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A Machine Learning Approach for the Performance Prediction of GCHPs with Horizontal Ground Heat Exchangers

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Abstract. This study aims to provide a machine learning approach to predict the performance of Ground Coupled Heat Pumps (GCHPs) with horizontal Ground Heat Exchangers (GHEs). Specifically, an ANN model was developed for this purpose which can potentially be generally applied to similar sites at different locations and climate conditions, with even limited types of input data. In this example, a TRNSYS model regarding a typical horizontal trench within a rural farm in Australia, has been developed and verified, covering over 50 different yearly loading patterns under 3 different climate conditions. The simulated performance data is then used to train the artificial neural network. As results, the trained ANN is able to predict the performance of GSHPs systems with identical GHEs even under climatic conditions (and locations) that has not been specifically trained for. With only limited input data, the presented ANN shows no more than 5% error in most cases tested.

Keywords. Ground coupled heat pumps, artificial neural networks, performance prediction.

1. Background and aim

Ground Coupled Heat Pump (GCHP) systems are a type of highly efficient device which utilizes the ground as the heat source when heating and as the heat sink when cooling. Ground Heat Exchangers (GHEs) are usually applied to transfer the heat between the working fluid and ground. There are many forms of ground heat exchangers, including vertical boreholes, horizontal trenches, energy piles, retaining walls etc. While vertical boreholes are the most common practice, horizontal trenches are cheaper options when land and space permit due to its low construction capital investment [1]. The design of the horizontal GHEs is challenging and time consuming as various factors such as thermal loadings and climate conditions affect the performance. Simulation tools based on phenomenological models have been developed and applied to predict the performance of the GCHPs and GHEs. However, modelling and computing time may be resource intensive and prohibitive for optimization runs of a site-specific case study. Previous studies [2, 3] have identified that Artificial Neural Network (ANN) can reduce the computing time significantly. However, no ANN has yet been available to predict

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the performance of GCHPs with horizontal GHEs under the rural industries' thermal loading conditions. This investigation aims to provide an ANN to predict the performance of the GCHPs with horizontal GHEs under rural industries' loading condition. The presented ANN is computationally fast and able to deal with limited input data.

2. Method

A TRNSYS model regarding a typical horizontal trench has been developed and verified. Using this model, over 400,000 hourly performance data have been obtained via simulations, covering over 50 different yearly loading patterns in the rural industry under three different climate zone conditions. The performance data is then used to train the ANN. The ANN network is a feedforward network with an input layer of three neurons, carrying three inputs, i.e. hourly loads, accumulated hourly loads and outdoor ambient air temperature, a hidden layer of 30 neurons and an output layer of a neuron for the COP.

3. Results and discussions

As shown in Figure 1, the results from the ANN prediction is reasonably agree well with the simulation results from the TRNSYS model. Apart from the data points when the heat pump is not in operation (when COP is zero), 80.7% of data points fall into the ±5 % error band. The ANN results show a slight under-estimation when the heat pump is at full load condition (i.e. in winter). This means that the ANN developed was not able to estimate the impact of weather conditions on COP extremely well at this stage.

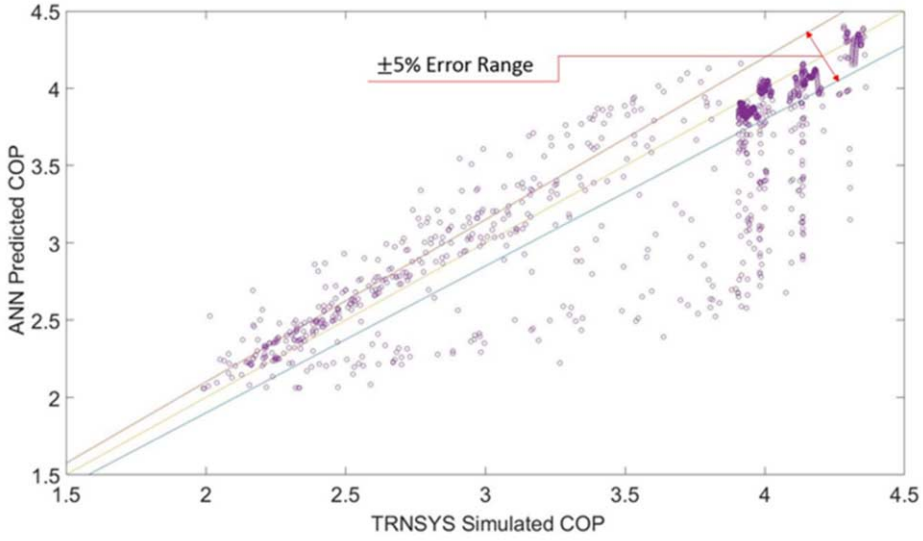

Figure 1. Hourly COP from TRNSYS simulations vs ANN predictions.

4. Conclusions

For rural industries' heating load patterns, the ANN developed is able to predict the performance of GCHPs with horizontal ground heat exchangers reasonably well even with limited input data. However, there is a trend that ANN underestimates the COP during winter when the heat pump is under full load.

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