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Recent Developments for wireless Electric Road Systems

- Preparing the Breakthrough -

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ABSTRACT: The progress in dynamic wireless power transfer (D-WPT) led to the availability of wireless Electric Road Systems (wERS) that offer smart infrastructure solutions that can substantially reduce transport emissions and electric vehicle (EV) range anxiety. The basis of this technology is resonant Wireless Power Transfer (WPT), which was first demonstrated in the 1890s by Nikola Tesla and has since been developed for various applications. This paper illustrates the state of Electreon's wERS technology by insights from current pilot projects as well as progress from active R&D activities.

KEY WORDS: Global Warming, WPT, ERS, ELINA, EMADI, E|MPOWER

1. INTRODUCTION

To mitigate global warming and avoid severe climate change, governments, NGOs and commercial sectors worldwide are working to decrease the use of fossil fuels. A growing number of cities around the world are not waiting for central government regulations and are implementing registration and zoning policies that promote clean transportation, including designating car-free city centers, as well as requiring road vehicles in these zones to meet certain emission requirements by a set date. Regarding this, transitioning to electric vehicles (EVs) is key to reducing internal combustion engine (ICE) emissions. The transport sector is responsible for 21% of worldwide emissions, 74.5% of which are caused by road vehicles. However, current EV charging systems consist mostly of plug-in charging stations, which inhibit a global uptake of EVs due to the limitations of range caused by inefficient battery technology as well as the significant amounts of real estate required to install charging infrastructure at a large scale. Also, batteries cause emissions in production; and can be expensive, heavy, and finite to supply a world of EVs. Furthermore, the rapid charging, which is the premier solution for long-haul mobility leads to higher battery degradation, as described in [1]. One alternative solution that has been proposed for charging EVs is the use of an Electric Road System (ERS), infrastructure which allows EVs to charge while they drive along the road.

This presentation focuses on the technology of the market leading wERS technology from the company Electreon as well as onto the most recent R&D activities to allow large-scale adoption and finally the revolution of the transportation industry.

2. RECENT DEVELOPMENTS

2.1. Large-Scale production and deployment – E|MPOWER

The current production and deployment of ERS technology is relying heavily on manual labor. While this is acceptable for smaller pilot projects (< 1 km), for larger projects more scalable solutions need to be developed.

A key factor in optimizing the process chain of WPT systems is the automation of production and deployment. Therefore, the process chain must be automated in several steps. Fig. 1 displays the fundamental component of ERS are the power emitters, here referred as "segments". These are resonant circuit modules that feature litz wire as conductor, capacitors for resonant compensation and potting materials for electrical insulation and environmental protection. [2]

In the previous projects, transmitter segments that feature foil-based capacitors have been employed, which caused an additional

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structure, effectively making the segments non-flat (cf. Fig. 1). This geometry offers the advantage of moving the resonance capacitor to deeper layers of the road structure, which provides better protection against thermal influences during asphalting [3], but comes with two main disadvantages: Firstly, for the installation of the segments a trench needs to be opened to install the capacitors and afterwards filled with concrete. This leads to higher installations costs, longer installation periods and reduced road durability. Furthermore, the asymmetrical structure of the L-shaped segments restricts storage, handling and automated deployment in the road. This limits the scalability of the laying process due to the manual and discontinuous production process within road construction. Secondly, segments of this shape cannot be easily installed by an automated process, so scalability is limited.

Due to this we developed within the public-funded E|MPOWER project [4] a new transmitter segment, which is based on multi-layer ceramic capacitors, which allow a massive shrinking of the capacitor compartment (cf. Fig. 2).

Fig. 1 Example of manually installed ERS transmitters

Fig. 2 Newly developed MLCC Segment

These transmitter segments have been tested in the lab in static conditions, even though they were meant for dynamic operation. Table 1 summarizes the test results after a certain time of operation.

The use of MLCC capacitors also allows the segments to be redesigned in the capacitor area, making the entire shape of the coils flat, as shown in Fig. 2. In this way, several segments can be linked together and easily stacked or rolled for storage and transportation (cf. Fig. 3). By using conventional reeling and unrolling devices used in cable construction, storing and deployment can be automated more efficiently. The interlinking of the segments also enables prewiring. This eliminates the need for additional manual cabling processes during road construction.

Table 1: Test results of MLCC vs. Foil-Capacitor Segments

	Foil		MLCC	
Time	Efficiency	ΔT [°C]	Efficiency	ΔT [°C]
1 min	0.942	0	0.943	0
60 min	0.927	40.0	0.932	30.8
120 min			0.934	31.2
180 min			0.934	34.1

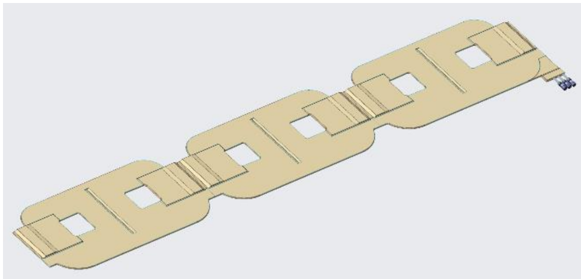

Fig. 3 Multiple MLCC segments linked with integrated cable management

2.2. Developments towards higher power

It is expected that the wERS system will be capable of providing energy to all kinds of vehicles, at least at a level of their average consumption [5]. This means that the most challenging application for electric road systems are heavy-duty trucks, which could feature continuous power demands of up to 150 kW.

This paper presents the technical solution for dynamic power transfer to a typical trailer-tractor combination that could transfer this power even under the tight restrictions of conventional ladder frames of a tractor.

Due to this the power class up to 75 kW look most promising to establish a sweet spot in ERS: Two receivers would be appropriate for a HD truck, whereas lower powers like 30 to 50 kW (which are suitable for passenger vehicles and light commercial vehicles are not too far off the nominal design power. Fig. 3 shows the test setup whereas Table 2 gives the performance results. Testing the transmitter drive between 60.9 and 71.2 kW led to efficiencies between 92.1 and 94.2%.

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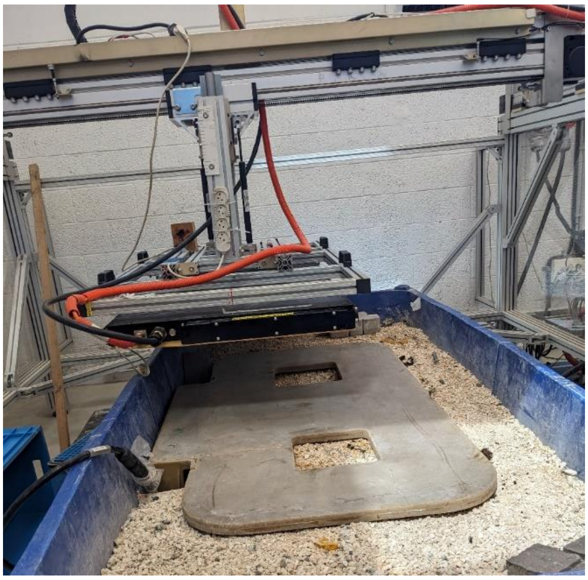

Fig. 3 Test setup for high-power transmitter

Table 2: Test results of the high-power transmitter

Longitudinal Misalignment	Output Power	Efficiency
0 mm (centered)	60.9 kW	94.2 %
0 mm (centered)	69.8 kW	92.4 %
100 mm	69.8 kW	92.4 %
200 mm	71.2 kW	92.1 %

The high-power transmitter prototype did undergo a thorough test campaign and qualified for road deployment. This was conducted within the French 'Charge-As-You-Drive' project [6].

Further results on real-world performance will be published soon.

2.3. Interoperability between static and dynamic systems

In many use cases it is preferrable to deploy a combination of static and dynamic systems. As a reference, we refer to the project 'ELINA' [7]. Here a wERS of 1 km length is combined with two static chargers (at the depot and at a central station) to supply energy to a city bus.

This combination of use cases is being considered in the various groups for standardization, and this leads to an elevated role of wERS systems: Whereas the need for interoperability for static WPT between light- and heavy-duty vehicles is doubtful, the role of the wERS as shared power supply is undisputed.

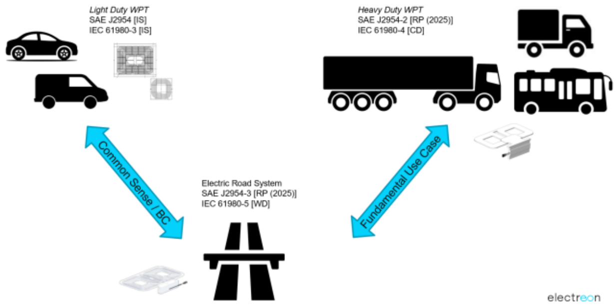

Fig. 2 Structure of the standardization of WPT systems

I turned out that there is a need for many flavors of wireless systems, from average power D-WPT for instantaneous power supply as well as low power for overnight charging and high power for opportunity charging, e.g. at traffic lights or bus stops. Thus, a multi-receiver layout seems to be favorable compared to monolithic systems, as they allow a wider range of output power. Further research will be conducted to investigate the performance of the presented multi-receiver system over a wide range of output power.

2.4. Retrofit ability of D-WPT systems

In contrast to static wireless charging, there are two types of communication needed for D-WPT. Firstly, the low-level communication defined as P2PS/P2PC specified in IEC 61980 handles basic power transfer such as coil activation and shutdown. Some concepts for authentication require an activation key and might also require some data for real-time power transfer. Based on the widespread 13.59 MHz carrier frequency, data transfer in the range of hundreds of kilobytes per seconds is studied. Progress will be reported.

Secondly, the high-level communication specified in ISO/IEC 15118 is needed for D-WPT as well. Aligned with IEC 61980 standards, ISO/IEC 15118 part 20 provides a basic set of communication features to guide the energy transfer for static WPT. Same as for conductive charging, each charging session needs to be authenticated, and the transaction authorized before starting the energy transfer. During the energy transfer, power demand and metering information about the received energy is being exchanged. In case of any failures, the high-level communication can provide additional information on the cause and description of the error. Once completed, the communication session terminates. This procedure specified for the static scenario now needs to adapt for charging while the vehicle is in motion. Additional needs of D-WPT are to be taken into consideration when designing the communication system. The physical layer of

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the high-level communication is investigated by comparison of cellular-operated cloud-based systems and fast-switching point-to-point connections via WI-FI within a public-funded project in Germany, results to be expected in 2026. Furthermore, the aspect of retrofitting existing vehicle fleets is investigated. Even though future vehicles may natively support the ISO/IEC 15118 part 20 (which then might include dynamic WPT), the existing fleet needs to be retrofitted. The same project will study the opportunity to retrofit vehicles that have implemented the chapters of ISO/IEC 15118 for conductive charging and use this communication interface to enable wireless power transfer. Here results are expected in 2027.

4. CONCLUSIONS

Continued improvement of this technology will enable the implementation of wERS at a large scale in the future and suit the individual needs of all kinds of road users. The vehicle-agnostic hardware and software is designed to work efficiently and effectively on passenger EVs, e-vans, e-trucks, and e-buses, regardless of differing alignments or speeds. This is backed by international standardization activities as SAE J2954/3 and IEC 61980-6.

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