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Research on Electric Load Forecasting and User Benefit Maximization Under Demand-Side Response

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ABSTRACT

In this paper, the real-time changes of demand-side response factors are accurately considered. First, CNN is combined with BiLSTM network to extract the spatio-temporal features of load data; then an attention mechanism is introduced to automatically assign the corresponding weights to the hidden layer states of BiLSTM. In the optimization part of the network parameters, the PSO algorithm is combined to obtain better model parameters. Then, considering the average reduction rate of various users under energy efficiency resources and the average load rate under load resources on the original forecast load and the original forecast load, the original load is superimposed with the response load considering demand-side resources to achieve accurate load forecast. Finally, "price-based" time-of-use tariff and "incentive-based" emergency demand response are selected to build a load response model based on the principle of maximizing customer benefits. The results show that demand-side response can reduce the frequency and magnitude of price fluctuations in the wholesale market.

KEYWORDS

Attention Mechanisms, Bidirectional Long-Short Memory Networks, Convolutional Neural Networks, Demand-Side Response, Load Forecasting, Maximum Efficiency

INTRODUCTION

The reform of the electricity market is an inevitable trend of our country's development and the requirements of the times. Electricity supply and demand will maintain a balance of resource utilization through real-time transactions, so as to fulfill the global strategic goal of energy conservation and

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emission reduction. In this context, high-precision short-term load forecasting can formulate efficient and economical power generation plans for power dispatch management departments, rationally arrange unit output, and ensure the safety and stability of the power system(Kong et al., 2017; Lekshmi et al., 2019). At the same time, various facilities such as pumped storage, electric vehicles, and energy storage power stations have been connected to the grid one after another, making the range and amplitude of the load-side response continue to increase, and the range of preferred users for demand-side response has gradually expanded(Hao et al., 2019 ;Mohamed et al., 2018).

The demand-side is an important part of power market planning. By analyzing the characteristics of the demand-side and integrating the supply and use methods of the electric energy system, it can assist the stable operation of the system and improve the market pricing mechanism.Adenso et al. (2002) comprehensively summarized the main problems encountered by OECD countries implementing demand side response projects, introduced the implementation experience of various countries, and clearly pointed out the important role of two demand side response mechanisms in power grid operation. In order to effectively implement demand-side projects,Hopper et al. (2006) conducted a study on the success factors of real-time electricity price project operation, emphasizing convenience, fairness, and information transparency in the implementation of electricity price projects. Based on the implementation of demand response projects under the smart power grid, Fell et al. (2014) considered factors such as time-of-use electricity prices, subsidy policies, accounting and energy storage technology and distributed power generation technology to construct the power distribution income-expense model of demand-side response projects. Under the premise of wind power uncertainty, Qadrdan et al. (2017) established a two-tier planning model for wind power system dispatch with day-ahead hourly electricity price optimization and incentive demand-side response. This model promotes power users to cut peaks and fill valleys, effectively guides the adoption of wind power, reduces the cost of thermal power generation, and improves the benefits of power users.

The purpose of this paper is to study the demand-side response problem under the premise of power load forecasting and power user comprehensive benefit maximization. Firstly, this paper proposes a new ultra-short-term power load forecasting method based on CNN-Bil STM-Attention(AC-BILSTM) for the characteristics of nonlinearity and timing of power load data. Among them, convolutional neural network CNN can effectiely extract the nonlinear local features of power load data. BiLSTM layer is used to extract bidirectional timing features of sequence data. The features generated by the hidden layer of BiLSTM are taken as the input of the Attention mechanism, and the Attention mechanism is used to distinguish the time information extracted from the BiLSTM layer by weighting the importance degree to reduce the influence of redundant information on the load prediction results. Second, in order to improve the prediction accuracy of electric load, an electric load prediction model using particle swarm algorithm (PSO) to optimize the hyperparameters of AC-BILSTM neural network is proposed. The PSO algorithm is used to find the global optimal solution effectively for model hyperparameter search, and the appropriate hyperparameters are found and validated by continuous training.The load level of the system is predicted, the potential of regional demand side response is fully analyzed, and the response load accounting of the original load and demand side resources is superimposed. Perform accurate load forecasting. Finally, a demand-side response model based on demand-side revenue maximization is constructed, and the relationship between electricity price and power demand after the implementation of the two measures is analyzed by examples. By introducing demand-side responses during peak periods of electricity consumption in the electricity market, consumers can adjust their consumption patterns according to price signals in the market. In addition, demand-side response can also reduce electricity consumption during peak load hours, which can generate a certain level of stable revenue in the market.

The contributions of this paper are as follows: 1) A CNN-BilSTM-Attention (AC-BiLSTM) based ultra-short-term power load forecasting method is proposed, which is also combined with PSO algorithm for model hyperparameter finding; 2) Considering the impact of the average consumption reduction rate of each type of users under energy efficiency resources and the average load rate under