Utilization of MLP and Linear Regression Methods to Build a Reliable Energy Baseline for Self-benchmarking Evaluation

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Abstract

This paper presents a reliable energy baseline model for self-benchmarking evaluation of energy saving potential by using multilayer perceptron (MLP) method. The measured energy data and product quantities of the sample plant in daily period dating back since 2011 to 2016 are used as variables and then normalized to represent the energy baseline (EnB) of the manufacturing plant. A comparison of MLP and linear regression (LR) methods for creating the baseline model is investigated during the factory expansion capacity. For LR method, we use the ASHRAE Guideline 14-2002 as a reference in recommended values for modeling uncertainty. As the uncertainty problem, the LR method is more sensitivity to the outliners, because the nature of plant variables has more complexity and nonlinearity. So we introduce the MLP method to solve or reduce the effect of nonlinearity by supervised learning in the short-term and long-term period of the production. For simulation results, in short-term period the LR method demonstrates some better results of uncertainty parameters. However, the proposed MLP with LR method can build a reliable baseline showing in better R-square values than LR method. This is useful for energy evaluation when the plant is expanding capacity to protect misleading interpretation occurring during the year. For long-term period, the MLP method can overcome the LR method in all uncertainty parameters. Therefore, the MLP method may be able to the alternative choice for creating the EnB in nonlinearity circumstances of the plants for short-term and long-term period.

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1. Introduction

Energy conservation in manufacturing plant is the energy-awareness management of modern industries. In many countries, the factories have to be controlled and operated under the energy conservation act or energy conservation standard such as ISO 50001:2011 [1]. The major procedure in this standard is to propose the energy saving measures to minimize the energy consumption by setting priority on the maximum load to be done first.

Furthermore, ISO 50006:2014 standard [2] indicates that we must create energy baseline (EnB) and choose a suitable energy performance index (EnPI) for comparison the saving between pre-retrofit and post-retrofit. Usually, we use the specific energy consumption index (SEC) to determine the energy efficiency. In addition, the baseline duration can range from less than one year to multiple years based on business condition information together with statistical method such as regression analysis.

In energy saving potential, energy service companies (ESCOs) need to evaluate the feasible energy saving of the factories or buildings by using the measurement and verification (M&V) procedures [3] and ASHRAE Guideline 14-2002 [4]. The limitation of ASHRAE Guideline 14-2002 is the use of least square regression in approximation of energy baseline and seems to be sensitive to outliers and nonlinear relationships.

Mostly reviewed papers, the research tasks are done in short-term (duration \( \leq 12 \) months). There is an attempt as in [5] proposed a comparison of Gaussian process regression and change-point regression for the baseline model in industrial facilities. In uncertainty analysis, the application of Gaussian mixture models [6] is used to model the baseline and localize adaptive uncertainty quantification. For weather season changing, there is a study of baseline model using linear regression for office building energy consumption in hot summer and cold winter region [7] by using monthly energy-bill. The application of multilayer feedforward artificial neural network is used for short duration [8] with 15-minute aggregate energy data and shows the performance with more accurate results than a baseline thin plate spline model.

At this point, the confusion of the duration used and the amount of information data for creating the baseline is arisen on how we could apply these to the suitable method. So, we propose the MLP approach for approximation on the reliable baseline, which rarely use in short-term and long-term analysis. Then, we can use this reliable baseline to develop the EnPI for self-benchmarking evaluation for the factory that hardly to find the companies to benchmark with or they have a big difference in technologies used in the process or machine.

2. Energy baseline approaches

In the case study, Mahasawat water treatment plant located in Nontaburi province, Thailand is chosen for investigation the baseline. The energy consumption data of the plant equipment and facilities is measured from local recordable power meters and complied into a daily report.

We can formulate the input-output variables of the system as independent variable vector of DDTF (Daily distribution and transmission flow) and dependent variable vector of DPEC (Daily plant energy consumption) for linear regression approach. For MLP approach, we use DRF (Daily raw water flow) as the independent variable to predict DPEC and DDTF as shown in Fig.1.

![Fig. 1 Mahasawat water treatment plant input-output formulated system](image-url)
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