Deep Learning-Based Power Baseline Modelling of a Range of Electrical Loads in Smart Green Buildings

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I. Introduction

Energy consumption modelling of electrical loads plays a crucial role in modern-day energy management systems for green commercial buildings. This project focuses on the development of power baseline modelling using deep learning techniques for a diverse range of electrical loads. The baseline model, an estimation of power or energy consumption before implementing energy management, is widely used to identify savings by comparing with the measured data after implementing energy management. Energy efficiency is crucial for both commercial and non-commercial applications. Power baseline models give reference to identify energy saving or loss. We can assess energy saving after implementing energy conservation strategies and identify energy wastage of the system when actual power consumption is higher than the power baseline model prediction. In this study specifically, a comparison is made between Karl's Pearson's and Random Forest-based deep learning approaches and Recurrent Neural Network (RNN) models. This project incorporates both simulations and real-world data to conduct the study.

Keywords: Power Baseline, Deep Learning, Neural Network, Energy Management, Abnormalities

II. Overview of the Projects

A. *Aim*

Develop a power baseline model using deep learning techniques for diverse range of electrical loads in building energy management systems (BEMS) to optimize energy usage.

B. *Scope*

The intended scope of this project involves the development, testing and validation of a deep learning-based power baseline model using real-world data sourced from specific electrical loads (mainly focused on air conditioners) within the University of Moratuwa.

C. *Project Objectives*

- The precise acquisition of necessary data for training, validation, and testing the model.
- Identifying Power usage patterns for different electrical loads.
- Developing a model that can accurately derive the power baseline patterns of various electrical loads.
- Presentation of a baseline model output in an easily comprehensive manner.

D. *Expected Outcomes*

- Identify abnormalities of the electrical loads.
- Assess the energy saving or loss, reference to the power baseline model.
- Take necessary actions to reduce the energy consumption using power baseline model.

III. Literature Review

Power baseline modelling approaches are methods used to establish a foundational understanding of power systems and their behavior. These approaches help in estimating the power baseline of the building. There are three common power baseline modelling approaches included as follows.

A. *Physical Modeling:* Physical modelling, often referred to as "white-box approaches," are methods rooted in the principles of physics.

B. *Data-Driven Modelling:* Data-driven modelling relies on historical data and machine learning techniques to build models that capture the behavior of the systems. This approach can be more flexible and adaptable, as it can handle complex, real-world scenarios and data, but it may require substantial data for accurate modelling.

C. *Hybrid Approach:* The hybrid approach combines elements of both physical and data-driven modelling.

Here are the benefits of the deep learning approach in contrast to traditional machine learning methods.

- Deep learning can learn complex relationships in data without considering complex thermodynamic principles. It relies only on relevant accurate data that influences the application.
- Deep learning's use of backpropagation across multiple layers often results in reduced training times when compared to conventional machine learning models.
- Deep learning fosters interconnections between its layers, bridging the information gap typically encountered in traditional machine learning, particularly when dealing with time series data [6].

The literature review reveals certain research gaps. There is a noticeable absence of baseline models that address and describe the baseline for distinct ranges of electrical loads individually. Additionally, there is a lack of effort in visualizing the operational patterns of specific electrical loads to detect anomalies or normal functioning. Furthermore, another gap concerns the absence of applications that can detect energy wastage or savings in specific electrical loads through the utilization of baseline models.

IV. MATERIALS AND METHODS

A. Required Materials

- OpenStudio
- Microsoft Excel
- Google Colab

B. Methodology

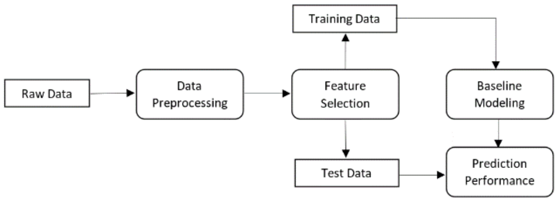

Figure 1: Methodology of Baseline Modeling

The data collection process for our study involves considering various loads such as air conditioners, and lighting systems. We measure power data, indoor temperature, and indoor relative humidity using specialized measuring units that we have developed. Additionally, real environmental data is obtained from the Weather station of the Faculty of IT, and we also collect simulated data through the OpenStudio EnergyPlus software.

Missing values are addressed, data is scaled, and outliers are removed in the data pre-processing stage to ensure the quality and accuracy of our dataset.

In the Feature Selection Process, Pearson's coefficient of correlation (r) is employed to identify which data attributes have the most significant impact on our modeling.

A deep learning approach for modeling will be employed due to the advantages highlighted in above literature review,

For performance evaluation, we utilize several metrics, including R-squared, the Coefficient of Variation of the Root Mean Square Error (CV-RMSE), and the Normalized Mean Bias Error (NMBE). These metrics help us assess the effectiveness and accuracy of our models in estimating power consumption.

V. RESULTS AND DISCUSSION

An experimental environment was established through the utilization of OpenStudio / EnergyPlus software to simulate a seminar room capable of accommodating up to 100 students. Within this simulation, electrical load profiles were recorded under real-world weather conditions. The focus of the simulation was to observe the cooling load variations and to identify how it varies under varying weather conditions.

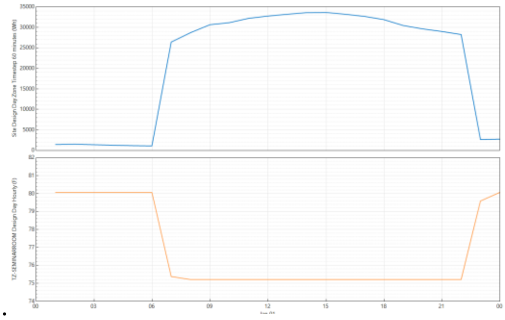

Figure 2: Sample simulation output: Hourly Cooling Load and Temperature variation.

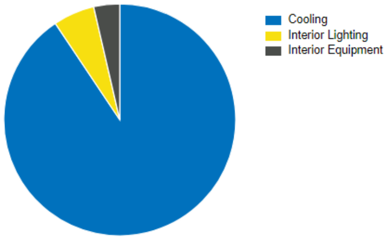

Figure 3: Contribution of Electrical Loads

VI. CONCLUSION

This project focuses on developing power baseline models for a wide range of electrical loads in the context of energy management for green commercial buildings. By employing deep learning techniques, including Karl Pearson's and Random Forest-based models, as well as Recurrent Neural Networks (RNNs), the study aims to accurately predict and assess energy consumption. The research combines both simulated and real-world data to provide a comprehensive analysis, contributing to the optimization of energy conservation strategies and the promotion of sustainability in commercial and non-commercial applications.

VII. REFERENCES

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