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Research Article

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# Dynamic lumped-parameter model of a heat pump designed for performance optimization

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## Abstract

In the next years, air-source heat pumps may become an important renewable-energy heating system in the temperate countries. These machines may be subject to changes in the operation conditions in order to maintain their performance in the face of variations in the outdoor climate and these changes may impact on the heat pump at the cycle level. In order to optimize the control of such machines, a dynamic model is mandatory. Therefore we illustrate the potentialities of a dynamic, lumped-parameter model, which is composed of moving-boundary exchanger sub-models and static compressor and expansion valve sub-models. Firstly, it is seen that the model succeeds in designing the installation as well as in controlling the superheating. Secondly, simulation results illustrate how a change of system parameters could affect the transient behaviour of the machine, thus requiring some adaptation of the controller parameters. Future developments will be devoted to model validation through experience, to design of a robust superheating controller and to model utilization towards fault diagnosis.

## Keywords

refrigeration,
heat pump,
dynamic modelling,
robust control

## Article History

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## 1 Introduction

In the framework of reducing the consumption of fossil energy and the emission of $CO_2$ gas, renewable and clean energy sources gain more and more interest. In temperate European countries, air-source heat pumps are a reasonable-cost technology, which can be viewed as a renewable heating system provided that the seasonal performance factor (SPF) is high enough to save primary energy compared to common boilers (Dumont et al. 2008). Due to rapid changes of the outdoor climate, the heat load, the condensation and evaporation temperatures are subject to fluctuations so that operation parameters must be adapted to maintain a minimum performance (an example of adaptation is capacity control). However these operation adaptations may impact on the heat pump at the cycle level (Liang et al. 2010). In order to understand the phenomena and to design/test control strategies at the cycle level, a dynamic model of the heat pump has to be considered.

The dynamic modelling of vapor compression refrigerating systems has been a subject of interest since the late 1970s, where first-principles models were used to describe the heat exchangers. Lumped-parameter, moving-boundary models appeared first (Wedekind et al. 1978; Dhar and Soedel 1979; Chi and Didion 1982), then MacArthur initiated a series of works focusing on a distributed-parameter formulation (MacArthur 1984; MacArthur and Grald 1987). Besides these main modeling streams, other authors have designed more complex models for analyzing specific phenomena but we refer to the review of (Bendapudi et al. 2002) and to subsequent works and the references therein (Rasmussen 2005; Schurt 2009). Later on in the 1990s traditional feedback control has also been investigated, as in (He et al. 1997) and, more recently, multivariable control strategies have been developed (Schurt 2009; Schurt et al. 2009; Rasmussen 2002, 2005). In other studies (Jensen and Skogestad 2007a, b), strategies are developed to select among the degrees of freedom the controlled and the control variables so that an optimal operation is nearly obtained.

In this work, we adopt a dynamic model of a refrigeration

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