IEA INTERNATIONAL ENERGY AGENCY
HYBRID & ELECTRIC VEHICLE TECHNOLOGY COLLABORATION PROGRAMME

HEV TCP TASK 26 WORKSHOP

MEETING 8: DYNAMIC WIRELESS CHARGING

25-26 JUNE 2018

HOSTED BY

POLITECNICO DI TORINO

FABRIC
Feasibility analysis and development of on-road charging solutions for future electric vehicles

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ABOUT US

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TCP on Hybrid and Electric Vehicles (HEV TCP)

Created in 1993, the activities of the TCP on Hybrid and Electric Vehicles (HEV TCP) are coordinated by the Working Party on Energy End-Use Technologies (EUWP). The aims of the HEV TCP are to produce and disseminate balanced, objective information about advanced electric, hybrid, and fuel cell vehicles. The HEV TCP accomplishes this through multilateral task-force projects. For further information on the HEV TCP see http://www.ieahev.org/. Views, findings, and publications of the HEV TCP do not necessarily represent the views or policies of the IEA Secretariat or of its individual member countries.

Version	Date	Details	Prepared by:	Reviewed by:	Approved by:
V 0.0	January 2019	First version	Richard Bogacz	Burak Ozpineci	
V. 0.1	March 2019	Edits included	Richard Bogacz	Lee Slezak	
V. 0.2	March 2019	Edits included	Richard Bogacz	All Task Members	
V 0.3	June 2019	Task Member edits included	Richard Bogacz	n/a	FINAL RELEASE

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1 Task Approach

Multilateral task-force projects within the TCP on Hybrid and Electric Vehicles (HEV TCP) are known as Tasks. Participation in a Task is an efficient way of increasing national knowledge, both with respect to the specific project objective and in terms of information exchange with peer institutions. Shared activity allows Task members to combine strengths, optimize resources, mitigate risk, and share knowledge.

1.1 Objective of Task 26

Task 26 aims to develop a greater global understanding of wireless power transfer (WPT) systems and interoperability through a focused study of WPT technologies being developed in the participating countries. This task includes a study of country-based standards (JARI, SAE, ISO/IEC), technical approaches, grid interactions, regulatory policy, and safety codes for WPT. The task will operate from Summer/Fall 2014 through May 2019 conducting two workshops per year, with each workshop focused on a particular aspect of wireless charging.

Participants in this task will benefit from their involvement. Some of the benefits of participation include:

- Broadening and deepening the expertise of automotive research organizations in WPT for electric vehicles (EVs) and related technologies.
- Strengthen working relationships and international collaborations.
- Access to information on research performed by other participants.
- Receive updates on recent developments in other countries.
- Remaining informed on the state of standards that may facilitate (or hinder) interoperability with WPT for EVs.

1.2 Focus of Workshop

Task 26 has conducted seven previous workshops (Figure 1). The focus of this workshop was dynamic wireless charging. The workshop was held in conjunction with the final event of the European Union's Feasibility analysis and development of on-road charging solutions for future electric vehicles (FABRIC) project.

Workshop #	Month	Year	Focus	Location / Host
1	October	2014	Kickoff	Vancouver, BC – Canada
2	May	2015	Leading Applications	Seoul, Korea / EVS 28
3	October	2015	Power Levels	Goteborg, Sweden / RISE Viktoria
4	June	2016	Interoperability & Standards	Rotterdam, The Netherlands / proov
5	October	2016	Safety of WPT Systems	Knoxville, TN USA / ORNL
6	April	2017	Installations & Alignment	Versailles, France / VEDECOM

7	March	2018	Wireless charging and V2X grid and market integration	Newcastle, UK/Newcastle University
8	**June**	**2018**	**Dynamic Wireless Charging**	**Turin, Italy/Politecnico di Torino & FABRIC**

Figure 1. Task 26 Workshop Topics

2 Workshop Activities

2.1 Host Location

This workshop took place 25-26 June 2018 in Torino, Italy. Our hosts for this event were Paolo Guglielmi of Politecnico di Torino, and HEV TCP. The meeting location was selected due to its proximity to FABRIC's final demonstration event in Susa, Italy. Attendees also participated in a tour of Politecnico di Torino's lab.

2.2 Presentation Topics

With the support of the task members, eight speakers were identified to present on dynamic wireless charging (Figure 2). Presentations provided insights into the technical challenges associated with dynamic wireless charging systems focusing on the vehicle and charging systems.

Presentation	Contributor[1]	Affiliation
FABRIC Final Event The story of the Italian test site	**PAOLO GUGLIELMI**	Politecnico di Torino
Charging Process Control of Dynamic Wireless Power Transfer System	**MOJTABA KHALILIAN**	Politecnico di Torino
Technology Development: Updates, Challenges and Opportunities	**BURAK OZPINECI**	Oak Ridge National Laboratory
Experimental performances assessment of a dynamic wireless power transfer system for future EV in real driving conditions	**STEPHANE LAPORTE**	Institut Vedecom
Feasibility analysis of dynamic wireless charging for electric vehicles: The achievements of FABRIC project	**CHRISTINA ANAGNOSTOPOULOU**	ISENSE ICCS
Collaborative, Pre-normative Research on electromobility: EMC, Interoperability, Efficiency	**HARALD SCHOLZ**	European Commission, Joint Research Centre
Maximizing the transferred energy with a high system efficiency in dynamic inductive charging of Evs	**IOANNIS KARAKITSIOS**	National Technical University of Athens
Optimal Sizing of a Dynamic Wireless Power Transfer System for Highway Applications	**BURAK OZPINECI,** A. Foote, O. Onar, S. Debnath, M. Chinthavali, D. E. Smith	Oak Ridge National Laboratory

Figure 2. Dynamic Wireless Charging Presentations

2.3 Demonstrations

Workshop attendees participated in a demonstration at FABRIC's on-road WPT installation in Susa, Italy. For the demonstration, vehicles were not available but a mobile platform was used to demonstrate the operation of dynamic wireless charging.

The setup in Susa was designed for a 100 m energized roadway with rectangular wireless charging coils of 0.5 m width and 1.5 m length. The vehicle side coil had a width of 0.5 m to match the width of the ground side coils. No shields or ferrites were used on the ground side to make the set up simpler. The coils were embedded in the road through micro trenches carved in the pavement.

The grid-side front-end converter was set up to receive 400 V ac from an isolation transformer and converted to 650 V dc, which fed the 22 kW rated high frequency inverters powering each coil (shown on the side of the road in Figure 3).

[1] Contributor listed in **BOLD** was the presenter at the workshop.

The research results showed that high voltage stress on the resonant capacitors and the impact of capacitance variation on the resonant operation required high-quality, high-accuracy, high-cost capacitors. To solve the cost issue, the researchers at Polito invented a new capacitor called RES power capacitor.

Another important result of the dynamic wireless charging implementation was that the coils embedded in the pavement did not function as inductors. The resonant frequency changed when the coils were embedded in the road. After six months of research, FABRIC came up with a material solution (patent pending) that eliminated the pavement interference on the coil.

The resulting dynamic wireless charging system could transfer 6.5 kW maximum power with 81% efficiency with maximum speed of 50 km/h. The system also tolerated 30 cm of misalignment.

Figure 3. Politecnico di Torino and FABRIC's on-road WPT installation, Susa, Italy

3 Key Findings

Based on the presentations of this workshop and the demonstration witnessed, Task Members had an in-depth discussion of dynamic wireless charging. A number of key points emerged during the workshop.

These ideas are listed below. The order in which they are presented is not intended to reflect their relative importance.

- Politecnico di Torino presented on power control methods in WPT systems. Existing power control methods work with establishing a communication path for the data exchange. There are several complexities with these solutions, such as higher construction costs, lower reliability, and time delay for data transmission. Controlling the output power from the receiver side and without any data exchange is desirable.
- Politecnico di Torino detailed a proposed bidirectional dynamic wireless power transfer (DPWT) system which has several advantages: Vehicles can regulate their power in a range from the maximum power level to zero without communication link with the transmitter converter; when the battery is near full state of charge, the vehicle can choose the amount of power required only on board; and the WPT system can operate with different types of vehicles traveling at different speeds that demand different power levels. The current control is in the transmitter side, which limits current in case of misalignment; and power control is in the receiver side.
- The European Commission presented on interoperability, which is the ability to charge conveniently, safely, and securely anytime, anywhere. Interoperability enables smooth integration of functions offered by energy service providers.
- Per the European Commission Joint Research Center (JRC), key targets for technical harmonization include EV and electric vehicle supply equipment (EVSE) interoperability; interoperability and monitoring of multi-band, multi charging points in fair billing schemes; load management; and harmonizing EVs and EVSE in the internet of things.
- JRC emphasized that the rollout of residential 2-way smart meters brings with it the possibility of features such as demand response and dynamic tariffs.
- FABRIC detailed a patented compensation capacitor for using in on-road systems, and a patented material for transition coil embedment.
- The FABRIC test site at Susa considered two DWPT architectures, one each from Polito and SAET. Each system offered its own strengths and demonstrated interoperability.
- FABRIC achieved in its testing of the Polito prototype a maximum power transfer of 6.5 kW at a maximum efficiency of 81% at a test speed of 50 km/h while maintaining compliance with electromagnetic frequency (EMF) exposure standards. Maximum manageable misalignment was 30 cm.
- ORNL observed asymmetry in power transfer curves in a DWPT demonstration because the test vehicle body was steel, which is a ferrous material that vacuums the magnetic field, reducing impedance and resulting in more current on the primary pads.
- ORNL detailed how analysis of vehicle energy consumption in different drive scenarios using DWPT showed that optimal sizing and placement of DWPT systems is needed.
- The National Technical University of Athens emphasized that it is crucial to define a high efficiency section (HES) in WPT, where high amounts of energy can be transferred to the EV at a high system efficiency. If the maximum possible energy is clearly transferred at the HES, then a

simple solution is to allow WPT operation in the HES only. A detection mechanism (e.g., sensors) would be required, which increases infrastructure cost.

- The National Technical University of Athens proposed not offering any additional test mechanisms in the primary pads, and utilizing the input power to be aware of the transition from a low efficiency section (LES) to an HES.
- The National Technical University of Athens found that no application of a control scheme during the transition from a LES to an HES resulted in an efficiency of 83%. Applying a proposed control scheme showed an efficiency of 93.9%.

4 Conclusions

In summary, the conclusions of the workshop are listed below. The order of the points is not reflective of their importance.

- Future research needs for WPT to EVs are interoperability for cross- and multi-brand functionality and keeping the advantages of simplicity of use.
- Energy management systems will be price-based. Thus, energy management systems need wireless communication, and a lot of it.
- The design of the DWPT system should meet power delivery requirements and minimize capital costs and operating costs.
- DWPT systems require optimal sizing and placement. Misalignment is a significant influence on functional range and charge performance.
- Safety: Developing further methodologies and thresholds for evaluating EMF and EMC is needed, particularly if power loads need to be increased.
- Wider scale experimentation is needed to evaluate grid impacts of DWPT.
- Enlarge case studies to include scenarios such as a vehicle entering into the middle of the charging zone, object detection issues, and possible human presence close to the charging zones.
- High voltage highly accurate low voltage capacitors are needed for WPT applications.
- There is a need for special pavement configurations that will not interfere with resonant operation of the WPT coils.