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Simulation analysis for the active solar heating system of a passive house

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Abstract

The active solar heating system consists of the following sub-systems: (1) a solar thermal collector area, (2) a water storage tank, (3) a secondary water circuit, (4) a domestic hot water (DHW) preparation system and (5) an air ventilation/heating system. An improved model for the secondary water circuit is proposed and two interconnection schemes for sub-systems (4) and (5) are analyzed. The integrated model was implemented to Pirmasens passive house (Rhineland Palatinate, Germany). Both interconnection schemes show that (almost all) the solar energy collected is not used for space heating but for domestic hot water preparation. The classical water heater operates all over the year and the classical air heater operates mainly during the nights from November to April. The yearly amount of heat required by the DHW preparation system is about 77% of the yearly total heat demand of the passive house and the classical water heater provides about 20% of the yearly heat required by the DHW preparation system. The solar fraction lies between 0.247 in January and 0.930 in August, with a yearly average of 0.597.

Keywords: Passive house; Active solar system; Domestic hot water preparation; Space heating

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Nomenclature

$T_{2,es}$	hot water temperature in the secondary circuit at the exit of water storage tank
$T_{2,is}$	hot water temperature in the secondary circuit at the inlet of water storage tank
$T_{w,f}$	fresh cold water temperature used by the DHW system
T_4	hot water temperature in the secondary circuit after the DHW preparation system
T_5	hot water temperature in the secondary circuit after the space heating system
$T_{rec,out}$	temperature of air exiting the heat recovery unit
T_{fe}	anti-freezing mixture temperature at the exit of solar collectors in the primary circuit
T_s	water temperature in the storage tank used to control the operation of pump in the water primary circuit
$\Delta T_{P1,ON}$	minimum temperature difference necessary to start the pump in the primary circuit
$\dot{m}_2$	water mass flow rate in the secondary circuit
$\dot{m}_2^a$	water mass flow rate entering the DHW preparation system
$\dot{m}_2^b$	water mass flow rate by-passing the DHW preparation system
$\dot{m}_2^c$	water mass flow rate entering the space heating system
$\dot{m}_2^d$	water mass flow rate by-passing the space heating system

1. Introduction

In residential buildings, a large proportion of the energy is used for space heating—on average about three quarters of the final energy consumption in the existing building stock in central Europe. In 80s, the low energy house standard arose after the oil crises, with a space heat load about 75 kW h/(m^2 y). First passive houses (PH) were built in the north European countries while the first German passive house was constructed in the year 1992. Passive houses need about 80% less heating energy than new buildings designed to the standards of the 1995 German Thermal Insulation Ordinance [1].

The Passive House Energy Standard is now the leading standard for energy efficient design and construction [2]. The main prerequisite of being a passive house is that the building annual space heating demand does not exceed 15 kW h/(m^2 y). Furthermore, the building annual primary energy consumption for space heating, hot water and building services must not exceed 60 kW h/(m^2 y). A set of yearly measures showed that these goals may be achieved) by using standard building material and technology with additional costs of about 5% upper the same implementation but according to the current building regulation.

It could be useful to remind a few basic facts about previous international efforts on passive houses. Research on the physics and technology of passive house is performed all over Europe [3,4] and an International Conference on Passive Houses is regularly held with its 9th event in 2005. The leading authority in the field is the Darmstadt Passivhaus Institut founded in 1996 as an independent research institution employing physicists, mathematicians and civil, mechanical and environmental engineers [5]. Another important research center is at Fraunhofer Institute for Solar Energy in Freiburg. There it has been proven that in solar passive buildings the remaining heating demand can be met with compact heating and ventilation units [6]. The CEPHEUS