Pre-study: Power Conversion Challenges with an All-Electric Land Transport System

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Title: Pre-study: Power Conversion Challenges with an All-Electric Land Transport System
Thematic area: Electrical Machines and Drives
Project manager: Francisco J. Márquez-Fernández
Partners: AB Volvo, Scania, Volvo Cars
Duration: 2016/06/01 – 2016/09/30
Cash funding: 320 000 SEK

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Summary

This pre-study aims to find out those research topics that present the highest interest for SHC's industrial partners in order to set up a proposal for the Thematic Area 2 researcher's main project. The study started June 1st and finished September 30th and the main delivery was a full project description for the main project, which is planned to span over 20 months after the conclusion of the pre-study.
The direction of the pre-study is towards charging solutions and main related issues for different types of vehicles, different forms of charging, for safety and automation, in a societal perspective, also including the electric utility grid impact.
All SHC partners are involved in the pre-study, in particular those represented in the Thematic Area 2 group.

Background

An all-Electric land transport system solution requires the following four fundamental systems:

1. A cost- and space-effective Electric Traction System in the vehicle.
2. An on board Electric Energy Storage providing a certain range, typical: 50...500 km.
3. An Opportunity Charging System, allowing an extension of the range within a reasonably short charging time, typical: << 1 hour.
4. A Continuous Charging System (SlideIn/Dynamic Charging/Electric Road System), without which a full electrification of e.g. Long Haul/Coach Bus/BRT will not be feasible and a full electrification of cars would require 5…10 times more batteries and a vast number of opportunity charging systems than would be the case if a Continuous Charging System for cars was available.

The first two of these systems have currently reached an industrial maturity level allowing a wide industrial introduction of hybrid, plug in hybrid and full electric vehicles in some niches, in particular cars and city buses, but not in heavy or light goods transport, not in coach bus applications and not in BRT applications.

The reason for this is to be found in the last two systems. Heavy goods transport, Coach Bus applications and BRT need a continuous charging solution. Light goods transport needs a low cost opportunity charging system. Light goods transport is particularly sensitive to opportunity charging, without which the battery weight for a full day operation would otherwise compete too much with payload capacity.

Neither a continuous charging solution, nor a low cost automatic opportunity charging solution is commercially available today, but a strong development is ongoing, in particular of continuous charging solutions, and to a lower extent on low cost, high power, automatic opportunity charging solutions.

This is a new territory for knowledge building on future electric land transport solutions. There are several issues to address, e.g.:

1. The most promising continuous charging solutions do NOT provide an electric ground connection for chassis potential limitation, which is most of a challenge at low speed in e.g. city operation. There are solutions underway, not building on a PEN (Protective Earth Neutral) but on a PEM (Protective Earth Minus) connection.
2. The need for on board galvanic isolation of the on board systems at high powers for continuous charging cannot, due to cost and size, be made with an isolated DC/DC converter, but requires “smarter” solutions.
3. A low cost opportunity charging solution for e.g. distribution trucks can probably not be made with a DC supply, also due to cost.
4. The grid impact of a vehicle charging and even more so – of many vehicles charging simultaneously. In particular, charging at high power levels brings about a stability problem on the electric utility grid. Today, opportunity charging of buses faces the problem of high local grid load that sometimes needs some kind of reinforcement of the electric utility grid. Whilst at present this problem is limited to these cases, it will grow fast with a growing full electric land transport.
5. The effect of a game-changing technological or societal breakthrough in the aforementioned topics. Examples of this may be the irruption of graphene batteries

in the market with 4 times the energy density of current LiIon batteries or the generalization of autonomous driving vehicles allowing for faster / higher power driving

The research field depicted above is to a large extent left untouched up to now, since most of the focus has been on driving the vehicles rather than charging them. It is not so that none of the above issues are unaddressed. Research is ongoing and it is clear that the solutions in many cases involve the re-design of the electric traction system on board as a part of the energy transfer from the grid to the energy storage and eventually the wheels. It is equally clear that detailed knowledge on electric safety, chassis potential limitation and electric grid impact in the grid connected vehicle is of fundamental importance to a successful all electric land transport system.

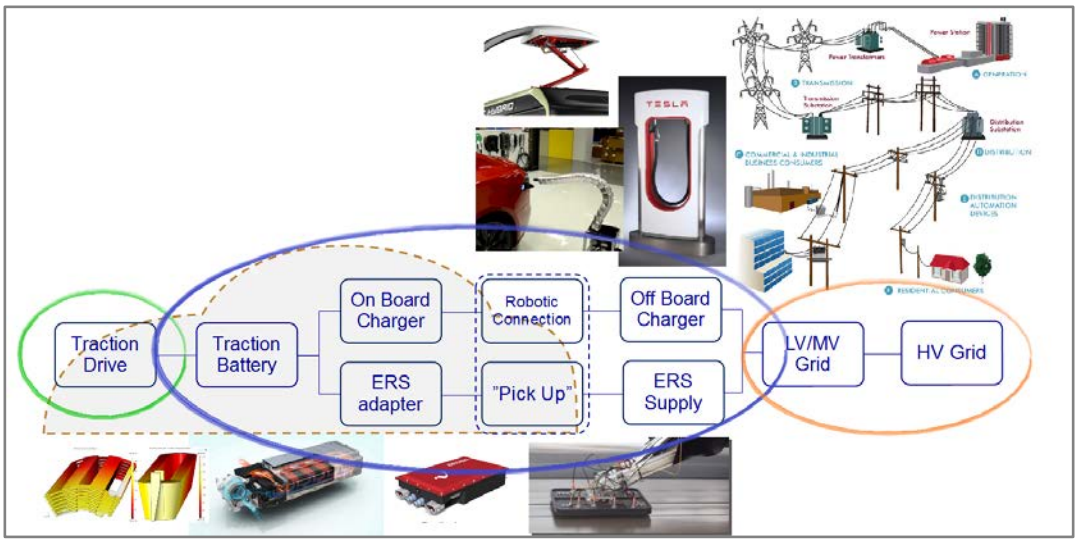

Figure 1. Illustration of the full electric land transport system. The targeted research topic fall within the parts enclosed by the blue line

It is thus the intention that the SHC Thematic Area 2 researcher shall take a lead in the direction of charging solutions, including the design of the traction drive and other related on board systems, vehicle safety and grid impact – with a large scale introduction of full electric vehicles in the land transport system as the expected vision.

The intention is to, together with all industrial and academic partners of SHC, in a pre-study develop a detailed project description in this field.

General project description

This project is a pre-study aimed to deliver a full project plan within the specified research area.

The project is performed in cooperation with the following SHC partners:

- AB Volvo
- Volvo Cars
- Scania CV
- LTH

The main activities carried out during the pre-study are:

- Selection of reference group members from each industrial partner.
- Initial meetings with each partner separately to understand the technical challenges they are facing within the proposed research area.
- Identify the primary focus items for the full project among the commonalities found between the partners.
- Meeting with each industrial partner to define their in-kind contribution to the full project.
- Writing of the full project proposal based on the information collected from the previous meetings in coordination/collaboration with the partners.
- Final meeting with the partners to present and agree on the final full project proposal and pre-study report.
- Initial meetings with International research partners for planning of joint research efforts and identification of potential funding sources. A full detailed plan with related funding applications is not within the scope of this pre-study, but it will be a part of the full project.

Results

The main result for this pre-study is a full project proposal for the full project for the Thematic Researcher in Electrical Machines and Drives.

Scheduling

The project started on June 1st 2016 and finished September 30th 2016.

Milestone	Description	Date
M1	Draft project proposal	2016-08-20
M2	Final project proposal	2016-09-09
M3	Final pre study report	2016-09-30

Project participants

Researchers (affiliation and role)

The researchers that participated in this pre-study are:

- Prof. Mats Alaküla, LTH
- Prof. Malcolm McCulloch, University of Oxford, UK
- Dr. Francisco J. Márquez-Fernández, LTH

Industry participants (affiliation and role)

- Jörgen Engström, Scania
- Pär Ingleström, AB Volvo
- Joachim Lindström, Volvo Cars

Project finance

The project cost for Dr. Francisco J. Márquez-Fernández is funded by SHC to a 80 % in the role as a Thematic Area researcher, corresponding to 320 000 SEK for the proposed project. The project costs for all other participants are in kind contributions for meetings within the SHC frame.

Utilization of results

The project results were presented to all involved SHC partners in a draft version in the middle of August (Milestone 1). The final project report resulting from this pre-study was presented to the SHC Advisory Board for approval in September.

Collaboration

The pre-study itself did not form part of a broader collaborative project. However, during the pre-study two collaborations were established within the main project frame:

- A collaboration with the Energy and Power Group in the University of Oxford, UK
- A collaboration with Vattenfall

In both cases, the collaboration aims to increase the competence level in the project regarding power grid modelling, in order to evaluate the potential grid impact of high power highly dynamic electric loads, such as those originated when fast charging EVs.