System level heat pump model for investigations into thermal management of electric vehicles at low temperatures.

James Jeffs[1] Dr. Andrew McGordon[1] Alessandro Picarelli[2] Dr. Simon Robinson[3] Dr. W. Dhammika Widanage[1]

[1]WMG, University of Warwick, United Kingdom, j.jeffs@warwick.ac.uk
[2]Claytex ltd., United Kingdom, alessandro.picarelli@claytex.com@company
[3]Jaguar Land Rover, United Kingdom, srobin43@jaguarlandrover.com

With the growth and spread of electric vehicles there has been increasing concern regarding their operation at low temperatures. At low temperatures batteries suffer from reduced capacity which limits range, leading to the requirement of battery heating. Additionally the cabin needs sufficient heat to satisfy occupants. Due to the heat wasted by engines in internal combustion vehicles, the cabin heating demand was previously met with ease. This new demand has resulted in a growth in heat pump related research. With this growth, a selection of different proposed vehicle architectures have arisen.

This paper describes a model which allows for the creation and comparison of many different theoretical vehicle architectures. The model allows for the motor, transmission, cabin exhaust, thermal storage unit and electric battery to be dynamically connected and disconnected from coolant circuits of the heat pump. The paper describes each of the relevant sub-models, how they are linked through coolant circuits and the control system for the heat pump. The control system has been designed to be robust to unseen potential vehicle architectures.

Two test cases are used to test that the model is capable of fulfilling the following four objectives:

1. The ability to dynamically connect and disconnect components from the thermal management system.

2. The ability to arbitrarily request heat flows between components (e.g. request 5kW for cabin heating), while being physically limited by sensibly sized heat exchangers.

3. Contain a control system for the heat pump which self regulates compressor speed regardless of vehicle configuration.

4. Run quickly enough to be useful for performing parameter sweeps and optimisations in suitable time frames.

The test cases selected are used to answer two proposed questions; can the battery be used as a thermal heat source at low temperatures, and is the transmission a useful source of heat to the heat pump. These questions demonstrate the flexibility of this model, but are also pertinent to the research area.

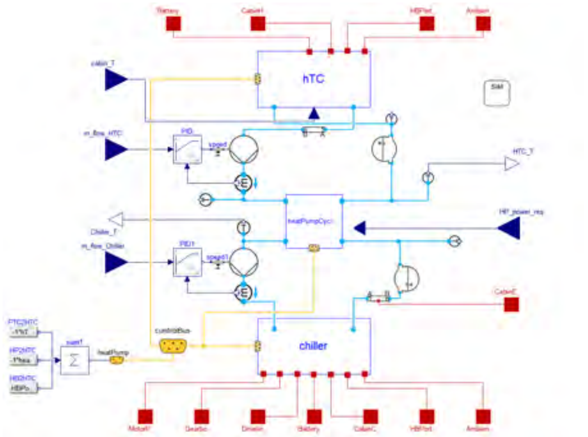

Figure 1. Heat pump capable of taking heat from multiple sources and distributing it to the cabin, battery or both.

The first objective, regarding dynamic connections, has been shown using the first test case. When the battery was heated the system successfully disconnected the battery from the thermal management system when its temperature became too high. To demonstrate the second objective, a heat demand of 5kW was requested for cabin heating which was successfully sustained when the heat pump was producing sufficient heat. Objective 3 was demonstrated by completing all the scenarios tested without the model failing due to coolant fluids, refrigerants etc. going beyond their operational limits. Finally simulation time for each of the cases is presented, confirming that the model is executed in sensible time, with regards to objective 4.

Two cases have been presented, with some interesting results, which both demonstrate the flexibility and robustness of the model presented. Given the breadth of thermal management opportunities that are arising in the heat pump research area, architectures similar to this could be used as an early tool in identifying which options show potential.