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Performance comparison for site-specific heat output prediction of solar collectors based on a modified collector efficiency equation model

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Abstract

This study compares the performance of estimation methods for site-specific solar collector yield using two simplified collector efficiency equations-based models for training and testing of the model. Two different collector efficiency equations are used for comparative evaluation: One employs a first order collector efficiency equation defined in terms of collector inlet temperature, solar irradiance, and outdoor temperature, termed first-order equation model with constant T_{ci} . The other equation model is a modified collector efficiency equation expressed with the terms of heating load, solar irradiance, and outdoor temperature, termed modified equation model with heat load input. In the approach with the first-order equation model, the collector inlet temperature term is treated as another parameter to be estimated as an effective collector inlet temperature. To evaluate the equation-based models, the Polysun simulation program is used for generating a data set of solar water heating system. For evaluation of daily solar collector yield estimation, two data sets were generated: training data set and testing data set. For evaluation of hourly solar collector yield estimation, training and testing performances were evaluated respectively. By using hourly simulated data, the hourly collector estimation performance was evaluated in terms of daily root-mean-squared error for the process of model training to compare the performance of fitness of the model for hourly estimation. The daily performance of two models showed quite similar estimation results. The comparison of the hourly performance of the two models resulted in a better performance of the modified equation model with heat load input.

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Nomenclature

A_c	solar collector area
b_i	parameters used in modified efficiency equation where $i=0,1,2,3$ and 4
c_i	parameters used in first-order efficiency equation where $i=0, 1$ and 2
G_s	solar irradiance on solar collector
Q_s	solar heat output from solar collector
Q_L	heat load of solar heating system
RMSE	root-mean squared error
T_a	ambient temperature
T_{ci}	collector inlet fluid temperature
η_c	collector efficiency

1. Background

When predicting or calculating the solar yield of solar heating systems, system simulation can be used with subsystem models including solar collectors, solar storage tank, heat exchangers, and heating loads. The system model will include temperature-level physical system models to define each component in detail. It would be more convenient if the performance of each subsystem could be modelled at the energy level instead of detailed temperature level. Aiming at developing simpler prediction models for solar yield of solar collectors, the standard first-order collector efficiency equation has been modified to derive a modified efficiency equation [1] that replaces the collector inlet temperature term with a heating load term.

This study describes the performance of estimating or predicting the solar yield by using the equation-based model, termed modified equation model with heat load input, and compares its performance with another ad-hoc model using the standard first-order efficiency equation with constant collector inlet temperature.

2. Evaluation method

For prediction or estimation of solar yield based on simple efficiency equations, two equations are considered in this study:

- A modified collector efficiency equation with heat load input [1]

$$\eta_c = b_0 - b_1 \left(\frac{1}{G_s} \right) + b_2 \left(\frac{T_a}{G_s} \right) - b_3 \left[\frac{\exp(-b_4 Q_L)}{G_s} \right] \quad (1)$$

where η_c =collector efficiency, b_0, b_1, b_2, b_3, b_4 =parameters, T_a =ambient temperature, G_s =solar irradiance on solar collector, Q_L =heat load of solar heating system

- A first-order collector efficiency equation with constant $T_{c,i}$

$$\eta_c = c_0 - c_1 \left(\frac{c_2 - T_a}{G_s} \right) \quad (2)$$

where c_0, c_1, c_2 =parameters, T_a =ambient temperature, G_s =solar irradiance on solar collector. c_2 is the collector inlet temperature T_{ci} in the original first-order collector efficiency equation [2].

The heat output of solar collectors is calculated by using the collector efficiency.

$$Q_s = \eta_c G_s A_c \quad (3)$$

where Q_s =solar heat output from solar collector, G_s =solar irradiance on solar collector. A_c = solar collector area. The Polysun [3] simulation program was used to generate data sets for a solar water heating system. A solar domestic hot water system was considered with 4 m² of collector area and 300 l of hot water tank. The daily hot water consumption was assumed to be 200 l and German BDH/BSW hot water usage profile was selected in this study. A flat-plate collector design was considered. The performance of estimating the solar yield using two equations is evaluated in terms of daily solar yield and hourly solar yield estimation. For performance evaluation of

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