A Deep Learning-Based Microgrid Energy Management Method Under the Internet of Things Architecture

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ABSTRACT

Given that the current microgrid incorporates highly connected distributed energy sources, the conventional model control methods do not suffice to support complex and ever-changing operating scenarios. This paper proposes a deep learning-based energy optimization method for microgrid energy management in the new power system scenarios. This article constructs a microgrid cloud edge collaboration architecture, which collects interactive network status data through terminal devices and network edge sides. A microgrid energy management model is constructed based on Bi-LSTM attention in the network cloud. And the model is sunk to provide real-time and efficient comprehensive load and power generation prediction output optimal scheduling decisions at the edge of the network, achieving collaborative control of microgrid light load storage. The simulation based on the actual available microgrid data shows that the proposed Bi-LSTM attention energy management model can achieve rapid analysis and optimize decision-making within 7.3 seconds for complex microgrid operation scenarios.

KEYWORDS

Attention Mechanism, Bidirectional LSTM, Energy Management, Internet of Things, Microgrid

INTRODUCTION

A microgrid utilizes and consumes renewable energy, interacts with the large grid, and can improve the utilization level of renewable energy, creating economic and environmental benefits while ensuring the safety and stability of the large grid (Dashtdar et al., 2022; Muchande & Thale, 2022). However, as the installed capacity of distributed power sources continues to expand, the uncertainty of their output could impact the large power grid.

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Microgrids need to manage various power generation and consumption equipment to meet the requirements for stability, cost-effectiveness, and safety so as to reduce the adverse impacts of renewable energy on the stability of the system and the economy (Zhang et al., 2022; Alvarez et al., 2023). Energy management of microgrids plays a vital role in ensuring economic operation, and its research has, therefore, become a matter of necessity and great urgency.

Currently, microgrids rely mainly on classical optimization methods, planning-based methods, Heuristic algorithms, etc. for energy management, which require precise mathematical model construction. In actual microgrids, however, wind and solar energy exhibit a high degree of randomness, which makes the traditional methods ill-suited for the actual situation (Ben Mansour et al., 2022; Nara, 2022; Zhang et al., 2020). At the same time, management of energy storage is so complex that it is difficult to use accurate data models and numerical calculation methods.

The emerging Internet of Things (IoT) has played an important role in the situational awareness of microgrids, which are gradually developing toward intelligent, information-based, and diversified new power systems (Altaf et al., 2022; Kandari et al., 2021). IoT devices are distributed at different power-equipment locations in the microgrid, achieving reliable network-state perception, providing complete data support for energy-scheduling optimization, and ensuring reliable monitoring, detection, and operation-optimization control of energy equipment (Tabassum et al., 2022; Savoli & Bhatt, 2022).

The traditional mathematical-modeling method faces challenges in extracting extensive and diverse microgrid-state data. In contrast, deep learning, with its complex neural network modules, excels at associating and extracting valuable information. Consequently, it offers a new and effective solution for navigating the complexities of microgrid energy-management scenarios.

Based on a multilayer network structure model, deep learning continuously trains and learns the power-grid dataset, constructs a complete and reliable energy-management model, and achieves effective assessment of network status and optimization of decision-making (Yang et al., 2022; Arul et al., 2021). Deep learning has allowed scholars to conduct energy-optimization research. Fang et al. (2021) combine reinforcement learning and deep-learning networks to design a deep Q-network model to achieve microgrid energy management and market-trading platforms, supporting stable operation. Parfenenko et al. (2023) adopt multilayer convolutional channels to optimize and improve the long-term and short-term memory network, improve the resource allocation of microgrids, and ensure energy-regulation security. Suresh et al. (2020) build an automatic encoder architecture based on the LSTM model and introduce an ant-colony algorithm to achieve global optimization, supporting the analysis of energy-optimization management in microgrids. Nahid et al. (2023) integrate a convolutional neural network (CNN) model and LSTM network model to achieve short-term output prediction for microgrid wind power. They focus on the application of deep learning in microgrid energy management, including the building of reliable energy-management models, optimization of decision-making, and integration with various deep-learning techniques to enhance performance.

However, most of the above methods are centralized decision-making management, and the analysis and calculation center is far from the terminal equipment, making real-time and rapid optimization scheduling analysis difficult to attain (Pu et al., 2021); at the same time, the presence of a great deal of redundancy in massive data requires energy-management models to discriminate and eliminate the redundant data to ensure the completeness of the model and achieve correct analysis of microgrid energy. For the redundant and abundant microgrid data, deep-learning models excel in capturing long-term dependencies and nonlinear relationships within time-series data. They can more precisely model the inherent complex dynamic characteristics of microgrid systems, enhancing the understanding of the relationships among energy generation, storage, and consumption. This deep learning–based approach is expected to better adapt to the complexity of microgrid systems, providing assistance in improving energy-utilization efficiency and system stability.

The paper presents a novel energy-management method for microgrids based on a Bi-LSTM-Attention model within an Internet of Things architecture. It develops a cloud–edge collaborative architecture for microgrid energy management, leveraging IoT technology. This structure facilitates