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Original Research Article

Construction of artificial intelligence load forecasting model for new energy grid connection and regulation strategy for stable operation of power grid

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Abstract: Aiming at the prominent load fluctuation, insufficient accuracy of traditional forecasting methods and great difficulties in stable power grid regulation under new energy grid-connection, this paper constructs an artificial intelligence load forecasting model and proposes supporting regulation strategies. The Long Short-Term Memory (LSTM) network is adopted to adapt to nonlinear time-series features, the 3σ criterion is applied for data preprocessing, and the Particle Swarm Optimization (PSO) algorithm is introduced to optimize the key parameters of the model so as to improve forecasting accuracy. The comparison results show that the PSO-LSTM model has lower errors and better fitting performance than the single LSTM model. Based on high-precision forecasting results, a coordinated regulation system of source-grid-load-storage as well as a voltage and frequency stability regulation system is established, which can effectively suppress new energy fluctuations and reduce operation risks. It provides technical support for accurate forecasting and safe and stable operation of distribution power grids with high penetration of new energy.
Keywords: new energy grid-connection; artificial intelligence load forecasting; power grid stability regulation

1. Introduction

The large-scale integration of distributed photovoltaic and wind power makes distribution power grids present strong randomness, nonlinearity and non-stationarity. Traditional load forecasting methods suffer from low accuracy, which easily leads to delayed dispatching, high pressure of voltage and frequency regulation, and increased operation risks. Against the background of the development of new-type distribution power grids, accurate forecasting and stable regulation have become key technical requirements. Artificial intelligence algorithms have outstanding advantages in time-series feature extraction and nonlinear fitting, providing a feasible way to solve the above problems. Based on the scenario of new energy grid-connection, this paper constructs an optimized PSO-LSTM forecasting model and designs supporting regulation strategies, so as to improve forecasting accuracy and power grid stability, and support the efficient consumption of new energy and safe power supply.

2. Analysis of load forecasting and power grid operation problems under new energy grid-connection

After the large-scale integration of distributed photovoltaic and wind power into distribution networks, their output varies in real time with meteorological conditions such as solar irradiation, wind speed and temperature, showing prominent intermittency and random fluctuation characteristics. This causes power output to deviate from the normal operating state and renders load time series non-stationary, making traditional forecasting methods inapplicable. The superposition of new energy generation and load forms compound fluctuations, which further intensify the nonlinearity and non-stationarity of load variation and increase the difficulty of model construction. Traditional forecasting methods have limited adaptability, while conventional neural networks are prone to gradient vanishing and insufficient fusion of multi-source features, resulting in unsatisfactory forecasting accuracy that fails to meet the requirements of high-penetration new energy scenarios[1]. The superposition of output fluctuations and forecasting deviations

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breaks the source-load balance and induces frequency and voltage deviations. Traditional regulation approaches suffer from slow response and low control accuracy, making it difficult to cope with complex power flow and expanding peak-valley differences. As power grid operational risks continue to rise, it is urgent to establish an adaptive regulation system.

3. Construction of artificial intelligence load forecasting model and power grid regulation strategy

3.1. Construction of AI forecasting model adaptable to new energy fluctuations

Given the strong load volatility brought by new energy grid-connection, the Long Short-Term Memory (LSTM) network is adopted to build the load forecasting model. It can capture long-term time-series dependencies and avoid the gradient disappearance problem of traditional neural networks. Multi-source information such as historical load data of distribution power grids and solar irradiance is taken as model input[2]. The forget gate, input gate and output gate realize the retention and updating of time-series information, completing dynamic memory and feature extraction of fluctuating random loads. In the data preprocessing stage, the 3σ statistical criterion is used to eliminate outliers and perform linear interpolation for data completion. Normalization maps data to a standard distribution, weakening the impact of noise and fluctuation on model training. The model structure adapts to the nonlinear and non-stationary characteristics of the coupling between new energy output and load, constructing a basic load forecasting framework dedicated to new energy grid-connection scenarios and providing stable structural support for subsequent forecasting.

3.2. Optimization of model algorithm to improve load forecasting accuracy

The basic LSTM model is integrated with the Particle Swarm Optimization (PSO) algorithm to realize adaptive optimization of key network parameters. It mainly adjusts the weights and biases of the forget gate, input gate and output gate to strengthen the model's fitting effect on fluctuating loads. The optimization process sets the population size to 50 and the number of iterations to 30. Global search is realized through iterative updating of particle velocity and position. A fitness function including RMSE, MAE and R2 is constructed, with each indicator assigned an equal weight of 1/3 to synchronously reduce multi-dimensional errors. The dataset is divided into a training set and a test set at a ratio of 70% to 30% for model training and verification[3]. Comparative analysis shows that the forecasting performance of the PSO-LSTM model is superior to that of the single LSTM model. The detailed indicator comparison is shown in **Table 1**.

Table 1. Comparison of model forecasting accuracy indicators.

Algorithm	RMSE	MAE	R2
LSTM	2.9167	1.5176	0.2997
PSO-LSTM	2.3145	1.2458	0.3619

3.3. Formulation of power grid stability regulation scheme based on forecasting results

Based on the load forecasting results output by the PSO-LSTM model, a power grid stable operation regulation system is constructed for new energy grid-connection scenarios, and the specific regulation process is shown in **Figure 1**. The trend of source-load imbalance is judged according to the forecasting curve, and a coordinated dispatching scheme of source-grid-load-storage is formulated to suppress power disturbances caused by random new energy fluctuations. To address voltage and frequency deviation, an adaptive regulation method driven by predicted values is adopted to adjust reactive power compensation and frequency regulation resource allocation, keeping system operating parameters within the safe range[4]. Load forecasting is used to realize power flow management of distribution power grids, optimize the power distribution of integrated distributed new energy nodes, and alleviate the operation pressure caused by the increasing peak-valley difference and complicated power flow. Taking real-time forecasting data as the decision-making basis, the regulation scheme features fast response and stable regulation effect. It can improve the consumption level of new energy and power grid operation reliability, and ensure the safe, stable, economical and efficient operation of new-type distribution power grids[3].

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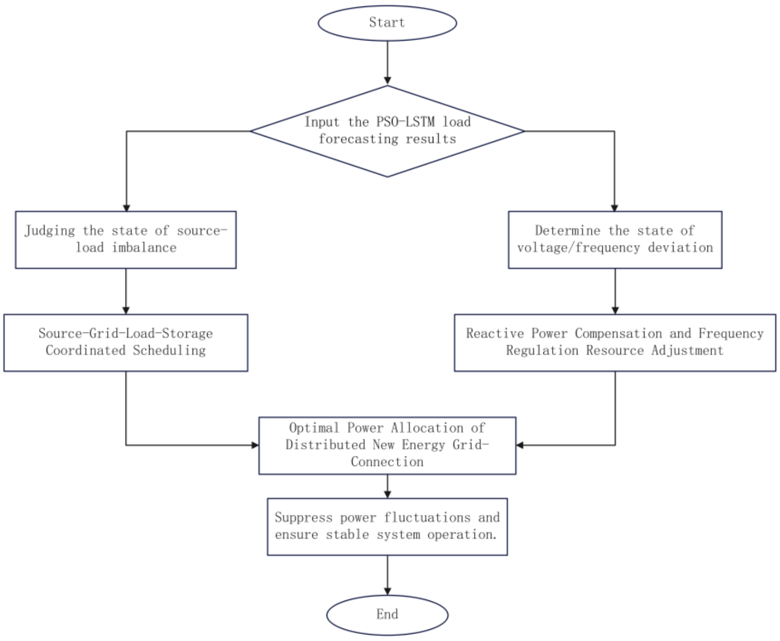

Figure 1. Flow chart of power grid stable operation regulation strategy based on load forecasting.

4. Conclusion

Focusing on the scenario of new energy grid-connection, this paper completes the construction of an artificial intelligence load forecasting model and the research on stable power grid operation regulation strategies. The combination of LSTM network for time-series feature processing and PSO parameter optimization effectively improves the forecasting accuracy of fluctuating loads. The coordinated regulation scheme formed based on accurate forecasting results can alleviate source-load imbalance, suppress power disturbances, and improve voltage and frequency stability. The results verify the effectiveness of the model and strategies, which can provide a reliable basis for the dispatching and operation of distribution power grids. In future research, more types of meteorological data and multi-dimensional load data can be further integrated to expand the applicable scope of the model, and the coordinated control mechanism of distributed energy can be improved to continuously enhance the intelligent, safe and economical operation level of power grids under the condition of new energy grid-connection.

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