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An Optimal Neural Network for Hourly and Daily Energy Consumption Prediction in Buildings

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ABSTRACT

In this work, hourly and daily energy consumption prediction has been carried out using multi-layer feed forward neural network. The network designed in the proposed architecture has three layers, namely input layer, hidden layer, and output layer. The input layer had eight neurons, output layer had one neuron, and the number of neurons in the hidden layer was varied to find an optimal number for accurate prediction. Different parameters of the neural network were varied repeatedly, and the prediction accuracy was observed for each combination of different parameters to find an optimized combination of different parameters. For hourly energy consumption prediction, a total of six weeks data (September 1 to October 12, 2004) of 10 residential buildings has been used whereas for daily energy consumption prediction, a total of 52 weeks data (January 2004 to December 2004) of 30 residential buildings has been used. To evaluate the performance of the proposed approach, different performance evaluation measurements were applied.

KEYWORDS

Daily Consumption Prediction, Energy Consumption, Feed Forward Neural Network, Hourly Consumption Prediction, Residential Buildings

INTRODUCTION

The energy prediction models can bring a considerable amount of improvement in overall energy savings and reduction in environmental impacts. In 2013, almost 57% of total energy was consumed by the residential and tertiary sector in the Metropolitan City of Turin (Pavone, 2014). A higher accurate energy consumption prediction is a very complicated and difficult to formulate the task but indeed very important and therefore is the focus of many researchers. There are many parameters that have a direct influence on energy consumption of residential buildings. The important of these are the structure of the building, the external weather conditions, the behaviour of residents, and the usage

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of home appliances and so on. Over the last many years, different mathematical models for energy consumption prediction have been proposed in the literature. In order to find the future demands of energy, the energy consumption prediction at various scales is very important. The accurate energy consumption prediction also plays a key role in efficient production, distribution, selling, operation, planning and management in the energy management system. Power generation systems can be made more reliable if with the accurate energy consumption prediction. Further, if efficient energy consumption is carried out, the economy, fuel utilization, and other sectors dependent on energy management systems can be managed in a better way.

The energy consumption prediction can be divided into, short term, medium term, and long-term categories based on the time in which the energy has been utilized. Different techniques have been proposed in the literature for the energy consumption prediction with various evaluation criteria, parameters and the varying degree of accuracies (Wahid and Kim, 2016). Likewise, the application of different types of AI techniques for energy consumption and other types of predictions was highlighted by Wahid et al. (2017), Shah and Ghazali (2011) and Shah et al. (2012).

A linear regression model was developed by Catlina et al. (2008) for the monthly energy consumption prediction of residential buildings in some areas of France. The authors have considered different parameters for an accurate prediction. The parameters considered were the compactness of buildings, the ratio of opaque and glass surfaces, the thermal diffusion of roof and walls and time constant of buildings. A maximum deviation of 5.1% between the actual and calculated consumption was observed whereas the average deviation observed in the simulation was 2%. The authors have concluded that the energy consumption can be optimized by considering the design of the building in terms of the strong relationship between the building compactness and the heat consumption. Some other parameters e.g. thermal inertia has also noticeable impact. Although, the authors have obtained a reasonable accuracy but still there is much room for improvement. The less accuracy is due to the fact that the authors have not considered the internal patterns of the consumption.

Different types of features have been explored by Zhou and Zhu (2013) that have a relationship with the energy consumption in residential buildings. The study was focused on residential buildings located in some parts of China and different seasons e.g. summer, winter and environmental conditions were considered in the study. The study was conducted for the annual energy consumption regression model was developed for simulation. The thermal diffusion of walls and the outdoor temperature were considered as independent variables. A maximum deviation of 15% was observed between the actual and calculated energy consumption values. Here, again the authors have focused more on the external parameters and have not considered the internal parameters representing valuable pattern in the energy consumption and hence the accuracy the found can further be improved. To emphasize on the importance of renewable energy systems and awareness of dangers by carbon dioxide, Wang and Liu (2017) proposed an energy optimization model based on particles swarm optimization (PSO) for efficient energy management in wireless sensor networks.

In another study conducted by Panwar et al. (2015), equality constraints like load balance and inequality constraints like system reserve and bounds like power generation, up/down time and ramp rate limits, finally shapes into a complex optimization problem were carried out using binary fireworks algorithm. Similarly, in continuation with the applications of artificial intelligence techniques, PSO was applied by Lin et al. (2014) for optimal design of power electric circuit that will facilitate in minimum power consumption. For long-term energy consumption prediction, Bianco et al. (2009) studied the effect of some demographic and economic variables for development of the prediction model and the Italian energy consumption historical data from 1970 to 2007 was considered in the study. In this study, the authors used some different types of independent variables e.g. gross domestic product (GDP), the electricity cost and the GDP per person. The consumption was divided into two categories namely domestic consumption and non-domestic consumption. It has been observed in the analysis that the cost of electricity has low influence on the energy consumption variability. On the other hand, the GDP and the GDP per person has a strong influence in energy consumption variations.