Charged in motion

Recharging electric vehicles (EVs) is still an inconvenient process, but this may soon change. In a joint project with industrial partners, Fraunhofer researchers have developed a system that enables EVs to recharge their batteries while in motion on the road through the inductive transfer of electricity - a technology that numerous Fraunhofer teams are helping to advance.

Text: Tim Schröder
Electric cars are silent and don’t emit offensive exhaust fumes. And they are miles ahead of conventional gasoline or diesel vehicles in terms of environmental impact, as long as the electricity is generated from renewable resources. The German government offers tax reductions and other incentives to encourage people to buy electric cars. And yet in 2014 only 21,000 electric vehicles were registered in Germany. This is a drop in the ocean compared with the 43 million conventionally powered vehicles circulating on German roads: electric vehicles have still not achieved the hoped-for breakthrough. This is partly due to their high price but also to their restricted range, which has been a problem from the outset, and the inconvenience of existing charging methods. To “fill up”, drivers have to plug in a special cable and arm themselves with patience.

If electric cars could be liberated from their charging cables and their range extended this would represent a huge step forward for e-mobility. This may sound like trying to square the circle, but one such solution has already been demonstrated on a test track. A number of companies have joined forces with researchers from the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials IFAM in Bremen and for Transportation and Infrastructure Systems IVI in Dresden to change the way electric cars are supplied with electricity. Their solution is to recharge the vehicle while it is in motion.

Their groundbreaking approach is based on a technology known as inductive or wireless charging, already widely researched solution for charging stationary vehicles. In inductive charging, electricity is transferred to the vehicle through the air by means of a magnetic field created between electromagnetic coils mounted on the underside of the vehicle and coils embedded in the road. Physicists have known about the principles of induction, in which a magnetic field generates a flow of current in an electrical conductor, since the mid-19th century. It is only in recent years that these principles have been applied in technical applications such as induction hobs or charging stations for electric toothbrushes.

“Filling up” while driving

It has been barely two years since the project was launched, but it has already taken inductive charging a decisive step further. With the support of the German Federal Ministry of Transport and Digital Infrastructure BMVI and the National Organization for Hydrogen and Fuel Cell Technology NOW, a 25-meter test track with integrated induction loops has been constructed on the premises of the engineering services company INTIS in Lathen, Emsland. The IFAM researchers’ role in this project was to integrate the necessary inductive charging technology in the vehicle. To conduct the tests, they fitted a sports car with an electric engine to create a demonstrator named FreccO – short for Fraunhofer electric concept car, generation 0.

“We showed that it is possible to charge the battery while driving round the circuit at a moderate speed,” reports project manager Bartels of the institute’s Electrical Systems department. “This is proof that the concept of dynamic charging, i.e. recharging the vehicle while it is in motion, is technically viable.”

The researchers went to huge efforts to create a realistic test environment. One major requirement was that the road surface should closely resemble that encountered in real-life driving situations. This task was entrusted to two project partners: a road construction company integrated the induction loops in the test track and Alcatel provided the electronic control system. Another important component was the vehicle detection system, which ensures that a current is induced in the loops only when a vehicle drives over them.

Inductive energy transfer

The IFAM researchers were responsible for integrating the inductive charging system in the electric vehicle. “The challenge was to find the best compromise between vertical clearance, required mounting space in the vehicle, and system efficiency,” says Bartels. The distance between the charging coil in the vehicle and the induction loop in the road plays a major role in this respect. The shorter the distance between the charging coil and the road surface, the simpler and more efficient the transfer of energy.

The IFAM engineers added a voltage converter to adapt the high-frequency alternating current supplied by the induction loop to the onboard DC network. They also installed a charging regulator in the vehicle, together with the necessary electronics. And finally they integrated all of these components in the electric powertrain and...
linked them into the vehicle’s electronic communication system.

The IFAM researchers have demonstrated that this sophisticated technology works on the indoor test track. Their concept car charged its batteries from the induction coils in the ground as it traveled from one end of the building to the other at a speed of 35 kilometers per hour. “If the track was longer, I’m sure that we could charge the battery at higher speeds,” says Bartels. The researchers envisage that it would perfectly possible to recharge vehicles even when traveling in the fast lane of the freeway. But this would mean installing induction coils over long stretches of road. Christian Rüther, who heads Fraunhofer IFAM’s strategic project management team, is convinced that this might one day be possible. “Obviously, it would be impossible to equip all existing freeways with this technology in one go. But there is no reason why it couldn’t be incorporated in new roads or sections of freeway already scheduled for major reconstruction.” Another of the project’s objectives was to ensure that the induction loops embedded in the road would have an insignificant impact on overall construction costs.

Rüther sees the introduction of dynamic charging as a gradual process, starting with small-scale applications in places such as bus stops or taxi stands, where vehicles move slowly up the waiting line. The contribution by the Fraunhofer IVI research team focuses on precisely this type of application. They have installed the inductive charging system not in a car but in their AutoTram. This cross between a bus and a streetcar with rubber tires was developed by the institute as a research platform. Up to now, it has been used to demonstrate various drive technologies including batteries, super-capacitors and fuel cells. In the future it will also be able to top up its batteries on the go by means of dynamic inductive charging.

**Stationary systems**

The big advantage of both stationary and dynamic inductive charging is that it does away with the need for cables. Cables can accumulate dirt, and charging stations are susceptible to damage by vandals. Wireless charging by means of induction loops gets rid of these problems. Stationary inductive charging generally involves immobilizing the vehicle in a parking bay for a significant length of time. And because the charging pads transfer high levels of energy, there is an increased risk that objects underneath the car could overheat or even burst into flames. The resulting high-intensity electromagnetic field also presents a danger to cats and other family pets who might be tempted to take a snooze under the warm engine.

To solve these problems, researchers at the Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen have developed an alternative to charging coils mounted in the floor of the vehicle. In their novel solution, the receiving coil is situated in the nose of the vehicle, near the number plate. The key to this innovative solution is a charging bay that allows the car to park within a very short distance of the pillar. By reducing the distance between the transmitting coil and the vehicle, it is possible to use coils with a much smaller diameter than those needed when the transmitting coil is installed at ground level: ten instead of 80 centimeters. And if the driver accidentally bumps into the pillar, it automatically folds away to prevent damage to the vehicle.

Inductive charging is also an interesting proposition for car sharing. The six Fraunhofer Institutes participating in the GeMo project (shared use of e-mobility: vehicles, data and infrastructure) have chosen to implement a range of future-oriented technologies including an infrastructure consisting of inductive charging stations and cloud-based charging management. The inductive charging system for electric cars was developed by researchers at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. The first prototypes of this charging system are capable of transmitting up to 22 kilowatts of power. This level of efficiency is sufficient to charge the batteries of a conventional electric car to 80 percent of their rated capacity in less than one hour.

In either case, wireless solutions for recharging electric vehicles without pesky cables will soon be commercially available, thanks to Fraunhofer research. “Both dynamic and stationary solutions are necessary to improve the acceptance of e-mobility. For this reason we intend to reinforce collaboration between Fraunhofer Institutes in the months to come,” says Christian Rüther.