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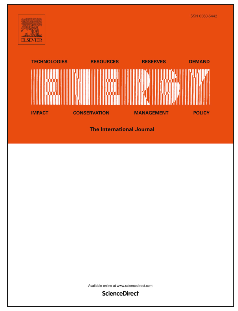

Solar thermal modeling for rapid estimation of auxiliary energy requirements in domestic hot water production: Proportional flow rate control

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Solar thermal modeling for rapid estimation of auxiliary energy requirements in domestic hot water production: Proportional flow rate control

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Abstract

A simplified solar water heating model with proportional flow rate control, controlled by the production temperature, was developed. Yearly climate data and daily consumption load data were applied at hourly time steps. About 15 additional simulation days ensure a yearly periodic simulation. Model simplifications were validated through a time step dependency analysis, indicating that a one-hour time step results in a maximum deviation from the exact solution of about 2 %. The solar fraction increases, but its rate of increase decreases, with collector area. The solar fraction increases, but its rate of increase decreases, with storage volume. For low temperatures, the solar fraction increases with production temperature, up to a maximum above the consumption temperature; afterwards, the solar fraction decreases with increasing temperature. Increasing the collector area and decreasing the storage volume increases the temperature that maximizes the solar fraction. If the storage tank is adequately insulated, neglecting heat losses results in a maximum solar fraction deviation of around 2 %. Assuming heat transfer efficiencies of 100 % in the storage tank, when the actual efficiencies are of 75 %, results in solar fraction deviations of about 2 and 20 % due to production/storage and storage/consumption heat transfer, respectively.

Keywords: solar water heating, active system, proportional control, simulation, parametric study

1. Introduction

In 2014, 94 % of the energy supplied worldwide by solar thermal systems was used to produce domestic hot water [1]. The basic elements of a solar water heating unit include a solar collector, a thermal accumulator, an auxiliary heater, and one or more working fluids. The solar collector absorbs solar radiative energy and transfers it to the working fluid; the thermal accumulator is a tank that stores the energy transferred to the working fluid; the auxiliary heater supplies supplementary thermal energy to the working fluid, whenever the solar thermal system cannot meet the hot water consumption load; the working fluid circulates between collector, accumulator, and consumption through interconnected insulated pipelines. Regarding the working fluid circulation mode, solar water heating systems can either be active, if a pump forces the flow of the fluid, or passive, if the fluid flows due to natural convection [2, 3]. As far as the collector fluid is concerned, solar water heating systems can either be direct, if the fluid of the collector is the same as that of the accumulator, or indirect, if the fluid of the collector is different from that of the accumulator [3].

Design methods of solar water heating systems involve the long-term estimation of system performance, which depends on controllable variables, such as the size and properties of system elements, and uncontrollable variables, such as meteorological parameters and the load of hot water consumption. Design methods can be divided into two major classes [2, 4, 5]: simple methods and computer simulations. Simple methods are based on correlation techniques and/or utilizability concepts, and although these methods are fast to

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