Energy efficient control of heat pump in fully electric vehicle

Jan Glos, Pavel Vaclavek, Petr Blaha
CEITEC - Central European Institute of Technology,
Brno University of Technology

March 22, 2017

Since fully electric vehicles (FEV) do not have enough waste heat for cabin heating as internal combustion engine (ICE) vehicles and hybrid vehicles do, it is beneficial to employ a reversible heat pump in FEVs. The reversible heat pump can be used for both the cabin cooling and heating and especially under winter conditions it is able to substantially improve the FEV driving range compared to heating with PTC heater.

This paper is focused on energy efficient control for the reversible heat pumps using both R1234yf and R744 refrigerants. The main goal of these control algorithms is to achieve a satisfactory passenger thermal comfort with as low as possible energy consumption. This energy consumption does not include only the compressor power consumption, but also consumption of additional devices (like fans etc.) needs to be included. A coefficient of performance (COP) of a heat pump in heating mode is described by

$$COP_h = \frac{Q_{cond}}{W_{comp}}, \tag{1}$$

where Q_{cond} is heat supplied to the cabin by the condenser and W_{comp} is the compressor work needed for it. Due to additional equipment power consumption (1) needs to be rewritten as

$$COP_h = \frac{Q_{cond}}{W_{comp} + W_{fc} + W_{fe}}, \tag{2}$$

where W_{fc} and W_{fe} are the work done by condenser fan and evaporator fan respectively. If we consider the steady state situation, we assume that the heat needed to warm the air supplied to cabin is constant. Then the control problem consists of minimizing the denominator in (2). It is well known that power consumption of the compressor depends on refrigerant pressure difference in low and high sides of heat pump circuit. The pressures are dependent on heat source and heat sink temperatures and on evaporator and condenser air mass flow rates.

The condenser mass flow rate can be influenced only by condenser fan, which is operated by variable speed drive electric motor. The evaporator mass flow rate is determined by the evaporator fan (also with variable speed drive motor), but it is also affected by current vehicle speed.

We developed a set of control algorithms, which are able to drive both R1234yf and R744 heat pumps and HVAC equipment in such a way that energy consumption of overall system is as minimal as possible. It can be also said that the highest possible COP_h from (2) needs to be achieved. These algorithms are able to deal with variable FEV velocity as well as with the changes of ambient temperature and user requested temperature in FEV cabin. Also cooperation of heat pump control algorithms with overall high-level management of energy flows was formulated to achieve a maximal prolongation of driving range. The control algorithms were evaluated in simulations with standard driving cycles and the verification on heat pump test bench is currently in progress. An experimental results are planned to be included in following full paper.

This research was carried out under the project H2020 653514 OSEM-EV - Optimised and Systematic Energy Management in Electric Vehicles, which belongs to GV-2-2014 call.