Modelling of traction motors and power electronics for passive cooling analysis

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Introduction

The introduction of Silicon Carbide (SiC) semiconductors in electric traction has brought about several benefits including the possibility to switch from active cooling systems to passive cooling system, reducing complexity and weight. To study passive cooling systems, it is vital to adequately characterize the traction system, its relationship with train operations, and solve conjugate heat transfer problem. Although numerous steady state simulations exist, there is a lack of models that address transient solutions for the conditions in regular rail operation. To develop such analytical models, it is vital to understand the current, voltage, and torque requirements of the motor as this has a significant impact on the power losses in the converter.

This research work explores relationship between the motor and the inverter. Two analytical models are derived to model the temperature distribution and variation. They are then validated against the results from numerical simulations. In parallel, an electric motor model is used to derive the power losses in the converter, defining the heat flow to be dissipated. Finally, the complete model is tested for realistic drive cycles where the driving operational conditions define both the power losses to be dissipated and the free flow speed due to the vehicle speed as depicted in Figure 1. Results show that the developed model can successfully translate the motor requirements into temperature variations for the different stages of the drive cycle. Thus, a simple and reasonably accurate analytical model has been developed that can derive temperature variations with faster computation times compared to transient FEM simulations.

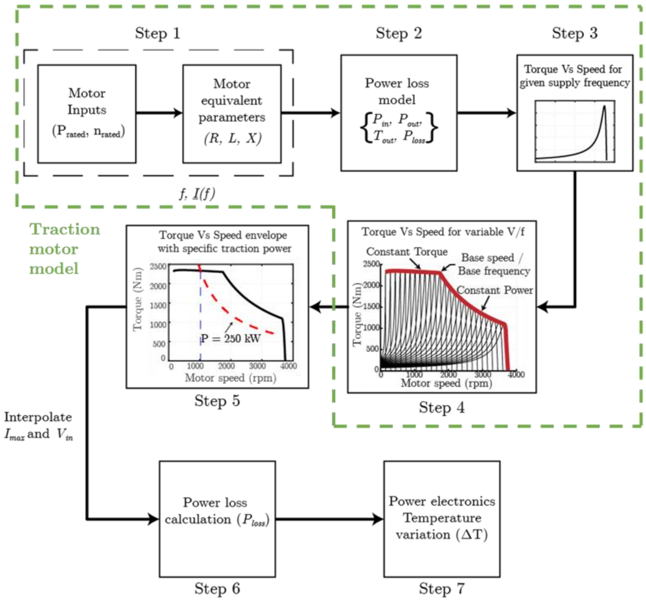

Figure 1: Overall procedure for calculation of temperatura variation

Development and application of heavy-duty hydrogen energy hybrid shunting locomotive

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Introduction

Hydrogen Energy has advantages of zero emission and high efficiency. Hydrogen energy hybrid locomotive is able to operate in non-electrified zone instead of diesel locomotive, thus to reduce carbon emission of railway transport section. A high-power "hydrogen fuel cell+Li-ion battery" hybrid power system was developed and applied as the on-board power source of a heavy-duty shunting locomotive.

Analysis

The hydrogen energy hybrid power system consists of proton exchange membrane fuel cell (PEMFC) and lithium-titanate battery, which are connected in parallel to output DC current to the inverter and traction motor, as shown in Fig. 1.

All the fuel cell system components, including fuel cell module, hydrogen storage module and heat radiator are installed on top of the roof, as shown in Fig. 2, thus to avoid hydrogen gathering in case of hydrogen leakage.

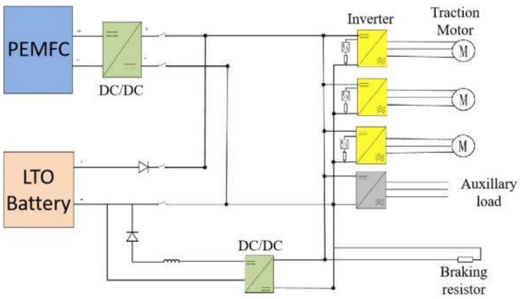

Fig. 1 Main circuit of hydrogen energy shunting locomotive

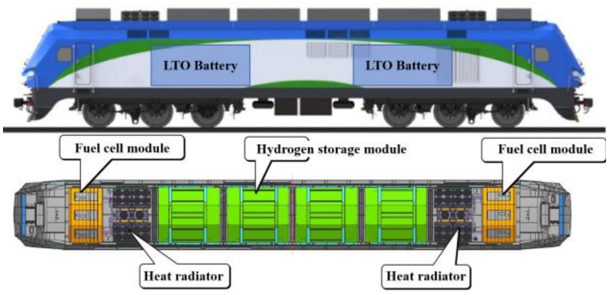

Fig. 2 The hydrogen energy hybrid power system equipment layout

The total output of the fuel cell system is 400 kW, and the hydrogen storage amount is 137 kg, equivalent to 2000 kWh electricity. The energy storage capacity of LTO battery is about 700 kWh, and the continuous output power is 2000 kW. The output power of the hydrogen energy hybrid system reaches 2400 kW. The shunting locomotive therefore has traction load of 5000 tons and starting traction effort of 560 kN.

Conclusions

The result demonstrate the feasibility of applying hydrogen energy hybrid power system for heavy-duty shunting locomotive.

References

Fan, Y. X. "Key technologies and applications of hydrogen hybrid power locomotives"[J], Electric Drive for Locomotives, 2023(3): 12-23.