World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:13, No:06, 2019

Forecasting Thermal Energy Demand in District Heating and Cooling Systems Using Long Short-Term Memory Neural Networks

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Abstract : To achieve the objective of almost zero carbon energy solutions by 2050, the EU needs to accelerate the development of integrated, highly efficient and environmentally friendly solutions. In this direction, district heating and cooling (DHC) emerges as a viable and more efficient alternative to conventional, decentralized heating and cooling systems, enabling a combination of more efficient renewable and competitive energy supplies. In this paper, we develop a forecasting tool for near real-time local weather and thermal energy demand predictions for an entire DHC network. In this fashion, we are able to extend the functionality and to improve the energy efficiency of the DHC network by predicting and adjusting the heat load that is distributed from the heat generation plant to the connected buildings by the heat pipe network. Two case-studies are considered; one for Vransko, Slovenia and one for Montpellier, France. The data consists of i) local weather data, such as humidity, temperature, and precipitation, ii) weather forecast data, such as the outdoor temperature and iii) DHC operational parameters, such as the mass flow rate, supply and return temperature. The external temperature is found to be the most important energy-related variable for space conditioning, and thus it is used as an external parameter for the energy demand models. For the development of the forecasting tool, we use state-of-the-art deep neural networks and more specifically, recurrent networks with long-short-term memory cells, which are able to capture complex non-linear relations among temporal variables. Firstly, we develop models to forecast outdoor temperatures for the next 24 hours using local weather data for each case-study. Subsequently, we develop models to forecast thermal demand for the same period, taking under consideration past energy demand values as well as the predicted temperature values from the weather forecasting models. The contributions to the scientific and industrial community are three-fold, and the empirical results are highly encouraging. First, we are able to predict future thermal demand levels for the two locations under consideration with minimal errors. Second, we examine the impact of the outdoor temperature on the predictive ability of the models and how the accuracy of the energy demand forecasts decreases with the forecast horizon. Third, we extend the relevant literature with a new dataset of thermal demand and examine the performance and applicability of machine learning techniques to solve real-world problems. Overall, the solution proposed in this paper is in accordance with EU targets, providing an automated smart energy management system, decreasing human errors and reducing excessive energy production.

Keywords : machine learning, LSTMs, district heating and cooling system, thermal demand
Conference Title : ICMLA 2019 : International Conference on Machine Learning and Applications
Conference Location : Copenhagen, Denmark
Conference Dates : June 11-12, 2019