

FORECASTING SHORT-TERM HEAT LOAD USING ARTIFICIAL NEURAL NETWORKS: THE CASE OF A MUNICIPAL DISTRICT HEATING SYSTEM

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Overview

In 2014, over 6000 different district heating systems (DHS) were present all across Europe, accounting for a heat market share of 40 – 60% in the Nordic and Baltic countries, and representing a total revenue (for heat sold) of approximately B€30 per year [1]. With the advancements of sustainable energy systems based on renewable energy sources (RES), the development of a new generation of district heating systems (4GDH) [2], and the key role that DH will play in the inclusive and sustainable growth of the European Union economy [3], it has become crucial to find new tools that can lead to improvements in production planning, energy efficiency, and at the same time, lower the costs of heat generation. A large number of heat load forecasting methods have been proposed as possible mechanisms for improvements in energy efficiency and production planning. These methods include multiple regression methods, exponential smoothing methods, as well as linear and nonlinear programming models. In recent years, Computational Intelligence (CI) methods used for the estimation and forecasting of energy demand have drawn considerable attention due to their advantages over linear and nonlinear programming models.

The main aim of this paper is to evaluate the predictive performance of an artificial neural network (ANN) for the application in district heating systems. The ANN was constructed to forecast the thermal load of a municipal DHS by taking into consideration previously observed heat load data, weather data and social factors (e.g. working hours, weekends, holidays). The paper is structured as follows: Section 1 presents a brief overview of artificial intelligence and in particular artificial neural networks. Section 2 describes the methodology applied in the development of the ANN model. Section 3 presents the computational results while section 5 presents a summary and conclusions.

Methods

In this study, we develop a computable model based on the artificial neural network (ANN) approach that can be effectively applied for the prediction of hourly heat load (short-term) in a municipal district heating system. The model is trained with previously observed heat load data, weather data, and social behavior components. The hourly weather data sets (e.g. outdoor temperature, humidity) were obtained from MERRA2, a numerical weather reanalysis [4] [5]. The predicted values of the model were compared with real observed data (hourly heat load) from a Polish municipal district heating network. Fig. 2 presents a simplified workflow of the heat load forecasting method.

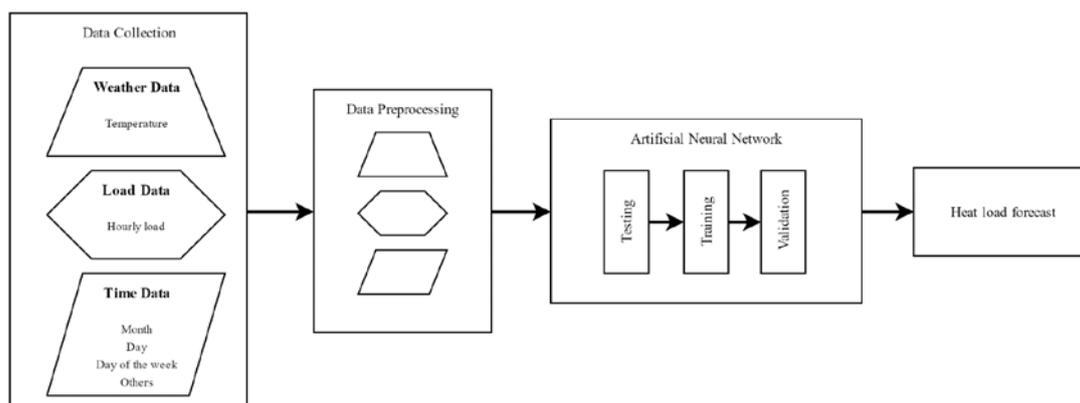


Figure 1 – Simplified workflow of the heat load forecasting model
Source: Own work

The model was computed under various configurations of hidden layers and number of neurons. The predictive performance of the neural network is measured by the mean absolute percentage error (MAPE), root mean square error (RMSE), and the coefficient of determination R^2 .

$$MAPE = \left(\frac{1}{N} \sum_{t=1}^N \left(\frac{|\hat{y}_t - y_t|}{y_t} \right) \right) \cdot 100\% \quad (1)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{t=1}^N (\hat{y}_t - y_t)^2} \quad (2)$$

Results

The results presented in this paper show that an ANN model is capable of predicting short-term thermal load values of a district heating system. Furthermore, the model shows a significant advantage over multiple regression methods, exponential smoothing methods, linear and nonlinear programming models, due to its capability to quickly adapt the forecasted values depending on weather conditions and social factors. The model can accurately predict heat load by using data such as observed heat load data, hourly weather data and social factors. This forecasting method can be applied as a possible mechanism for the improvement of energy efficiency and production planning in DHS.

Conclusions

The developed model based on the ANN approach can accurately predict short-term thermal load values of a municipal district heating system. Furthermore, the proposed method could be applied to individual buildings and small-scale cogeneration plants. The model can be adapted to forecast heat load from real-time input data such as weather conditions and observed heat load data. An ANN method implemented to a DHS would lead to the economic benefits of both, consumers and producers, due to fuel savings and emissions reductions. Furthermore, its implementation can encourage the deployment and expansion of smart DHS.

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