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High Efficiency 22 kW Inductive Charging System for Electric Vehicles

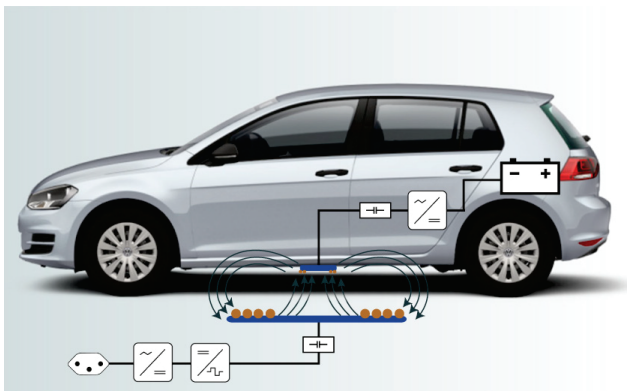
Inductive power transfer (IPT) for electric vehicles is an emerging field of research around the globe, focusing on economic aspects of the use of wireless power transfer as well as its implementation. IPT systems increase the convenience for the owner of an EV and enables a new method of charging cars and therefore overcome one of the main limitations of cars powered solely by electric energy. The commercial success of such a wireless charger is highly dependent on the energy conversion efficiency. The presented design consists of a rectangular receiver coil mounted on a car and a rectangular transmitter coil fixed to the ground. Even with a lateral misalignment of ±75mm in driving direction and ±150 mm transverse to it and a ground clearance range of 100 mm to 250 mm high efficiencies can be reached. A fully functional prototype was built and verifies the behavior of the FEA simulation results, electrical simulations and demonstrates a DC to DC efficiency of up to 95 %.

Simon Nigsch, Janosch Marquart, Kurt Schenk
University of Applied Sciences NTB, Institute for Energy Systems
Buchs SG, Switzerland / http://www.ntb.ch/ies/
simon.nigsch@ntb.ch; janosch.marquart@ntb.ch; kurt.schenk@ntb.ch

Motivation

Inductive power transfer has become fairly common for low power applications such as handheld electronic devices. In laboratories around the globe, considerable research effort focuses on extending this technology to higher power systems. The main application is the charging of electric vehicles (EVs). This charging principle will allow the charging process to be performed without any action of the driver, providing even greater comfort and convenience. At a charging rate of 22 kW, every minute of charging time provides approximately two kilometer of driving range. The success of such a wireless charger is highly dependent on the charging efficiency compared to conductive charging systems, which are in the range of 95 %. There are a number of challenges to overcome in order to realize such a system with high efficiencies, meet the functionalities, size restrictions at the same time.

Charging Principle



The transmitter coil is fixed to the garage floor or parking space, whereas the receiver is attached to the car. In order to charge the battery, the car has to be parked such that the receiver coil is aligned over the transmitter coil. For practical reasons some lateral misalignment must be taken into account.

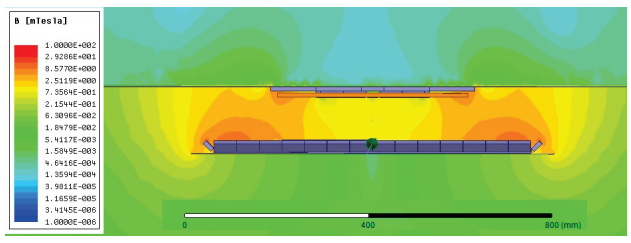
Specifications

The design is based on the key specifications shown in the table below. The charging system can be connected to a standard three phase 16 A outlet and allows charging an EV within a few hours. The values for the ground clearance and the frequency range meet the standards IEC 61980 and SAE J2954.

Nominal power	22000 W
Input voltage	600 – 800 V
Battery voltage	330 – 440 V
Nominal switching frequency	81.3 – 90 kHz
Transmitter dimensions	800 mm x 800 mm
Receiver dimensions	500 mm x 500 mm
Ground clearance	100 – 250 mm
Misalignment	±75 mm / ±150 mm

Optimization Process

The central element of an IPT system is the magnetic coupler. Its magnetic characteristics strongly depend on the lateral misalignment range and the air gap variation for which it is designed. Lateral misalignment and air gap variations lead to variations in the inductance values. The variation of the inductance and with that the variation of the coupling, has a direct impact on the system design and efficiency. The main goal is to keep the variation of the coupling coefficient as small as possible while achieving a coupling as high as possible.

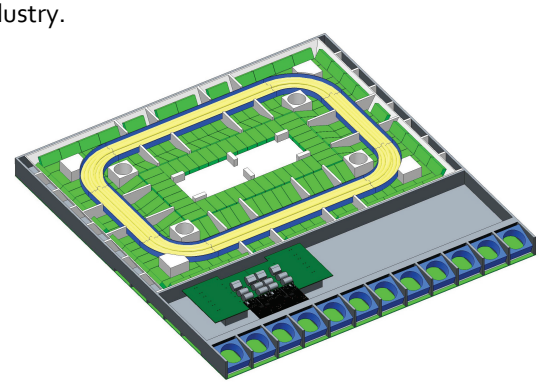


Mechanical Prototype

To verify the behavior of the FEA simulation results a fully functional prototype was built. A 22 kW wallbox was designed with a power density of 4 kW/dm³, which is shown in the figure below. The wallbox is connected to the transmitter coil including the compensation capacitance with a size of 800x800x60 mm³. To keep the dimensions of the receiver small a 3D printed version has been designed and built.

Conclusion

In this work a 22 kW inductive charging system has been designed, optimized and built. The measurement results verify the FEA and electrical simulations. To optimize the efficiency, various coupler designs have been analyzed considering the given specifications. Measurements showed that a DC-DC efficiency of higher than 95 % is possible for inductive charging systems with the specification constraints given from industry.



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