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An intelligent fault detection system for a heat pump installation based on a geothermal heat exchanger

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ABSTRACT

The heat pump with geothermal exchanger is one of the best methods to heat up a building. The heat exchanger is an element with high probability of failure due to the fact that it is an outside construction and also due to its size. In the present study, a novel intelligent system was designed to detect faults on this type of heating equipment. The novel approach has been successfully empirically tested under a real dataset obtained during measurements of one year. It was based on classification techniques with the aim of detecting failures in real time. Then, the model was validated and verified over the building; it obtained good results in all the operating conditions ranges.

1. Introduction

The increasing price of the energy or the environmental laws, for instance, is what makes people try to use renewable energies when it is possible [41]. The most typical renewable sources are solar and wind energy; but nowadays, others like ocean energy, are increasing their use [32]. Some research works are oriented to optimize or develop new methods on the renewable energy field, with the aim of increasing the installations' performance [30]. Despite people trying to preserve the environment, the installations based on renewable energies must usually have, at least, the same cost as non-renewable solutions to ensure their installation [30]. The above reason concerns to installations based on heat pump with geothermal heat exchangers [30]. These installations carry out large investments with relatively uncertain profitability and, their payback

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periods are usually very long [40]. The payback is variable, depending on the main source, and even can be a net loss [55].

1.1. Heat pump systems

A heat pump provides energy by taking it out from a source, and then transferring it into a house [37]. This energy can be obtained from any source, whether it is cold or hot. But, if this source is warm, then it is possible to achieve higher efficiency [50]. The ground can be a source for the heat pump and, the heat exchangers topology can be vertical or horizontal [37,31]. Horizontal configuration is usually more economical than the vertical type [31]; however this configuration has less efficiency than the other one. With the aim of increasing the performance of the horizontal exchanger, frequently, installers place the exchanger deeper in the ground [45]. Also, a new type of exchanger was developed, by combining the two described topologies; the exchanger is placed in helicoidal form that goes deeper in the ground [20].

Both configurations, vertical and horizontal have their own operation problems, but the horizontal has more disadvantages than the other, among others because the exchanger is closer to the ground surface [38,49]. Due to the proximity to the surface, the weather has influence over the exchanger and the efficiency could be lower [51,39,14]; even that, there are some studies like [16] that show the effect of the exchanger over the ground temperature. For the same reason, the installation may be damaged due to different reasons like crushing, perforations, and so on [4]. Typically, the performance is the same throughout the year, but if any problem appears, then, the efficiency could drop significantly or even disappear [38].

1.2. Fault detection

Fault detection involves the monitoring of a system and the detection when a fault has occurred [28]. The monitoring task differs a lot depending on the system. For example, a use of QCM [15] to control the oil degradation is explained in [9]. Other papers like [8] and [23] use the vibration analysis to monitor a self-levitating bearing. The monitoring task of solar thermal fluid transfer systems is carried out using Neural Network based models and rule based techniques in [24].

The system must be modeled or a knowledge based system must be created with the aim of detecting deviations of the correct performance [29]. There are many systems where fault detection has been implemented with satisfactory results. For instance, [27] proposes a two-stage recognition system for continuous analysis of ElectroEncephaloGram (EEG) signals. [1] proposes a model-based Robust Fault Detection and Isolation (RFDI) method with hybrid structure. A fault detection strategy for wireless sensor networks is presented in [34]. A hybrid two stage one-against-all Support Vector Machine (SVM) approach is proposed for the automated diagnosis of defective rolling element bearings in [26]; [52] shows the robust fault detection problem for non-linear systems considering both bounded parametric modeling errors and measurement noises. As can be seen on the mentioned examples (of fault detection), different soft computing techniques have been used to solve the problem.

1.3. Intelligent systems

Intelligent Systems are being used to solve or optimize several problems on engineering fields nowadays [7,6]. Some researches have been made with the aim of improving a system performance, because classical methods, like the applications based on PID controller [2], are not capable of solving this task. In other investigations, new intelligent techniques are developed to ensure a right system operation [17,33]. Some studies are focused on the development of a hybrid controller combining classical and intelligent techniques; a Neuro-PID controller is designed in [10]. Other papers design a new type of controller like the one explained in [12], an adaptive inverse controller using an online learning algorithm for neural networks.