SHC PROJECT SUMMARY REPORT

EMC Analysis of Electric Drives

Version (no. or date):

Project manager: Prof. Mats Alaküla
mats.alaküla@iea.lth.se; mats.alakula@volvo.com
+46 46 222 92 84
+46 73 902 21 45 (mobile)

Modelling of electrical drive systems for hybrid vehicles from electromagnetic compatibility (EMC) perspective, in order to calculate how a drive system should be designed by hardware and software to fulfil the necessary EMC requirements.

Focus is placed on electric motor design parameters to meet compatibility requirements in conducted emission range i.e. frequencies up to 30 MHz

Summary

The Licentiate thesis presented in the fall of 2012 focused on modeling the parasitic components in a winding on a ferromagnetic core. The developed methodologies and modeling tools are applied to the complete machine in a complete drive system structure. For the second phase of the project a prototype of an electrical machine with three different types of windings has been built to facilitate the validation process of the proposed model. The model predicts the capacitive and inductive couplings over a frequency band of interest for a stator slot structure inside the electrical machine. This micro-level representation can be considered as a building block in any electrical machine.

Background

Conducted and radiated Electromagnetic Interference (EMI) emissions is the downside of power electronics systems development towards increasing power density and decreasing size and losses. Pulse-Width Modulation (PWM)-Inverter-Fed machines inherently result in Common-Mode (CM) voltage which has both instantaneous and average value. On the other hand parasitic capacitance exist literally all over the electrical drive system not least between the junction of power semiconductor switching elements and the heat sink, and also between the stator machine winding and iron core. Parasitic capacitances can interact with the high-frequency CM voltage waveform and can provide various low-impedance paths for the common-mode current to take. Common-mode current, if not reduced, can produce undesirable effects like (EMI) interference, higher losses and heating besides resonance problems. Bearing current, false triggering of protection equipment and winding insulation premature breakdown are also manifestation of the same problem.

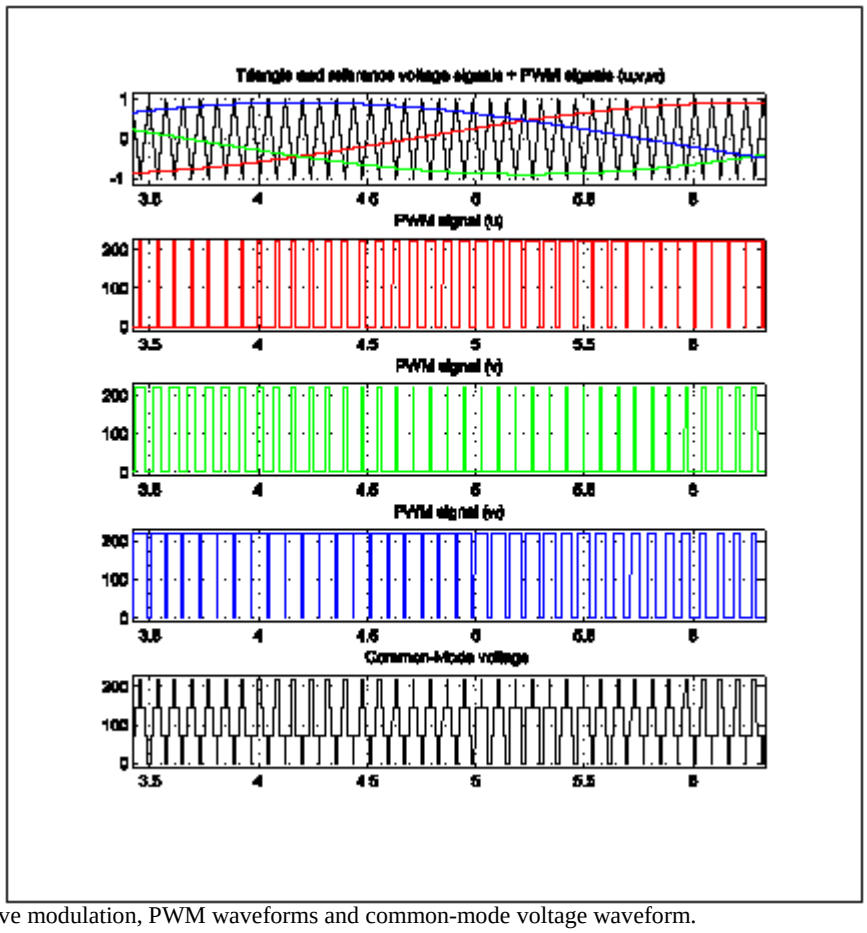

Fig. 1. Triangular wave modulation, PWM waveforms and common-mode voltage waveform.

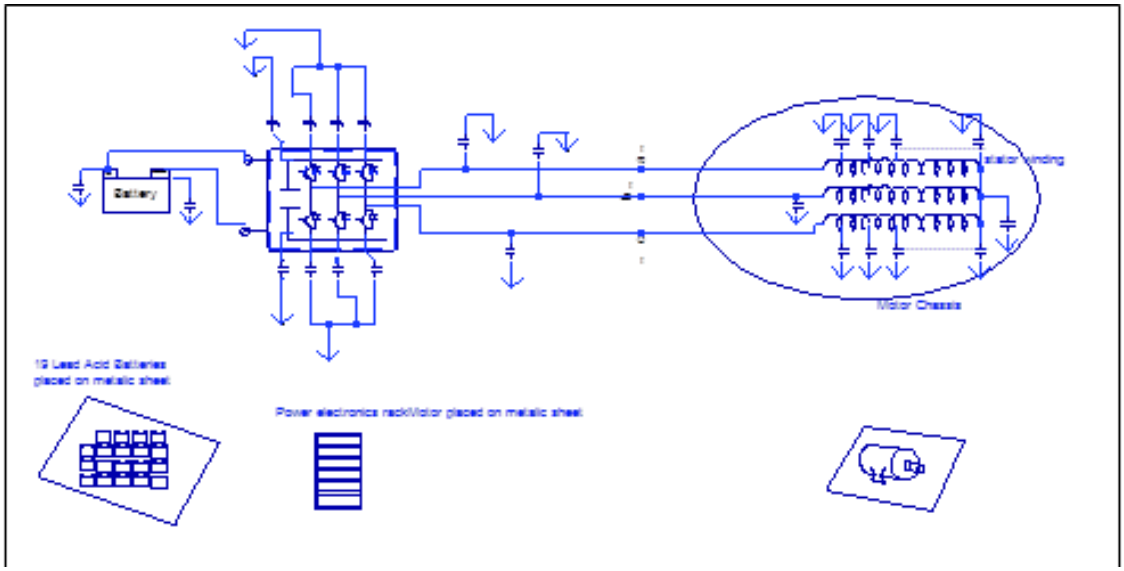

Fig. 2. Parasitic capacitances in an electric drive system

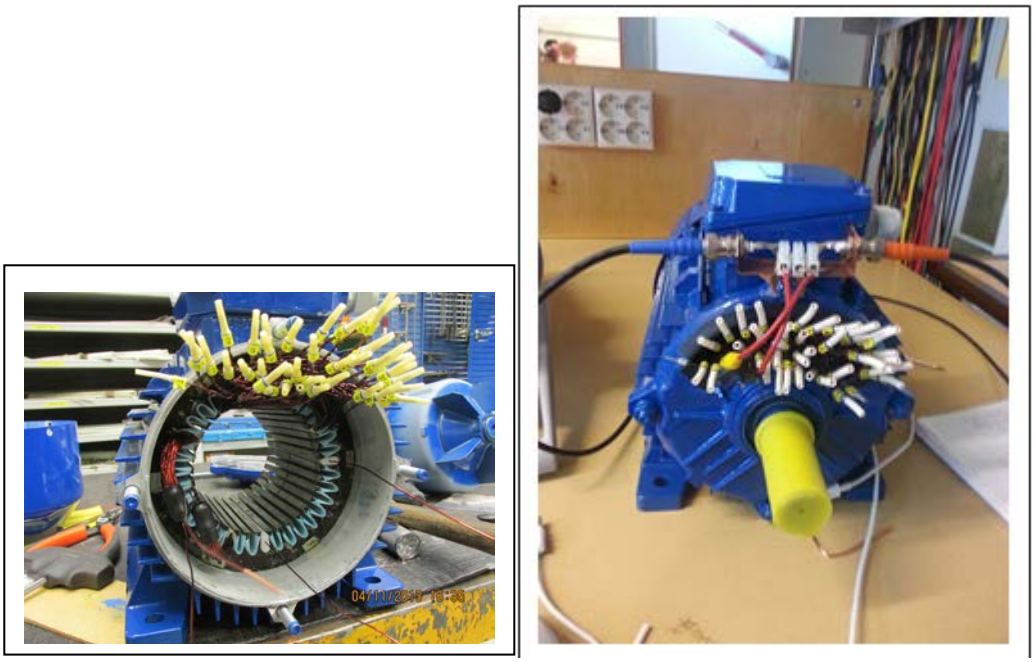

Fig. 3. Photographs of the built prototype with special windings

General project description

To model electrical drive systems components for hybrid and electrical vehicles from electromagnetic compatibility (EMC) perspective so that relevant EMC requirements can be fulfilled. Attention is put on electric motor design parameters to meet compatibility requirements for the conducted emission range. High frequency measurements using network and impedance analyzers in addition to finite element analysis and circuit simulation softwares were used to propose models highlighting the coupling paths along the frequency band of interest.

Achieved results

The Characterization of capacitance couplings in electric machine windings in order to predict the magnitude and positioning of main parasitic capacitances. This has been achieved through the generation of detailed capacitance network modelling turn-to-turn and turn-to-ground capacitances. Complexity level of the structure and lowest capacitance value to be represented can be set in advance. FEMM, MATLAB® and LTspice® have been used as analysis tools. Inductive coupling analysis resulted in predicting self- mutual- and leakage- inductances of any two conductors in the multi-conductor system.

Reliable inductance and capacitance measurements vs frequency for machine winding can be produced with the aid of complex conversion from s-parameters of the input port reflection coefficient Γin for a two-port network using the network analyzer.

Contribution to hybrid vehicle technology

Provide a method, procedure and tools to predict and measure parasitic capacitances and hence the resulting common-mode currents and its different possible paths in a given drive system. When taken in consideration, this will help control the phenomenon of conducted electromagnetic interference, lower unnecessary losses and heating emissions which can result in premature bearing failures, winding insulation breakdown as well as the annoying frequent trips of earth leakage protection equipment. Rightsizing of electric drive components can be achieved including the recommendation of relevant type and size of filters, shielding and good wiring practices.

Uniqueness and news value

Not aware of other researchers/institutions within Sweden who have been tackling this problem, although some collaborations throughout the course of this project has been established with researchers in France, Germany, Poland and The Netherlands who have been studying this problem .

Timing and finance

Financed by the Thematic Area 2 "Electric drives" in the Swedish Hybrid Vehicle Centre (SHC). The budget covered 11 million for 3 doctoral-projects. One at LTH, one at KTH and one at CTH. The funds were divided equally among the institutions which provided 11/3 = 3.7 million SEK for LTH. This funding lasted till September 2013 and the project is currently funded totally by LTH.

Executors and collaboration

A reference group has been established as a support for this project including specialists from SP Technical Research Institute, Bombardier, Kockums, Emotron and Volvo Cars Corporation.

Papers and publications

[1] F. Abdallah. EMC Analysis of Electric Drives. Licentiate Dissertation, Tryckeriet i E-huset, Lund University, Lund 2012.

[2] Abdallah, F., Alaküla, M. (2013), “Capacitively coupled transmission line model and validation of a winding-on-core prototype”. *EMC Europe 2013*, Brugge, Belgium, 2-6 September, 2013.

[3] Abdallah, F., Alaküla, M. (2014), “Inductive coupling matrix of a multiconductor system for a winding-on-core prototype”. *2014 International Symposium on Electromagnetic Compatibility (EMC'14)*, Tokyo, Japan, 12-16 May, 2014.