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Bio-inspired model of ground temperature behavior on the horizontal geothermal exchanger of an installation based on a heat pump

J.L. Casteleiro-Roca, J.L. Calvo-Rolle, M.C. Meizoso-López, A.J. Piñón-Pazos*, B.A. Rodríguez-Gómez

Departamento de Ingeniería Industrial, University of A Coruña, A Coruña, Spain

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ABSTRACT

Nowadays the Heat Pump is one of the best systems to warm a building with a good performance. Usually, with the aim to increase the efficiency, a geothermal heat exchanger is added to the installation. This component shows a disturbing effect on the ground where it is placed. On this research a bio-inspired system was developed to test the ground temperature behavior where there is a heat exchanger. The novel approach has been implemented and tested under a real dataset. One year temperature measurements were recorded. The final approach is based on clustering and regression techniques. Then, the model was validated and tested with a dataset from a real installation with a good performance.

1. Introduction

The heat systems in buildings based on a Heat Pump provide heat into a house by taking it out from a source [1]. The warmth can be obtained from any source, whether it is cold or hot [2]. If it is the second case, then it is possible to achieve higher efficiency [3]. Usually, the ground is a source for the Heat Pump and, the heat exchangers topology can be vertical or horizontal [1,4]. The horizontal exchanger is cheaper than the vertical configuration [4]; however, this configuration is less effective. Due to this reason, frequently, installers place the exchanger more deeply in the ground to increase the efficiency [5].

Both configurations of heat exchangers present certain drawbacks, but the horizontal is more problematic than the other one, because among others, regardless of the depth, the exchanger is closer to the ground surface [6,7]. Due to the proximity to the surface, the meteorological conditions affect the exchanger and the efficiency could be lower [8,9].

The horizontal heat exchanger configuration usually is confined to a small space. Then, it is possible that the exchanger has an influence over the ground. If this happens, the temperature behavior of the ground could be different due to the influence of the exchanger [10]. When this phenomenon happens, the heat system could show perceptible changes in behavior, and the nonlinear behavior of the system increases [6]. Due to this fact, in this research, to determine the ground temperature behavior, a bio-inspired system has been developed based on local models. The aim of the study is to obtain a model to predict the ground performance that could allow to create, modify or improve the control algorithms of the system.

It is possible to divide the design of the prediction models in two methods [11]:

- *Global models*: only one model is generated based on all training data. The main aim is to minimize the error for all input patterns with the same model. Different techniques can be used to generate the model: Multi-Layer Perceptron (Artificial Neural Networks, ANN) [12–14], or Polynomial Regression [15] for instance.
- *Local models*: all the dataset is divided into subsets (clusters), depending on the features of the input data. The clustering algorithms are often used with this purpose like *K*-means or Self-Organizing Map (SOM) [16,17]. The first local models' approaches were developed by [18,19], and were considered as promising techniques in the field of time series prediction.

The combination of the local models with different regression techniques allows us to obtain very satisfactory global results. When global models' topologies were used, the results were poorer than with local models. A system of unsupervised learning

* Corresponding author.
E-mail addresses: jose.luis.casteleiro@udc.es (J.L. Casteleiro-Roca), jlcalvo@udc.es (J.L. Calvo-Rolle), mmeizoso@udc.es (M.C. Meizoso-López), andres.pinon@udc.es (A.J. Piñón-Pazos), benigno@udc.es (B.A. Rodríguez-Gómez).

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SOM and K-means have been applied for the clustering phase. This bio-inspired model was created with a real dataset of a year of operation, then all four seasons, with all weather conditions, were taken into account.

This paper is organized as follows. It begins with a brief description of the case of study followed by an explanation of the bio-inspired model approach to describe the ground temperature behavior, and the dataset conditioning to obtain the best configuration through local models. In the next section, results are presented, and finally the conclusions and future works are shown.

2. Case of study

The model has been obtained to study the ground temperature behavior where a geothermal heat exchanger is placed. The heat exchanger is part of the Heat Pump installation within a real bioclimatic house. The system is described in the following sections.

2.1. Sotavento bioclimatic house

Sotavento bioclimatic house is a project of *demonstrative* bioclimatic house of Sotavento Galicia Foundation. The Foundation was created to study renewable energy and energy saving. It is located within the 'Parque eólico experimental de Sotavento', between the councils of Xermade (Lugo) and Monfero (A Coruña), in the autonomous community of Galicia (Spain). An external view of the bioclimatic house is shown in Fig. 1.

2.2. Installations of the bioclimatic house

The bioclimatic house uses several sources of renewable energy for its facilities. The distribution of different thermal energy source is shown in Fig. 2. The whole thermal system, that includes the Domestic Hot Water (DHW) and the heating system, is powered by renewable sources, like Solar, Biomass and Geothermal.

For this research, we focus only on the thermal system, and inside this, only on a part of the geothermal installation.

2.3. Description of the thermal installation

The different components of the thermal installation are shown in Fig. 3. It is possible to see that the installation is divided into 3 functional groups.

Generation: Three renewable energy sources are part of the generation group:

- *Solar thermal system* (1): It heats a fluid that flows inside panels, that capture energy from the solar radiation. The fluid goes to the accumulation zone, where it heats the water stored inside the solar accumulator. It is necessary to install this accumulator, because the fluid inside the panels is not water, it is ethyleneglycol to prevent boiling in panels.
- *Biomass boiler system* (2): A biomass boiler, with a yield of pellets of 90%, provides hot water directly to the inertial accumulator to ensure a temperature inside of around 63 °C.
- *Geothermal system* (3.1 and 3.2): The system consists of a combination of a Heat Pump and a horizontal exchanger. The exchanger was installed at 2 m deep from the ground surface, and has 5 loops of 100 m each one. The warm water from the Heat Pump is driven directly to the inertial accumulator as the biomass boiler.

Accumulation: This group has two accumulators, one specific for the solar energy (4), and another to supply the consumption equipment in the house (5). As it is possible that the temperature in this accumulator is less than the consumers' desire, a preheating component (8) is installed in this section.

Consumption: The consumption is divided into two different uses: for warming the house (6.1 and 6.2) and DHW (7). Both uses are supplied through the inertial accumulator. The heat system is able to maintain the temperature inside the house between 18 °C and 22 °C, and the DHW system was designed to supply a maximum of 240 l per day, according to the Spanish Technical Building Code [20].

2.4. Geothermal system under study

This section gives a description of the real geothermal system and its components.

System description: The Heat Pump is a MAMY Genius – 10.3 kW with a horizontal heat exchanger as shown in Fig. 4.

This study is only focused on part of the horizontal exchanger, framed in Fig. 4. This is the primary circuit of the Heat Pump, the secondary circuit, the output, is connected to the inertial accumulator.

Geothermal exchanger: The horizontal exchanger has five different loops. This configuration allows the isolation, of part of the exchanger, in case of failures. The exchanger has another four

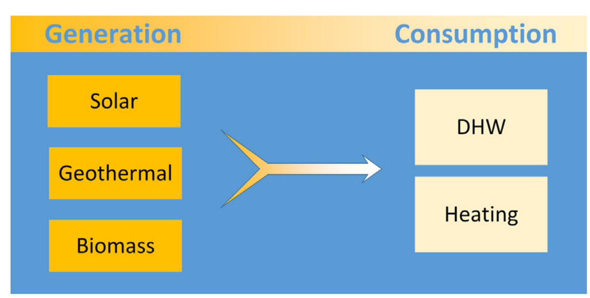

Fig. 2. Thermal installations of the house.

Fig. 1. External view of the bioclimatic house.