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International Journal of Refrigeration 29 (2006) 547–555
REVUE INTERNATIONALE DU FROID
INTERNATIONAL JOURNAL OF
refrigeration
www.elsevier.com/locate/ijrefrig

Investigating control strategies for a domestic low-temperature heat pump heating system

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Received 18 March 2005; received in revised form 19 September 2005; accepted 10 October 2005
Available online 4 January 2006

Abstract

Despite energy conservation regulations and efforts for improving HVAC operations, numerous domestic buildings do not perform energy efficiently and many times the indoor environment is far away from specified comfort levels. Especially in houses served from low-temperature heating systems the low ability of the heating system to respond to fast changing thermal loads is common. In such cases, the implementation of new, sophisticated controls is an important issue. In this study, we use a reference model of a domestic low temperature heat pump heating system developed in TRNSYS–EES and analyse its operation. Several methods of control strategies have been applied for specified time periods in order to keep the comfort within reasonable ranges. Prognostic climatic control and increased ventilation rates when required are some of these methods. The results depict the influence of the control method on the indoor temperature and the comfort indexes of PMV and PPD. The highest indoor temperature difference for a chosen day reaches 4 °C when there is no shading and when there is internal shading with the option of applying prognostic climatic control. Generally, the findings highlight the importance of dynamics in controlling functions and the difficulty of incorporating in models unpredictable factors as the solar radiation.

Keywords: Heat pump; Domestic application; Heating; Floor; Modelling; Regulation; Automatic

Etude sur les stratégies de contrôle pour un systéme de chauffage résidentiel à chaleur à base température

Mots clés : Pompe à chaleur ; Application domestique ; Chauffage ; Plancher ; Modélisation ; Régulation ; Automatic

1. Introduction

Regarding energy efficiency in the built environment, the strict legislation and the new building codes reveal an increasing requirement for well-insulated buildings served by effective energy systems. There are various trends in optimising on one hand the overall performance, on the other hand performances separately in the building sector

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doi:10.1016/j.ijrefrig.2005.10.009

Nomenclature

I	instantaneous irradiation to horizontal surface (MJ $m^{-2}h^{-1}$)
T	temperature (°C)

Subscripts

a	ambient
s	solar
z1	zone 1
z2	zone 2
z3	zone 3
z4	zone 4
z5	zone 5

and in the sector of applying energy for heating, ventilation and air conditioning (HVAC). Despite energy conservation regulations and efforts for improving HVAC operations, many buildings do not perform energy efficiently and many times the indoor environment is far away from the specified comfort levels. Part of the problem seems to appear due to the fact that old energy control strategies based on buildings with low level of shell heating resistance are still applied for controlling complex dynamic functions of modern HVAC systems in new houses [1]. Furthermore, dimensioning low-temperature energy systems based on the outdoor design temperature (ODT) seems to be a limited method. Steering the process by following standard heating and cooling curves tends to become an insufficient technique for continually providing acceptable indoor air quality. Apart from the fact that the chance for mismatch between the demand and the supply is high, the method of following standard heating and cooling curves does not take into consideration fast changing thermal loads that can be caused by solar radiation and internal gains.

What is surely of great importance is the implementation of better more sophisticated controls in order to achieve the objective of sizeably reducing HVAC related energy costs without compromising indoor air quality. Nowadays, there is an increasing demand for modifying the control functions since the dynamic interaction between the HVAC system, building and controls becomes more complex. Getting more realistic predictions of changes and attaining rapid responses to fast altering thermal loads is of high need.

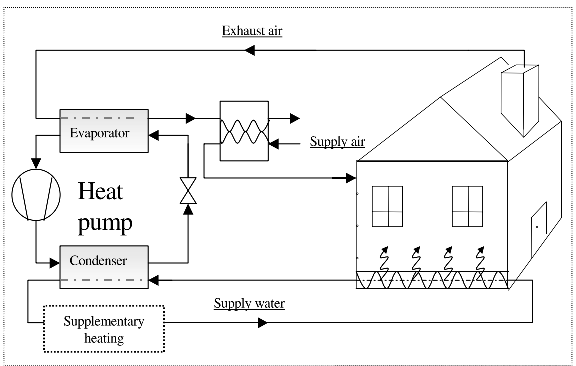

Fig. 1. A simple scheme of the reference system.

This study seeks to highlight the effect of several control strategies, regarding the operation of a specific HVAC system in a domestic building, on the indoor temperature and the comfort indexes of PMV and PPD. Prognostic climatic control is one of these strategies. More specifically, the analysis focuses on a low-temperature floor heating system in a single-family house served by an exhaust-air heat pump. To achieve the scope of this paper a model of a tight building construction, its HVAC system and controls have been developed and analysed in TRNSYS–EES. The main objective of this study is to investigate to what extend the control methods, that are applied, affect the indoor climate in chosen time periods.

2. Description of the reference system

A reference system is developed for studying the interaction between the building and the heating system. The reference system consists mainly of a well-insulated single-family house, an exhaust air heat pump and a floor heating system. Fig. 1 shows a simple drawing of the reference system. The exhaust ventilation air is the heat source to the heat pump and its temperature when it leaves the evaporator is around 4 °C. In order to further exploit the heat remained, the exhaust air passes through a heat exchanger and it preheats the supply air when the ambient temperature is lower than 4 °C.

The system model is developed in two simulation tools: TRNSYS for the building model and EES for the heat pump model. There is a possibility to link the simulation tools by a method of exchanging information between the programs. More precisely, EES provides an embedded simulation within a TRNSYS simulation. Hence, outputs from the EES-program can be inputs in the TRNSYS-program and vice versa. In this way the simulation can be run in iterative loops.

Fig. 2 illustrates the interaction between the two simulation tools. Despite the fact that the simulation programs are built in two separate environments, the simulation runs simultaneously (co-solving), connecting the models as if they were one. Therefore, the annual HVAC process in the chosen building construction can be attained.