UNIVERSITI TEKNOLOGI MARA

NON-LINEAR BASELINE ENERGY MODELLING IN EDUCATIONAL BUILDING USING NARX-ANN

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Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Electrical Engineering)

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Multiple Linear Regression (MLR) technique has been extensively used for the development of baseline energy models (BEM) and prediction of energy consumption for educational buildings. The energy consumption of educational buildings behaves differently according to the window of operation (lecture and non-lecture week). Difficulty in modelling accurate BEM arises since different windows of operation yield different energy consumption due to dissimilar operational behaviours and variables affecting the energy. Furthermore, the use of MLR technique becomes irrelevant given the non-linearity of relationships between the independent variables and energy consumption in educational buildings. Therefore, this thesis proposed a new approach that modelled the BEM for educational buildings based on the window of operations using Non-Linear Auto Regressive with Exogenous Input Artificial Neural Network (NARX-ANN) for energy consumption prediction purposes. Two educational buildings in Malaysia were used as case studies. The initial NARX-ANN BEM used trial and error approach to optimize the ANN network structure has led to a sub-optimal condition. The model was then improved by integrating the NARX-ANN BEM with Particle Swarm Optimisation (PSO) to determine the optimum NARX-ANN BEM input and output Tap Delay Lines (TDL) numbers and neuron numbers. The new model was called NARX-ANN-PSO BEM. The resultant of the best input and output TDL number of the NARX-ANN-PSO BEM were then further optimised using Binary Particle Swarm Optimisation (BPSO) to select the best structure of the NARX-ANN-PSO BEM hence created a more accurate model which is named as NARX-ANN-PSO-BPSO BEM. Integrating the PSO and BPSO into the NARX-ANN model has significantly improved the accuracy of the proposed non-linear BEM in this thesis. The NARX-ANN-PSO-BPSO BEM recorded the lowest Mean Absolute Percentage Error (MAPE) with below than 10% errors in all the cases. In the best case, the MAPE for NARX-ANN-PSO-BPSO was found 20 times lower that the MAPE produced by the MLR BEM. Consequently, these show that the BEMs developed in this thesis are capable in predicting the non-linear and dynamic energy consumption in educational building with better accuracy. The models could be used for energy management and efficiency planning as well as determining energy savings for educational buildings taken into account the different operational windows.

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