Wireless charging using a resonant auxiliary winding

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Summary

The project has investigated different types of inductive power transfer coils and also the possibility of adding an extra winding to the system. The extra winding is connected to a capacitor and by means of resonance or near resonance the reactive power that is needed comes from this extra winding.

The best type of the investigated coils is the so called DD-coil which has low leakage field and can be used with larger air gaps compared to a circular coil. The bar type which has been used in a student project has been tested and works fine, but the leakage flux is higher compared to the DD-coil and it will be harder to shield the passenger compartment from to high flux density. A DD-coil with the size of 400 * 400 * 20 mm can handle the power of 6 kW. A work done by Qualcomm indicates that the size may be lowered by 40 %.

The extra coil and capacitor works well and make the system more tolerant to misalignment. The total number of turns and the amount of copper will however increase compared to a two coil solution.

During the project methods for analysing the system has been developed. The methods includes FEM-analysis and simulations and to some extent laboratory work. It should be possible for skilled personal to follow the workflow.

Next step could be to develop a working system out of specifications from VCC.

The technology has a potential to make it easier to use electro mobility. The plug-in cars that will soon come to the market have small batteries and the need for easy and convenient charging will be high in these vehicles.

The project has been ongoing on Chalmers between 1403-1505 and financial support from SHC has been given with the amount of 1800 kSEK.

Background

Inductive charging, inductive power transfer or wireless charging is about delivering power over a distance from the ground to the under body of the vehicle. The situation may be static and standstill at a parking place or it may be done when the vehicle is moving, so called dynamic charging. At standstill it's possible to move one of the coils in order to minimize the air gap.

The inductive power transfer takes place between two coils of which one is buried in the ground and the other one is placed under the car. The distance between the coils can be relatively large which means that the leakage factor is rather high. There is also a need for reactive power in the form of capacitors, which will be used for compensating for the big air gap, which can be as high as 15-20 cm. In order to manage the power transfer a resonant circuitry is used at a relatively high frequency.

For the time being inductive chargers as a home charge device will be an option to the plug-in and electric vehicles in a couple of years. It is also likely that it will be an option for city buses, where a lot of test activity is ongoing. In Korea a semi-commercial line of buses is already in use.

The need for convenient charging differs depending on the vehicle. As an example a plug-in hybrid (PHEV) where the battery needs to be charged every 30 minutes or less, it has to be convenient to charge the vehicle. An inductive charger is more convenient than the handling of a cable. For purely battery electric vehicles (BEV) it's probably no need for inductive charging, of course this is depending on range and use. When an electric vehicle has a range of 300 km or more it's probably enough for the average car owner to use a wall box at home or fast charger on longer trips.

An example is Qualcomm that claims a power rating of 6.7 kW from a secondary coil with the dimensions of 40 * 40 cm2 and they also think that this may be lowered by 40 %.

General project description

The project has been divided into several work packages, see Table 1.

Workpackage	Activity
1.1	Survey of coils
1.2	Magnetic Evaluation without extra coil
1.3	Magnetic Evaluation with extra coil
1.4	Study of high frequency transformer
2	Bachelor project 6 kW
3	Series or parallel
4	Construct and build experiment
5	Testing
6	Enhanced power electronics
7	Documentation
8	Ref. group meeting
9	Workshop

The work has proceeded well except that the laboratory activities had to be changed. The bachelor project occupied the lab and some activities collided, partly because the simulation activities where late. Instead a master thesis worker has been engaged on testing on smaller coils.

Achieved results

The survey of coils resulted in that the best type of the investigated coils is the so called DD-coil which has low leakage field and can be used with larger air gaps compared to a circular coil. A DD-coil with the size of 400 * 400 * 20 mm can handle the power of 6 kW. A work done by Qualcomm indicates that the size may be lowered by 40 %.

The extra coil and capacitor works well and make the system more tolerant to misalignment. The total number of turns and the amount of copper will however increase compared to a two coil solution. The magnetic analysis of two and three winding coils revealed no big differences except a slightly lower flux density with the extra coil.

During the project methods for analysing the system has been developed. The methods includes FEM-analysis, simulations and to some extent laboratory work. It should be possible for skilled personal to follow the workflow.

The technology has a potential to make it easier to use electro mobility. The plug-in cars that will come to the market have small batteries and the need for easy and convenient charging will be high in these vehicles.

Contribution to hybrid vehicle technology

The project mainly contributes to electro mobility with knowledge of how to analyse and dimension inductive chargers.

From academic point of view the knowledge has increased and can contribute to future courses where inductive charging is a part of the education. The work concerning three winding concept has been accepted as a conference article and increased the knowledge on this type of inductive charger.

Uniqueness and news value

In comparison to what was presented at EVER 2015 we are late and have smaller resources. Qualcomm presented a broad study including tests that pinpointed the differences between different magnetic configurations.

The work around the third coil has been acknowledged at the EVER conference and hopefully one more article will be presented.

Timing and finance

Workshop in January 2015

Article to EVER 2015 in March.

The total project budget is SEK 1.8 million, which is funded by SHC.

Executors and collaboration

At Chalmers, Eva Palmberg, Saeid Haghbin and Robert Karlsson have been working on the project.

A master thesis worker Ivan Salcovice has been participating during the spring and mainly been supervised by SH.

A workshop where held together with Ellen Olausson, Viktoria ICT, who told us about the Wich and Sawe projects. Roy Andersson from Volvo informed about the project Unplugged.

Dissemination of Results

A Report has been finalised and the article 'Wireless Charging using a resonant auxiliary winding' has been published at EVER 2015.

A workshop 'Inductive charging of electric vehicles' was held in January 2015.

Papers and publications

E. Palmberg, M. Alatalo, S. Haghbin, R. Karlsson, S. Tidblad Lundmark, ' Wireless Charging using a resonant auxiliary winding', 2015 Tenth International Conference on Ecological Vehicles and Renewable Energies (EVER)

M. Alatalo, 'Wireless charging of vehicles using an extra resonant winding', Concluding report, Chalmers University of Technology 2015

E.Palmberg, 'Investigations on an inductive power transfer coupler with two or three windings', Chalmers report

I. Šalković, 'Wireless charging using a separate third winding for reactive power supply', Master theses report 2015

A. Holm, A. Hultin, L. Petersson, J. Stelin ,A. Thorslund ,C. Tisell, 'Förbättring av verkningsgraden i ett induktivt laddningsystem genom design av ny växelriktare', Kandidatarbete ENMX02-15-07

Coming papers:

Ivan Šalković, Saeid Haghbin and Torbjörn Thiringer, 'The control design and practical measurement of a wireless power transfer system with an auxiliary transformer winding,' will be submitted to IEEE International Conference on Renewable Energy Research and Applications (ICRERA) 2015, Italy

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