HEV TCP TASK 26 WORKSHOP

MEETING 9:

WIRELESS CHARGING

6 NOVEMBER 2018

HOSTED BY

HYUNDAI MOTOR GROUP

HYUNDAI AMERICA TECHNICAL CENTER, INC.

DETROIT, MICHIGAN, U.S.A.

ABOUT US

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IEA Energy Technology Network

The **IEA Energy Technology Network (ETN)** is comprised of 6 000 experts participating in governing bodies and international groups managing technology programmes. The Committee on Energy Research and Technology (CERT), comprised of senior experts from IEA member governments, considers effective energy technology and policies to improve energy security, encourage environmental protection and maintain economic growth. The CERT is supported by four specialised Working Parties:

- Working Party on Energy End-use Technologies (EUWP): technologies and processes to improve efficiency in the buildings, electricity, industry, and transport sectors
- Working Party on Fossil Fuels (WPFF): cleaner use of coal, improvements in gas/oil exploration, and carbon capture and storage
- Fusion Power Co-ordinating Committee (FPCC): fusion devices, technologies, materials, and physics phenomena
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Each Working Party coordinates the research activities of relevant IEA Technology Collaboration Programmes (TCPs). The CERT directly oversees TCPs of a cross-cutting nature.

IEA Technology Collaboration Programmes (TCPs)

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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 on:
V 0.0	January 11, 2019	First version	Richard Bogacz	Burak Ozpineci Lee Slezak	n/a
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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 eight previous workshops (Figure 1). The focus of this workshop was updates on important wireless charging issues, and included a demonstration of Hyundai/Kia's wireless charging capabilities.

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

Workshop #	Month	Year	Focus	Location / Host
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
9	**November**	**2018**	**Wireless Charging**	**Detroit, MI USA/Hyundai American Technical Center, Inc.**

Figure 1. Task 26 Workshop Topics

2 Workshop Activities

2.1 Host Location

This workshop took place in Detroit, Michigan, USA from 6-7 November 2018. Our hosts for this workshop were Hyundai-Kia American Technical Center, Inc. (HATCI), and IEA's HEV TCP. The meeting location was selected for its proximity to the American Center for Moblity's (ACM) Willow Run, Michigan test environment, where a Kia Soul WPT demonstration took place. Presentations provided good insight into the technical challenges associated with wireless charging systems and focused on both the vehicle and wireless charging systems.

2.2 Presentation Topics

With the support of the task members, 10 speakers were identified to present on wireless charging. Presentations covered several areas of importance for wireless charging, such as dynamic wireless charging, power levels, system-level studies, cyber security, standards, and system, coil, and air gap considerations (Figure 2). Stakeholders from a broad range of perspectives presented, including presenters from national laboratories, the private sector, a vehicle original equipment manufacturer, a government agency, and a state university.

Presentation	Contributor[1]	Affiliation
IEA Hybrid Electric Vehicle-Technology Commercialization Programme (HEV TCP) Task 26: Wireless Charging for EVs	**BURAK OZPINECI**	Oak Ridge National Laboratory
Bidirectional Wireless Power Flow for Medium-Duty Vehicle-to-Grid Connectivity	**OMER ONAR**	Oak Ridge National Laboratory
Risk Analysis of Communication Protocols for Smart Modules in Vehicles	**MUSTAFA SAED**	Hyundai
Cutting the Charging Power Cord An Industrial Perspective	**LAURENCE DUNN** and Khurram Afridi	Hyster-Yale Group and Cornell University
Innovative Chargers and Converters	**OMER ONAR**	Oak Ridge National Laboratory
Material Classification for Electromagnetic Shielding and Infrastructure Impacts	**JASON PRIES**	Oak Ridge National Laboratory
NREL's Managed WPT Experiences and Lessons Learned	**AHMED MOHAMED**	National Renewable Energy Laboratory
An Optimized Single-stage 120 kW Wireless EV Charging System	**GUI-JIA SU** and Veda Galigekere	Oak Ridge National Laboratory
Practical Challenges in Designing a Dynamic Wireless Charging System	**REGAN ZANE** and Dr. Abhilash Kamineni	Utah State University
Prospective views on Versaille-Satory site infrastructure developed for integrating and testing DWPT solutions	**STEPHANE LAPORTE**	VEDECOM

Figure 2. Wireless Charging Presentations

2.3 Demonstrations

The workshop concluded with a tour of the ACM test environment at Willow Run. While at the ACM, workshop attendees observed a WPT demonstration of a Kia Soul. The vehicle charged at 10 kW and featured WiFi communications for a control loop.

The ACM wireless charging facility includes a high-performance computing data center that has been operational for 1 year. This is a global testing site, and Intertek is the operating partner. The facility consists of two quads. The southern area is a new construction and features bi-directional charging, and the northern area is a testing loop that was formerly Michigan Department of Transportation property. To create different exiting and merging scenarios, the test quads utilize two different lighting patterns and road lanes with multiple exits. Other features inlcude ESRC units for vehicle communications, global positioning systems within 2μ accuracy, and 4G WiFi. System capabilities include controlled signals, car-to-car technologies for developing technologies, and lane-keep and blind assist.

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

3 Key Findings

Based on the presentations of this workshop and the demonstration witnessed, Task Members had an in-depth discussion of 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.

- Per Hyster-Yale, an alternative approach to WPT is capacitive WPT, which does not have ferrites and can be less expensive, more efficient, smaller, lighter, and easier to embed in roadways. Challenges include small coupling capacitance due to the large gap between the road and vehicle, the need for high-frequency operation to achieve high power transfer levels, and the need for high-voltage/current gain to limit fringing fields and meet safety limits.
- Utah State University discussed collecting data from real-world projects that can be used for better understanding the technology, controlling the design, and validating design tools.
- Per Utah State, desirable specifications for dynamic wireless charging include compatibility between light-duty consumer vehicles and heavy-duty vehicles, compatibility with light-duty specifications (SAE J2954), and a constructible design that is scalable. Consider that dynamic WPT systems cannot be designed in isolation. State Departments of Transportation and standards bodies have a role in standardizing dynamic wireless charging.
- Electrical designs for dynamic wireless charging need to be flexible to accommodate stakeholder needs and requirements.
- Hyundai presented on cybersecurity. As part of a risk analysis effort, Hyundai explored four different vulnerability types using a risk matrix and seven types of attacks. The risk analysis was followed by a risk mitigation. Future plans include a formal security analysis of three security protocols, and a manual analysis of the protocol to check for possible redundancies and using future hashing algorithms.
- FABRIC discussed the optimal coil, resonant stage, and power electronics architecture to enable compact high-power wireless charging systems in excess of 20+kW.
- FABRIC tested dynamic WPT solutions for 20 kW. Future demonstrations of safety and optimized power levels are needed.
- Presenters noted that misalignment was a significant influence on functional range and caused some decrease in efficiency.
- Hyundai's laboratory and safety performance of a 7.0 kW WPT system satisfied SAE J2954 performance. Test results at Idaho National Laboratory showed 88.4% efficiency, which was similar to Hyundai's results.
- Next steps for the 7.0 kW WPT charging include auto alignment, size and weight optimization, and incorporating SAE communication protocol compatibility.
- Per Oak Ridge National Laboratory, barriers for a bidirectional WPT system for a medium-duty vehicle (UPS delivery truck) include an 11" airgap because most applications are 6-8" for 20 kW WPT to maintain 85%+ efficiency, and meeting grid and utility standards on the grid side.

- Challenges and risks to a bidirectional WPT system include scaling coupling mechanisms to greater than 20 kW at an 11” airgap, meeting electromagnetic field emissions standards, and meeting efficiency targets.
- A finding of the bidirectional WPT project has been 585 W of power loss across the airgap using a UPS medium-duty truck. However, the charging maintains a 97% coil-to-coil efficiency.

4 Conclusions

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

- Dynamic wireless charging requires adapting to vehicle height differences.
- Demonstrating WPT technology in real-world scenarios requires better understanding of how wireless charging behaves at high speeds.
- Dynamic wireless charging requires compatibility between light-duty passenger vehicles and heavy-duty commercial trucks while maintaining compatibility with the light-duty SAE J2954 specification.
- Future research & development for WPT to meet safety limits is required. For capacitive WPT to meet safety limits, there is a need for high-voltage/current gain to limit fringing fields.
- Continued cyber security analysis is needed, such as security analyses of security protocols.