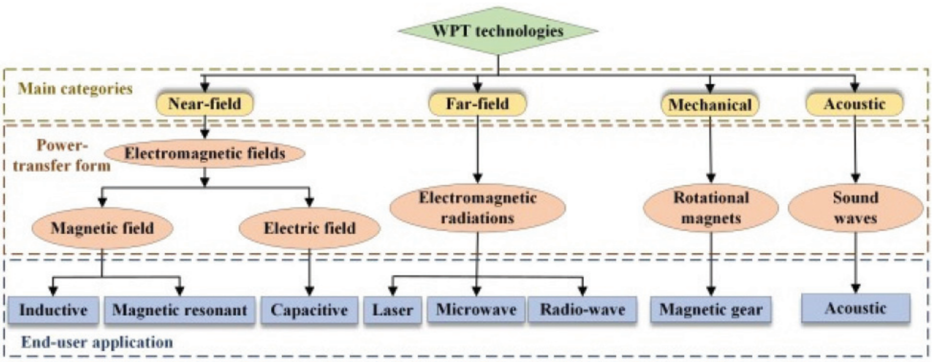

Fig.1: Categories of WPT technologies (Ahmed A. S. Mohamed et al., 2020) (Courtesy:https://www.sciencedirect.com/science/article/pii/S0306261920300969#f0005).

wave. In this technology, a high power can be transported over long distances, but this requires complex tracking strategies, direct line-of-sight transmission path, and very large antennas.

Inductive power transfer

Inductive power transfer (IPT) system involves one resonance network on each side (transmitter and receiver). In the last few decades, this technology shows successful implementation in a wide range of applications, such as biomedical implants, electronic devices, home appliances, and EV charging industry. IPT technology is the most attractive for EVs applications due to: (1) its ability to transfer high-power through a relatively large air-gap (10–40 cm) [54], which covers the ground clearance for most of the vehicles, (2) it is noise-free, (3) it requires minimal maintenance due to the absence of moving parts and it is not affected by contaminants, and (4) the components are electrically isolated.

The integration of an IPT system and EV is depicted in Fig.2. The system has two electrically isolated sides: ground (transmitter, grid, or primary) and vehicle (receiver, or secondary). The transmitter side is embedded in the road to receive a low-frequency power from the grid, convert it to a high-frequency (HF) power, and feed the transmitter coil. The EMFs generated from the transmitter are coupled with the receiver coil (in the vehicle) to induce HF voltages and

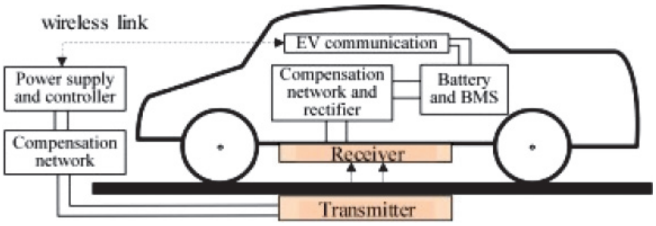

Fig.2: Integration of IPT system for EV charging (Ahmed A. S. Mohamed et al., 2020)

currents in the secondary circuit. The HF secondary power is recertified to charge the vehicle's energy storage system (e.g. battery). The two sides (vehicle and ground) are talking to each other through a wireless communication link. The system operates at high frequency (80–90 kHz), which helps to reduce its size (transmitter, receiver and power converters), and enhance its power transfer capability. For high-power and high-efficiency operation, resonance capacitors are connected to both the transmitter and receiver coils. These capacitors help to compensate for the large leakage inductances due to the large airgap and provide the required reactive power for magnetizing this airgap. These capacitors can be connected in series, or in parallel, and can be a combination of LC circuits.

Holcim trial

Swiss building materials company, Holcim is partnering with the German startup Magment to improve its magnetizable concrete technology for road surfaces enabling electric vehicles to recharge wirelessly while in motion. This "inductive charging," breakthrough concrete-based solution reduces the need for charging stations, while saving time. It is made possible by a unique concrete with high magnetic permeability jointly developed by Holcim and Magment's Research and Development teams.The technology is currently being tested by Researchers at Purdue University (US) in Indiana. Other applications under development include the electrification of industrial floors to recharge robots and forklifts as they work.Edelio Bermejo, Head of Holcim's Global Innovation Center: "At Holcim we are innovating to put concrete at the center of our world's transition to net-zero. With Magment, we are excited to be developing concrete solutions to accelerate electric mobility. Partnering with start-ups all over the world we are constantly pushing the boundaries of innovation to lead the way in sustainability."

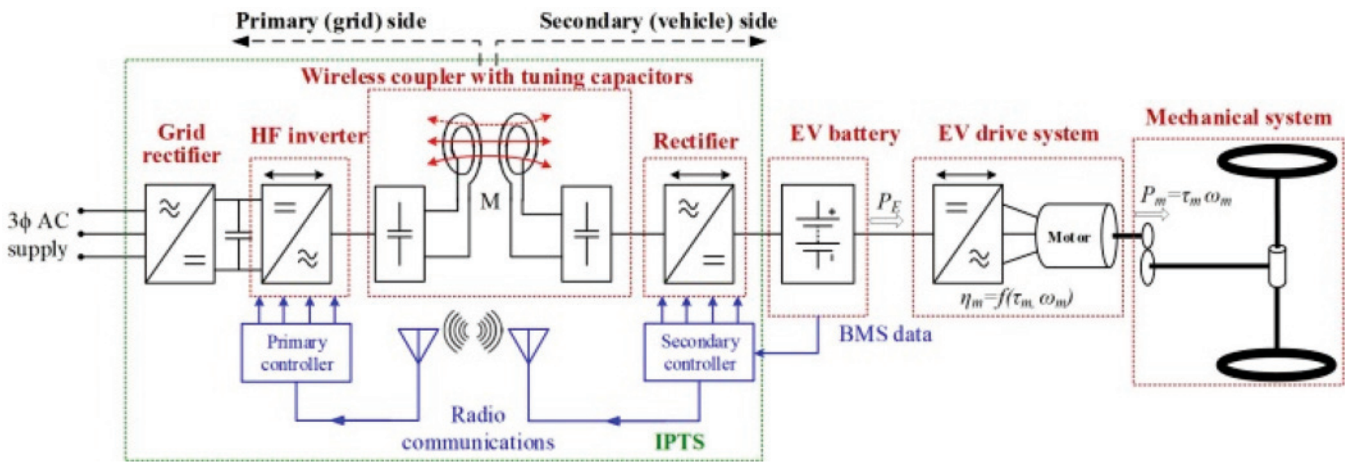

Fig.3: Schematic diagram of an IPT system for EV charging (Ahmed A. S. Mohamed et al., 2020)

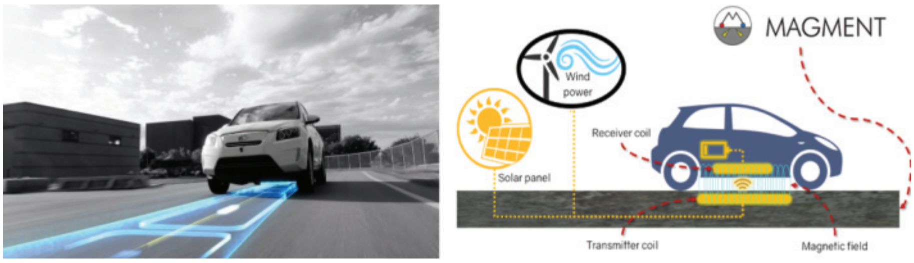

Fig.4: Conceptual view of dynamic paved road EV charging (Courtesy : Holcim and Magment)

Challenges and future opportunities

Besides what have been documented so far, activities are needed to improve the system's performance and find reasonable solutions for the challenges impede the technology. Some of these challenges along with recommended directions are presented below:

a. Fast charging: There is a current need to design chargers that are able to bring the charging time down to less 15 min. Therefore, exploring high-power wireless chargers (>200 kW) is a gap that needs to be filled. Novel pad designs with new magnetic materials and wires are crucial so that the system can transfer high-power efficiently at reasonable cost.

b. Cost: More effort is required to bring the system's cost down by using less expensive materials, manufacturing, and installation process.

c. Durability: This system will be installed outdoors in for public use, so it needs to be robust enough to handle the harsh environmental and operating conditions. In addition, the way to integrate the pads with both the vehicle and road is an open question that requires extra research effort.

d. Safety: There are quite concerns related to the safe operation of the system. The first safety concern is related to EMFs, which requires additional effort to explore novel shield designs, especially active and reactive shielding. Another safety concern is associated with the heat generated in metal objects near the system, which requires an effective foreign metal object detection method. In addition, a living object detection mean is necessary to prevent accessing of pets and animals to the hot region during operation. All the current foreign object detection techniques are exploring a way to detect the object and shut-down the system. However, it is important to explore what needs to be done after shutting the system down.

e. Interoperability: Extra effort is required to explore the interoperable operation among different pad designs.

Reference

Ahmed A. S. Mohamed et al, (2020): A comprehensive overview of inductive pad in electric vehicles stationary charging, Applied Energy, 12 February.

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