Sustainable Energy Technologies and Assessments 30 (2018) 114–120

Contents lists available at ScienceDirect

Sustainable Energy Technologies and Assessments

journal homepage: www.elsevier.com/locate/seta

Hot water temperature prediction using a dynamic neural network for absorption chiller application in Indonesia

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ARTICLE INFO

Keywords:
Neural network
Absorption chiller
Solar radiation
Hot water

ABSTRACT

Weather condition particularly for solar radiation and dry bulb temperature has important role in absorption chiller performance. In this paper hot water temperature prediction in generator inlet of absorption chiller has been conducted under various weather conditions. Dry bulb temperature and global horizontal radiation are selected as predictors. Three artificial neural network (ANN) types including feed forward back-propagation, cascade forward back-propagation, and Elman back propagation models have been investigated for prediction. Moreover, numbers of neuron and time delay effects were analyzed to achieve an accurate prediction. The results show that hot water temperature in generator inlet can be predicted precisely using a feed forward back propagation neural network with the configuration of a three hour delayed input on radiation, current dry bulb temperature, seven neurons, tan-sigmoid transfer function and Bayesian regularization algorithm. The prediction results perform a good agreement between predicted and experimental values. The error resulting from training and validation is 3.1 °C and 2.6 °C with a coefficient of variation at 4.4% and 3.5% respectively.

Introduction

Energy has been a hot topic of discussion in the last few decades due to the reduced availability of fossil fuels. The burning of fossil fuels contributes greatly in producing greenhouse gas (GHG) emission in the world. Renewable energy development such as geothermal, wind, solar, hydropower, and biomass can be alternative solutions for new energy generation [1]. The use of renewable energy to substitute fossil fuels can reduce GHG generation and save the environment [2]. Building is one of the sectors that consume a lot of energy after industry and transportation. Heating ventilating and air conditioning (HVAC) system generally spend very large portion of total building energy usage. The application of absorption chiller is very beneficial for cooling system in tropical countries to reduce building energy consumption. This system consumes less electricity than a vapor compression system because it doesn't require a compressor to increase the refrigerant pressure to transfer heat from a low temperature to a high temperature space. The system utilizes absorption technology to replace the role of compressor. Consequently, the system requires a lot of heat to run the system continuously. Since a heat is the main energy source in this system, it is most appropriate to install in a tropical country e.g. Indonesia where intensity of solar radiation is abundant. The use of solar energy in residential buildings can save roughly 50% of primary energy [3].

In absorption cooling system, solar collector and thermal storage has important role in utilizing solar energy. The energy absorbed by the solar collector is transferred to the thermal energy storage and used to separate the absorbent and refrigerant in generator. When the intensity of solar radiation is inadequate to supply the heat in generator, the additional heat produced by gas combustion is provided as an alternative instead. Ideally, the absorption system should be connected to city gas distribution network to easily control gas usage and ensure the system can work continuously. However, the gas distribution system for residential consumer in Indonesia is not well organized. In the fact, the gas should be ordered for several day operations and delivered conventionally by vehicle. In the other hand, natural gas distribution using piping system requires high investment cost which is difficult and complicated to implement in developing country. Accordingly, the system performance prediction respect to weather condition can help the energy management to maintain the reliability of system. When the accurate weather forecast for several days ahead is available, the gas consumption for the system can be efficiently managed.

This paper covers the study on predicting the hot water temperature of a generator inlet using solar radiation and ambient temperature based. This prediction method represents the behavior of hot water

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https://doi.org/10.1016/j.seta.2018.09.006
Received 9 March 2018; Received in revised form 1 September 2018; Accepted 24 September 2018

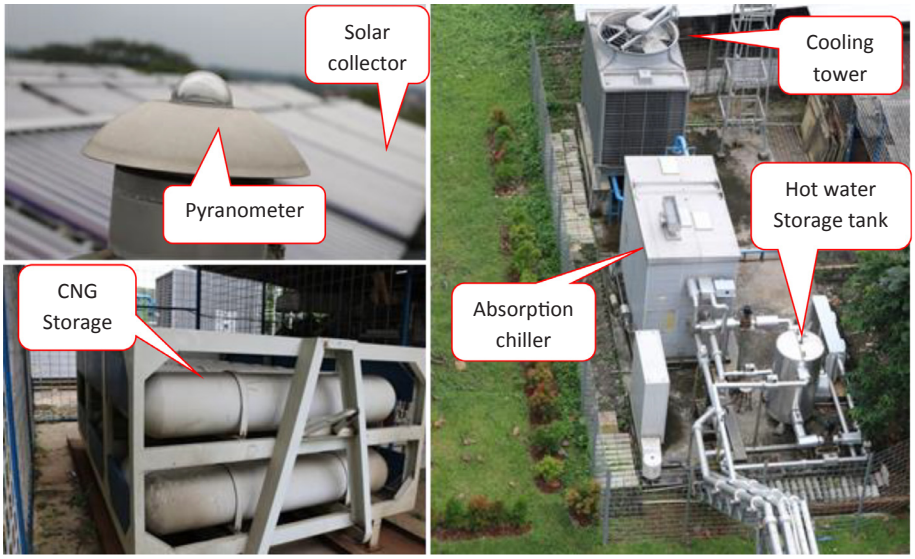

Fig. 1. Absorption chiller components.

temperature in generator inlet to the weather conditions. Practically the hot water temperature in inlet generator should be maintained at certain temperature to avoid solution crystallization, otherwise the hot water flow rate can be efficiently controlled if the temperature is very high to increase system efficiency. Hence, it is important to know the hot water temperature in generator inlet to manage the availability of gas to ensure the system operates continuously.

Several works on solar collector modeling have been established using physical model which includes heat transfer theory [4–6]. However they require many mathematical functions, assumption, and high effort to solve the equations. Sometimes the detail of some parameters should be extracted from manufacture. Owing to this complexity, modeling using ANN can be selected which is simpler and faster compared to physical based model if input output data is available.

In the recent years, the use of ANN technique has been increasingly used for modeling solar collector in various applications. Several ANN models have been developed to predict the performance of solar water heater [7]; solar air heater [8]; open-cycle solar collector [9]; evacuated tube solar collector [10]; solar-driven ground source heat pump [11]. Mohanraj et al. introduced ANN model to predict the effect of solar radiation intensity on the performance of solar assisted heat pump system [12] and demonstrate the exergy analysis [13]. In the next study, they conducted the similar work to develop the ANN model to predict power consumption, heating capacity, energy performance ration, compressor discharge temperature in solar assisted heat pump using three different training algorithms [14]. The results show that the optimal ANN model with Levenberg-Marguardt (LM) algorithm and 10 neurons has high prediction accuracy. Yaïci and Entchev [15] applied the ANN technique to estimate the performance of a solar thermal energy system (STES) which is intended for domestic hot water and space heating application. The network is developed to predict several system performance, namely the heat input to the auxiliary propane-fired tank, the preheat tank stratification temperatures, the heat input from the solar collectors to the heat exchanger, and the derived solar fractions. The performance of two different training algorithms is also investigated. Then the conclusion indicates that the precise prediction can be achieved by LM algorithm with 10 inputs, 20 neurons, and 8 outputs.

Most of papers discussed in aforementioned literature use ANN to evaluate the performance of solar collector for direct expansion heat pump, domestic hot water, and space heating application. The ANN model was developed by different training algorithm. As author's knowledge there are no works that study the use of ANN with Bayesian regularization to predict hot water temperature behavior in generator inlet under various weather conditions using experimental data. In this paper, three different network configurations are investigated to find the best ANN model with high prediction accuracy. The research presented in this work can help building management to manage the gas availability and maintain reliability of system.

System description

A single- double effect absorption chiller with the capacity of 239 kW has been installed in the campus building University of Indonesia for cooling system. Generally, the system has at least two important components, namely absorbent and refrigerant [16]. The common substances of H_2O and LiBr are used as refrigerant and absorbent respectively to transfer heat from a conditioned space to the ambient. There are several main components that are inter connected i.e. solar collector, hot water storage tank, absorption chiller system, and air cooled cooling tower. An evacuated tubular solar collector type with a total area of 240 m^2 is placed on the rooftop fitted with the tilt of 45° to the roof. The heat collected in the solar collector is transferred to the hot water storage where it will be used to separate the absorbent and refrigerant in the generator which is located inside the chiller system. A fan coil unit is utilized to distribute district cooling inside the building. Moreover, the heat generated by gas combustion is provided to supply the heat in the generator whenever the heat from the solar collector is insufficient to avoid the solution crystallization. Furthermore, centrifugal pumps are employed to circulate hot water, chilled water, and cooling water. The system components used in the experiment can be seen in Fig. 1.

An absorption chiller is operated under specified operation routine procedures as seen in Table 1. The chilled water temperature outlet is

Table 1
Chiller operation scenario.

	Entering	Leaving
Chilled water		
Chilled water temperature	15 (°C)	7 (°C)
Flow rate	25.7 (m^3/h)	
Pressure drop	30.4 (kPa)	
Cooling water		
Cooling water temperature	32 (°C)	37.6 (°C)
Flow rate	68 (m^3/h)	
Pressure drop	93.9 (kPa)	