Swedish Electromobility Centre

Theme 2: Electrical Machines and Drives - Roadmap

Introduction

Electrification of both on-road and off-road transportation develops now faster than ever before, and all predictions indicate that this development will continue in the foreseeable future. This development drives a need for better, more efficient, reliable, cost effective and sustainable components and systems for the supply and conversion of electric energy. These new systems and components make electric and hybrid electric vehicles not only comparable to but superior than their combustion engine counterparts. *Theme Electrical Machines and Drives* of the Swedish Electromobility Centre has its focus on knowledge building, research and technology development within this field, with a pre-competitive industrial perspective, i.e. long enough into the future so that it is possible to influence future product lines.

The research activities conducted in the theme span over a broad area, including theoretical and numerical modelling and simulation of the components (analytical equations, Finite Element, Computational Fluid Dynamics, etc), integration of these component models into a complete drive unit dynamic model (e.g. Matlab / Simulink), development and lab testing of prototypes for validation purposes and even real-life conditions testing when relevant.

Scope and boundaries of the theme

Theme Electrical Machines and Drives is responsible for being a **competence base for technology related to electric energy supply and energy conversion related to electromobility**, both for traction and auxiliary loads. The main research focus lays on electrical machines, power electronic converters and their combinations, applied to the traction powertrain, auxiliary applications and charging technology. However, there is a need to understand the interactions on the mechanical, the power supply (e.g. batteries / fuel cells) and the power system boundaries. On the mechanical side, this includes the transmission to the wheels or to the combustion engine, and on the electrical side the interactions with the battery and other components on the DC link of the electric traction system. On the power system side, it includes the distribution grid up to the Medium Voltage level.

The time perspective should be such that the research conducted in the theme is able to influence industrial product plans, which normally means a time horizon in the range of 10 years to start of production (SOP). This does not mean that the Theme cannot focus on shorter perspectives if the research topic is interesting for some/all theme partners. However, the long-term perspective is a way to encourage thinking “out of the box”, not limited by existing solutions, regulations or limitations, while keeping the research at a pre-competitive stage thus allowing competing companies to cooperate.

Cooperation with other competence areas

Theme Electrical Machines and Drives aims also to interact with all other competence areas within the Centre, as well as external Research & Education institutions and Centres of Excellence. These collaborations could consist on the development of parameterized component models for power electronic converters and traction machines to be used in more comprehensive system models, tailored models for battery development, or the design and development of power electronic interfaces and their control system for alternative power sources such as fuel cells.

In order to facilitate and promote the knowledge transfer between the different areas, it is encouraged to engage researchers from these external areas in the reference group of relevant projects.

Trends in the area

A review of the current research conducted in the area of electrical machines and drives reveals a number of interesting trends, which are described in this section.

Countries with large vehicle production facilities (e.g. China, India, but also Germany and the US) are focusing on improving **manufacturing technology** for the expected high production volumes of electromobility related components. Swedish automotive manufacturers currently source these components from foreign suppliers, and until now, there are no large production facilities of either electrical machines or power electronics in the country. This situation may change in the near future however, and research on manufacturing processes and design for manufacturing could gain relevance.

On the power electronics field, the use of **wide-gap band semiconductor technologies**, especially SiC, pushes for higher voltage levels and higher modulation frequencies. This has obviously a number of implications in the design of the power converter itself, the choice of passive components, the control algorithm, the insulation system in the electrical machine, and the EMC performance of the drive.

EMC itself is growing in importance as a research topic. Unlike combustion engines, electric drivetrain components can be located in different places within the vehicle. This increase in packaging flexibility allows for different integration possibilities, however, with increasing power levels, higher voltages and faster switching frequencies, EMC phenomena become more important and there is a need to investigate them.

Another interesting trend in automotive application research is **safety and reliability**. With increasing number of electric drives in vehicles, there is a need for condition monitoring and lifetime estimation techniques for the relevant components already from the design stage. This is necessary not only for safety reasons, but also for economic reasons, to make electric vehicles competitive with the traditional combustion solutions – also called “right sizing”.

Finally, a trend for **integration** of different components in the same space, or even different functions in the same component is observed. For this reason, the drivetrain becomes somehow more complicated, and in order to optimise its design multi-physical conjugated models are needed in order to approach simultaneously the electromagnetic, thermal, mechanical and even acoustic challenges.

Long term objective

With the above background, there are some key areas of technical development to be addressed by *Theme Electrical Machines and Drives* in the Swedish Electromobility Centre:

- Development of **cost efficient and environmentally friendly electric drives both for propulsion and auxiliary applications**, taking into account the manufacturing and recycling perspectives as well. This includes the investigation of new electrical machine and power converter topologies that could benefit from the future developments in the areas of material science, semiconductor devices and production technology to name a few.
- **Integration of existing functionalities and/or development of extra features** that give an additional value to electric drivetrains. Examples of this could be the integration of different components in the same package, thus reducing the number of connectors and sharing the cooling circuit, or the integration of other functions also needed in the vehicle into a single unit, e.g. using the electrical machine and inverter as a battery charger.

- Development of **stationary and dynamic charging technologies**, with a particular focus on automation and cost. Especially interesting in this field are the synergies between these two forms of charging, i.e. using the same equipment both for static and dynamic charging.
- To build a **sustainable (world class) competence** in the area, located both in Academia and Industry

Research Needs & Priorities

Sweden, with all research resources in academia and industry, with all funding available, is still a rather small player in a global perspective. It is thus important to focus on selected segments of the electromobility field. The following are selected:

- "Design of cost efficient environmentally friendly electric drive trains"
- "Charging systems".

Research efforts along these lines should be developed as joint cooperative projects between SEC partners. This should be supported by a functional way of getting reference groups with strong representation from industry, as a tool to convey the industry needs into SEC and the universities.
The aspects identified as most relevant to focus R&D efforts on, split into the different areas, are (not necessarily in order of priority):

Electric Traction Machines.

- Cost
- Performance: torque / power density
- Thermal management
- Development of additional features, e.g. integrated charging
- Commonalities and synergies with the rest of the drivetrain, e.g. integration with the power electronic converter
- PM material independence

Power Electronic Converters.

- Cost
- Commonalities and synergies with the rest of the drivetrain, e.g. integration with electric machines to reduce system size
- Peak power limitation of PE devices
- Thermal management
- Alternative semiconductor materials like SiC/GaN

Charging Systems.

The supply of energy is critical for electromobility to take off. Charging solutions can be implemented in several ways (inductive/conductive, manual/automatic, fast/slow, on-board/off-board, static/dynamic). The technology area is, in spite of both a long history of development and substantial standardisation, still subject to a lot of development. The power levels are pushed up, automation is still almost non-existing for light vehicles and dynamic charging is under extreme development with high expectations.
The R&D efforts should be oriented to those aspects of the charging process that are common to all vehicle types, or will likely be common within the proposed time perspective. A system perspective

should be kept, where battery cost plus charging infrastructure costs from both a vehicle customer and a societal level are maintained.
Some proposed research areas in that direction are:

- Build up knowledge about charging and energy transfer in a general approach.
- Automation of the charging process generally: inductive charging vs. automated conductive approaches. Developments in this area may be conducted with consideration of autonomous electric vehicles.
- Although it may not be one of the core research activities of the Theme, there is a need for standardisation of charging solutions, and the Swedish Electromobility Centre – in particular Theme Electrical Machines and Drives – should contribute and support the development of such standards.