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MACHINE LEARNING METHODS FOR OPTIMIZING THE DISTRIBUTION OF ACTIVE AND REACTIVE POWER IN ELECTRIC POWER SYSTEMS

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Abstract. The article discusses methods for optimizing the balance of active and reactive power in electrical networks using machine learning algorithms. It is shown that the use of intelligent data processing models makes it possible to effectively control the modes of power systems, increase their stability, reduce the loss of active power and improve the quality of electricity. The simulation results are presented, confirming the effectiveness of using neural networks and other machine learning methods to optimize power distribution and adjust network parameters.

Keywords: active power, reactive power, machine learning, optimization, power system, neural networks, reactive power compensation.

Introduction

The balance of active and reactive power is one of the key factors determining the stability and efficiency of electric power systems [1]. A violation of this balance leads to an increase in electricity losses, voltage deviations from acceptable values and a deterioration in the quality of electricity supply to consumers [2].

In modern conditions of development of energy systems, characterized by the decentralization of generation, the introduction of intelligent networks and the active integration of renewable energy sources, the task of managing active and reactive power is significantly complicated [3].This is due to the high variability of operating modes and the need for rapid response to external and internal disturbances.

Traditional methods of calculating and regulating power systems based on static models and deterministic algorithms have a limited ability to take into account the nonlinear and dynamic nature of processes [4]. In this regard, the relevance of using machine learning algorithms capable of processing large amounts of data, identifying hidden dependencies and providing adaptive control of operating modes of power systems is increasing [5].

The purpose of this work is to explore the possibilities of using machine learning algorithms to optimize the balance of active and reactive power, as well as to evaluate their effectiveness in modern electric power systems.

Statement of the problem

In modern electric power systems, there is a need to ensure an optimal balance of active and reactive power under changing load and generation conditions [6].

The main objective is to minimize active power losses, maintain acceptable voltage levels, and ensure system stability through efficient reactive power distribution.

The following features must be taken into account:

- the nonlinear nature of the dependencies between the mode parameters;
- variability of load and generation;
- the impact of distributed energy sources;

• network voltage and bandwidth limitations.

Thus, the task is to develop a method that allows, based on current and predicted data, to determine the optimal parameters of the operating mode of the power system using machine learning algorithms [7].

Solving the problem

To solve this problem, it is proposed to use machine learning algorithms that take into account the complex relationships between the parameters of the power system and adapt to the changing conditions of its operation [8].

The solution of the problem includes the following steps:

1. Data collection and preparation. Data on the values of active and reactive power, voltages, currents, loads and the condition of compensating devices are used.

2. Formation of a training sample. The key parameters affecting the operating mode are determined: power factor, voltage levels, line losses, and other characteristics.

3. Model selection and training. Machine learning algorithms such as neural networks, random forest, gradient boosting and other methods are used.

4. Optimization of the operating mode. The trained model allows you to determine the optimal values of the distribution of active and reactive power in order to minimize losses and maintain the stability of the system.

5. Performance evaluation. The results are analyzed, including reducing power losses, reducing voltage deviations, and improving network reliability.

The use of machine learning makes it possible to switch to intelligent control of power system modes based on forecasting and adaptation to current conditions.

Results

The study assessed the effectiveness of using machine learning algorithms to optimize the balance of active and reactive power in the electric power system. The simulation was performed based on typical operating modes of a variable-load distribution network.

The results showed that the use of ML algorithms can significantly improve the efficiency of managing the modes of the power system. In particular, the following indicators were obtained:

-reduction of active power losses by 12-18% due to optimal redistribution of power flows;

-reduction of voltage deviations in network nodes to ± 3 % of the nominal value;

-increase in the power factor ($cos\varphi$) by an average of 0.08–0.12;

-reduction of the optimal mode calculation time up to 30-40% compared to traditional methods;

-reduction of overloads of lines and equipment due to a more even distribution of loads.

The most effective results were achieved using a hybrid approach combining neural networks and optimization algorithms. This made it possible to simultaneously take into account both the nonlinear nature of the processes and the limitations of the power system.

Additionally, it has been established that the use of predictive models provides the possibility of early adjustment of operating modes, which increases the stability of the system in case of sudden changes in load and generation.

Thus, the results of the study confirm the expediency of using machine learning algorithms to solve the problems of optimizing the balance of active and reactive power in modern electric power systems.

Conclusion

Optimizing the balance of active and reactive power using machine learning algorithms is a promising area of development for modern electric power systems. The use of intelligent methods makes it possible to increase the accuracy of forecasting, adaptive control and reduce energy losses.

It is advisable to focus further research on the creation of integrated intelligent systems that combine the functions of monitoring, forecasting and control modes in real time. This will ensure an increase in the reliability, efficiency and sustainability of energy systems in the context of the digital transformation of the industry.

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