Model-based Development of a Holistic Thermal Management System for an Electric Car with a High Temperature Fuel Cell Range Extender

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In conventional automobiles with combustion engines, waste heat is used to heat the passenger cabin. Electric cars do not dispose of sufficient waste heat to cover all caloric demands. Furthermore, additional components, such as the traction battery, have a more sensitive operating temperature and require thermal conditioning. The thermal management system of the vehicle must therefore provide sufficient cooling and heating power. The range of an electric car is already limited due to the low energy density of the traction battery compared to conventional combustion fuels, and these thermal restrictions can cause a further range reduction.

Within the Fraunhofer innovation cluster “Regional Eco Mobility 2030” (REM2030) concept developments to improve the energy efficiency of regional eco mobility of the future are investigated. An AUDI A1 Sportback is used as a technology demonstrator with an entirely electric powertrain, completed to a serial hybrid by a fuel cell range extender. A methanol reformer provides hydrogen for the high temperature fuel cell.

Using Modelica, a holistic thermal management system for the considered vehicle is developed. The goal is to keep each thermally sensitive component (cabin, traction battery, power electronics, fuel cell and electric motor) in its optimal thermal operating range, while minimizing the electric energy demand of the thermal management system. Furthermore, the system must be designed to enable local zero emission operation. This is achieved by using all heat sources and sinks in a holistic approach. A heat pump, which uses the ambient heat and the waste heat from the powertrain components as heat source, is integrated. A four-way-valve within the heat pump allows then a flow reversal of the refrigerant to establish the A/C function of the system. The traction battery can be heated and cooled down independently from the cabin demand.

Owing to this developed system, the range of the considered vehicle can be extended in cold winter days by up to 30% depending on the ambient temperature and the chosen reference driving cycle.