D3.6 – New design of electric motor HD hybrid application, performance, and validation tests

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Publishable summary

Heavy-duty vehicles account for large portion of the CO_2 emission because of their higher power and longer daily operational time. Electrification with hybrid drive is one of the solutions to reduce their fuel consumption and CO_2 emission. Compared to a passenger car, a 40-ton battery powered electric long-haul truck may need 5-6 time more power for highway operation. The efficiency of the electric powertrain is very important to increase the vehicle range or reduce its battery size.

In this part of the project, the goal is to develop a new type of the electric motor, which has higher efficiency at high-speed and partial load. This feature favors the work duty of long-haul trucks. The targeted reduction of losses in the new electric motor at the cruising mode should reach 50 % compared to the commonly used electric motors.

The inputs to this work are the system requirements of the long-haul trucks and their operational data. The results of this work are used in the system simulation for the proposed hybrid high-efficient powertrain for long-haul trucks. The results are also useful for future development of pure electric drivetrains with highway operation efficiency as the focus.

Electrically Excited Synchronous Machines (EESMs) are selected for the drivetrains studied in this work. Compared to commonly used Permanent Magnet Synchronous Machines (PMSMs), EESMs do not use rare earth materials and may have beneficial efficiency for long-haul applications. In order to understand the behaviors of EESMs for traction applications and verify the methods and solutions developed for EESMs, a 60 kW down-sized EESM with hairpin windings is developed and tested before the full-size machines are built. The verified methods and solutions include rotor design, inverter design, control algorithm, brushless excitation, and telemetry.

A full-size EESM and a full-size PMSM both with hairpin windings are designed according to the powertrain requirements on performance and dimensions. The required continuous power and continuous torque for the machines are 200 kW and 580 Nm, respectively. The parts for these 2 machines are manufactured and procured according to the designs. The brushless excitation system and telemetry system for the EESM are built and assembled at Chalmers. Two SiC based drive inverters in 250 kW, 800V are designed and assembled at Chalmers according to the continuous power and voltage requirements of the machines. In the inverters, the latest SiC modules and laminated busbars are used for high efficiency and high-power density.

The motor control system and measurement system are configured and built according to back-to-back testing requirements. The control system includes a PC, a dSPACE, own-made signal process box, and inhouse control codes. The measurement system includes 8-channel oscilloscope with its voltage probes and current probes, temperature sensors, telemetry, and torque transducer. Direct oil cooling method is used for the hairpin stators of both the full-size EESM and PMSM. Oil cooling is also used to cool rotor windings of the EESM. The cooling ducts in the machines are dimensioned according to the continuous operation at 200 kW. Oil splashing in the end-winding area is also studied.

The performance of 2 EESMs is validated by simulations over the whole torque-speed range. Some operating points are verified against experimental tests on the prototyped machines in a back-to-back test rig at Chalmers. The experimental results agree to the simulations with acceptable differences. The sizes of EESMs are similar to the PMSMs even when the extra brushless excitation system is mounted. The machine losses at cruising operating point are roughly 50% of the PM counterpart. The objectives defined in the related tasks have been reached.

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Project partners:

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