# EMC and Safety Studies on Electric Road Systems

Lars Lindgren

Lund University, Industrial Electrical Engineering and Automation

Swedish Hybrid Vehicle Centre

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## Summary

Electric Road Systems (ERS) are systems that supply energy from the electric grid to electric vehicles while they are driving. ERS can reduce the needed battery size in electric vehicles and reduce the fuel consumption in hybrid vehicles. ERS can generate radio interference. (Electro Magnetic Compatibility (EMC) problems).

This project has analysed the electromagnetic emissions from an ERS with a new measurement method. The measurement result indicates that it should be possible to fulfil current standards.

The project also suggested EMC-standardization of conductive ERS, current standards is not fully relevant to ERS.

In addition to potential EMC- problems has the risk with short circuits through tires in some ERS-solutions been investigated and it was found to be less of a problem than expected.

Active Partners in the project are Lund University, AB VOLVO, ALSTOM.

Project period 2013-06 to 2015-06.

Project cost 2 MSEK.

# Background

For a large move of road transportation to electricity as prime energy supply form, charging of vehicles when parked is not sufficient. To reach a long driving range, the batteries become unrealistically big and expensive and the charging of them either demands extreme power levels or becomes very time consuming. Charging of parked vehicles is best used for vehicles in commuting or other short distance daily use. Long trips, in particular highway traffic like Long Haul, cannot benefit enough from overnight charging to make such transportation contribute significantly to a transfer of road transport to electric energy supply. The net result is that with stationary charging alone, electric vehicles can only displace somewhere between one quarter and half of the fossil fuels used for transportation. That is by far not enough.

The solution is charging while driving, a.k.a. “Dynamic Charging”, “ERS” (Electric Road Systems) or “Slide In” charging. ERS enables all road traffic forms to transfer to electricity as primary energy supply form. The development of ERS is today fast with several alternative solutions in various levels of (pre) commercialization like Siemems/eHighway, Alstom/APS, Olev Technologies, Elways and more. The World Economic Forum has recently ranked the top 10 emerging technologies1 where ERS is ranked number one! The main challenges are addressed in Europe via e.g. the FP7-project FABRIC (FeAsiBility analysis and development of on-Road charging solutions for future electric vehiCles – FABRIC) where many automotive OEM’s in Europe participate. In Sweden several full scale research studies are run on ERS.

There is a need to build detailed knowledge on EMC and safety issues related to ERS. In conductive ERS the sliding contacts will generate some arcing.

As a consequence, all these vehicles pose risks of being a transmitter of electric disturbances either conducted or radiated. In some ERS-solutions with exposed conductor tracks tires of adjacent vehicles could in some situations be exposed to energized conductors posing a risk of short circuits. These risks must be minimized in the design choices, which require deep understanding of how the risks and design relate.

This project builds knowledge on EMC and safety issues related to ERS by experimental validation. The results will be shared with the scientific community and present national projects.

# General project description

In this project an overview of EMC – standards for road vehicles, trolley busses and trains and how they relate to ERS is made.

A small scale test rig for testing the behaviour of sliding contacts in an ERS context is built and used to determine the generated EMI.

A full scale electromagnetic physical model of an ERS with a car is built and the electromagnetic propagation is measured in this model.

[1] http://forumblog.org/2013/02/top-10-emerging-technologies-for-2013/

The results from the small scale test rig and the full scale electromagnetic physical model is combined to a emission spectra that have been compared against EMC-standards.

In addition to the EMC related activities the probability and effects of short circuits through tires is investigated. The general structure of different types of tires is investigated by contacting the tire manufacturer Bridgestone. The probability of short circuits is evaluated by measuring the insulation e.g. between screws puncturing the tire. A capacitor discharge rig has been built and used to test what happens if a short circuit through a tire happens. The capacitor discharge circuit consisted mainly of a 600 V capacitor bank of 10 mF with reverse polarity protection diodes, a 70 µH current limiting inductor and a mechanical switch.

# Achieved results

### Standards

It is found that EMC-standards are inconsistent in this area. Trolley buses have a special rule so that they follow the railway and tram standard EN 50121 while other road vehicles follow CISPR 12 and CISPR 25. It is unclear if a bus with an electric pickup under the bus can be defined as a trolley bus. It is also illogical that vehicles operating in the same system with similar drive trains should use different standards depending on if it is a bus or not. The railroad standard EN 50121 - 2 is the most applicable since it defines how measurements should be made while a vehicle passes the measurement site on a track. CISPR 12 and CISPR 25 are mainly based on measurement on stationary vehicles and components. Measurement on stationary vehicles with no sliding contacts without a way to emulate the sliding contacts is useless in order to evaluate the generated EMI. Therefore does it seem best if the special rule for trolley busses would be extended to other vehicles powered through sliding contacts or generally from a road side system.

### EMC level

The EMI levels from a ”Slide In Pick Up” is measured and calculated and fulfils the requirements from EN 50121-2 but as far as it can be judged with the current measurements are just on the limit of fulfilling CISPR 12. When the result is linearly scaled to 250 kW power transfer a few peeks exceeds the limits of EN 50121-2 with a few dB so some improvements are probably needed. No concerning EMI levels was found below 10 MHz.

### Measurement method

The measurement method of separate small-scale test of sliding contacts and full scale tests of electromagnetic propagation is tested and can be performed with a simple spectrum analyser with tracking generator. The result seems to be promising but no comparisons are made with other measurement methods.

### Probability of short circuit through tires.

It is found that the steel wires reinforcing tires are insulated from each other and even when two screws was inserted in the tire with the intention of hitting the same wire the probability of a short circuit was less than 10 %.

**Consequences of short circuit through tires.**

A capacitor discharge circuit capable of generating currents up to 6500 A with a rise time of about 1 ms is used to experimentally test a ERS short circuit through a tire. When charged to 600 V it has a stored energy of 1.8 kJ. This is equivalent to the short circuit power a few hundred meters from the feeding station. In all tested cases the tire damage is very localized and unlikely to cause catastrophic failure of the tire except for the potential case were a fire are initialized inside the pressurized tire by sparks from the short circuit. This is especially relevant if the tire is filed with flammable substances such as some canned tire inflators. No test of this could be performed safely in our laboratory.

The results of this test is of relevance for the development of ERS technology since it eliminates the concern that the tested kind of short circuit situation could be a major threat to the energy transfer technology.

## Contribution to hybrid vehicle technology

Electric Road Systems (ERS) are the single most promising technological possibility to significantly reduce energy consumption and emissions from road transport. ERS also brings the traditional automotive industry into the field of electric propulsion from a continuous supply, where so far trolley buses is the only product.

It is thus relevant to establish a better understanding of how the EMC situation with the new ERS technologies relate to existing standards. In that respect, the contributions from this project are important.

The project also addresses the challenge of tire short circuit, another concern that is very relevant for the automotive industry to address.

## Uniqueness and news value

Since these systems are new very little studies on these subjects is published before. The development of ERS technology is very much about “breaking new grounds” and all challenges addressed as well as results achieved in this project are unique.

## Timing and finance

The budget in the project application was 5 MSEK of which 2.5 MSEK was applied for from SHC, LTH in kind 500 kSEK, VOLVO in kind 1.5 MSEK, SCANIA in kind 500 kSEK. SHC approved 2 MSEK funding.

The possibilities to access the real test track in Hällered are very limited and is planned to happen in the early fall 2015. At the time of writing this report, these tests are prepared. The In Kind costs on AB Volvo for access to this test track are to be spent during the second half of 2015.

For similar reasons, Scania’s In Kind contribution to the project is very low.

## Executors and collaboration

The main experimental design, equipment selection/design and experimental work are done by Lars Lindgren research engineer at Lund University and the main author of this report. During the later part of the project very valuable assistance in the experimental work was given by Freddie Olsson project employee at Lund University.

A one day project meeting for this project was arranged with participants from Alstom, LTH, Victoria institute and AB Volvo, 10 participants in total was arranged at 2014-03-06 at LTH.

It resulted in a good discussion of the problems at hand and some directions for the continued work. Especially the comment from the Alstom representatives based on their experience is very useful.

## Dissemination of Results

Since many of the results are accumulated to the end of the project period, no workshop activity is performed yet, but planned for the early fall 2015. The workshop will be about EMC and Safety aspects of ERS technology and involve reserach fromb both Lund and KTH.

A paper on the same topic to the CERV (Conference on Electric Roads and Vehicles) conference in February 2016 is also planned.

## Papers and publications

No publications based on these results have been published yet.

Swedish Electric & Hybrid Vehicle Centre
Chalmers University of Technology
Hörsalsvägen 11, level 5
SE-412 96 Göteborg

Phone: +46 (0) 31 772 10 00

www.hybridfordonscentrum.se