
INDUCTION CHARGING

Mind the gap

Detailed physical testing is underpinning vital standards work, as wireless charging of EVs moves from labs to the real world

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The first wave of modern EVs – the Nissan Leaf, Renault Zoe and BMW i3 – arrived in the absence of a global charging standard. As a result, the trio require quite different rapid-charging cable solutions: CHAdeMO for the Leaf, Combined Charging System (CCS) for the i3, and a Type 2 Mennekes connector for the Zoe. As a consequence today's rapid chargers tend to be three-tentacled beasts, carrying the costs and complexities of doing the same thing three ways.

As such, OEMs and infrastructure providers are keen to avoid a repeat in the emerging technology of wireless charging. This technique uses resonant magnetic coupling to transfer energy between a transmitting coil built into a pad fixed to the ground and a receiving coil carried on the underside of the vehicle, separated by an air gap. Several companies have brought their own variations of this technology to production readiness, but the ideal scenario would



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be to have full compatibility, so that an EV fitted with any given receiver will be able to charge reliably from any manufacturer's transmitter.

"The introduction of EVs with wireless charging capability has been delayed – the technology was ready two to three years ago," says David Schatz, director of business development at wireless technology provider WiTricity. "One of our licensees – Toyota – was already field testing but chose to wait for standardization because this is a long game and the car companies really feel the pain of the profusion of standards for conductive charging. They have to go through quite elaborate testing of every charging system that's on the market because of differences in standards and connectors and because of the differences in behavior between the chargers."

Standardization efforts

The SAE J2954 task force is the longest running standardization effort in the wireless power transfer field. The International Standards Organization (ISO) and the International Electrotechnical Commission (IEC) are also involved on the vehicle side and the ground side respectively.

"The good news is that there's a lot of synchronization and harmonization between those efforts – a lot of the same people serve on the various committees and their goals are very well aligned," comments WiTricity's David Schatz.

Standards activity is also underway in China under CATARC, the Chinese automotive research council, which is also deeply connected to SAE and ISO/IEC. And in Germany, a publicly funded consortium called STILLE is working to align development among its members – primarily German manufacturers and suppliers but with participation from others including Qualcomm, WiTricity, Ford, Nissan and Toyota.



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Barney Carlson, research engineer, Idaho National Laboratory

One organization leading compatibility efforts is SAE International, through its J2954 working group, which was set up in 2010. The group has already reached agreement on a common frequency band for light-duty vehicles, from 81.39kHz to 90kHz (nominally 85kHz), and has also outlined four wireless power transfer levels dubbed WPT1 to WPT4. The first two are the focus of current standardization work, with rates of 3.7kW and 7.7kW. Work beginning this year will address WPT3 operating at 11kW, while WPT4 at 22kW and further levels beyond will also be tackled in due course.

OPPOSITES ATTRACT?

Last summer a substantial project was undertaken at Idaho National Laboratory (INL) and funded by the US Department of Energy, to assess compatibility between rival systems using the standard frequency.

INL research engineer Barney Carlson, a member of the J2954 committee, coordinated the work. "We tested various coil topologies – circular and multicoil designs – to see if they are interoperable from design to design, across power classes and across different coil gaps," he says.

Power transfer was the sole focus of the study. A deployed system also requires data transfer between

ABOVE: WiTricity is currently evaluating an advanced wireless charging prototype on a 2017 Chevrolet Bolt under a recently established partnership with GM

Tests conducted by Volvo with an electric C30 showed that the car could be fully charged without a power cable in around 2.5 hours







transmitter and receiver, as is the case with cabled charging, but this need fell outside the test's scope.

"We're trying to avoid duplication of effort," notes Sebastian Mathar, a senior engineer at technology provider Qualcomm, who participated in the INL tests. "ISO 15118 standardizes communication for both cable and wireless charging. The objective is to reuse at least 95% of the work that has been done for cabled charging. A wi-fi based system is emerging as the preferred communications carrier," Mathar adds.

To gather repeatable results, INL employed a non-metallic rig to hold the two pads apart. The frame allowed precise adjustments to the vertical separation (z-axis) as well as horizontal displacements in the x-y plane. Rotational misalignment, to reflect skewed parking for example, was not assessed.

Prior work at INL had established that a pad bolted to an actual car behaved rather differently from a coil in isolation – as might be expected of a magnetic device positioned close to a ferrous chassis. Therefore, the test rig included a flat steel backing plate to emulate the vehicle body as well as an aluminum shield between the plate and the receiver pad. "The specifications of those two components were much discussed in the committee," Carlson notes. A battery emulator was used to receive the transferred power.

When it came to test subjects, Toyota provided a WPT1-level system using circular coils, while WiTricity and Nissan brought more powerful WPT2 circular coils, and Qualcomm and Jaguar Land Rover participated with another WPT2 system employing double-D (DD) coils. According to Qualcomm, a DD configuration provides a more compact design for a given level of performance. "The coils are on average 30-40% smaller than a circular coil," says Mathar.

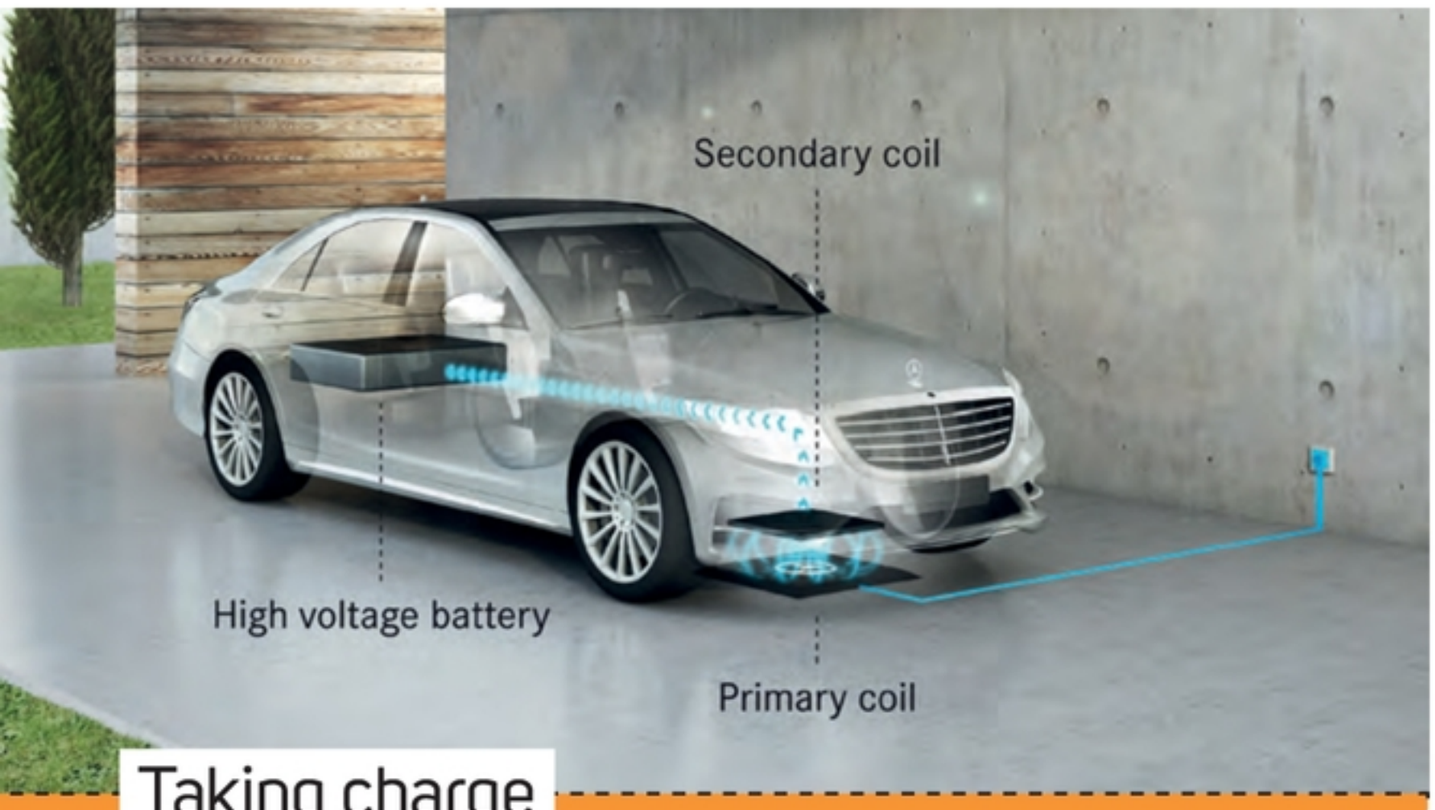
THE RIGHT MOVES

As well as assessing whether rival coils could work together at all, INL's study measured power transfer efficiency across the kind of misalignments likely to be seen in the real world. The different permutations of receiver and transmitter, various air gaps and a series of x and y deflections meant collecting tens of thousands of datapoints. The tests took several months to complete.

Carlson oversaw engineers from the participating providers, who carefully conducted each test scenario. Qualcomm's Mathar describes the process: "We'd set

ABOVE (LEFT): INL tests, which support validation of the J2954 working group, evaluated wireless charging systems from Toyota, WiTricity and Qualcomm

ABOVE: The WiTricity unit, which was submitted in cooperation with Nissan, operated at up to 7.7kW



Taking charge

Plug-in hybrid drivetrains represent the biggest strand to Daimler's e-powertrain road map – at least if you're talking actual numbers. Currently Mercedes-Benz has eight PHEVs on the market, and that will grow to 10 by the end of 2017, including the facelifted S-Class.

In addition to a huge leap ahead in battery technology, e-motors, range and power, the facelifted S 500e will also feature inductive charging, which is something that Mercedes-Benz has been testing and developing since last year. The system comprises two essential components: a secondary coil in the vehicle floor and a base plate with an integrated primary coil, which is placed within the garage floor or a protected area in front of a carport.

Via a display message in the cockpit, the driver can see whether the vehicle is in the tolerance range over the charging station. As soon as the correct position has been reached, the charging process automatically begins and is then monitored by the iductive charging system.

The electrical energy is transmitted at a power output of 3.6kW. Daimler says that with an efficiency rate of almost 90%, the 500e's high-voltage battery can be efficiently and safely charged, representing the future for this kind of technology.





those issues now. If we were to do it again it would work 100% smoothly."

The tests also provided confirmation of computer modeling. "For the first time we really saw it working," adds Mathar. "It was expected from our simulations, but we were positively surprised because you have to keep in mind that all three systems were developed completely independently. There was no communication during the development and interoperability was not the main focus. Nonetheless, interoperability was demonstrated and really worked very nicely."



"What we saw was 95% super, great results, and the remaining 5% were not unexpected. And we know how to solve those issues now"

Sebastian Mathar, senior engineer, Qualcomm

TOP (RIGHT): Qualcomm's Halo wireless electric vehicle charging has been rigorously tested and refined in the Formula E BMW i3 and i8 safety cars. Lessons learned are being implemented into its consumer technology

ABOVE (RIGHT): Halo uses resonant magnetic induction to transfer energy wirelessly, from a ground-based pad to a pad integrated into the vehicle's base

up our vehicle pad on the test rig, for example, with the agreed separation. We'd talk to the ground-pad engineers and agree a certain current, voltage or power that they needed to generate on their pad. Then we'd monitor the energy we received on our pad, to see what fraction of power we got – typically 91% or 92%. That's what we did all summer long. Then, once we finished one, we'd switch off the power and go to the next offset."

The results of the tests were encouraging, Carlson reports: "There was a high degree of interoperable performance among all these systems, and across all the test conditions," he summarizes. Meanwhile, Mathar's verdict is more quantified. "What we saw was 95% super, great results, and the remaining 5% were not unexpected. And we know how to solve

Following the tests, the SAE working group was able to reach agreement in January on specifications for a test station, which manufacturers will be able to use in order to verify compatibility of production designs. The test station uses a circular coil but, as the INL tests have demonstrated, other compatible topologies are also possible.

But as with any good working standard, the emerging SAE work will leave plenty of scope for innovation in other areas, such as system efficiency, cost, complexity, durability and longevity. As Mathar astutely observes, there is still plenty of work to be done before the automotive industry is able to create a fully formed standard. "Discussions on foreign object detection and living object protection are both on the agenda for 2017," he notes. ❮