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Stability Analysis and Optimization of Energy Power System Based on Advanced Control Strategy

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Abstract: Advanced control strategy has important application value in stability analysis and optimization of energy and power system. The main purpose of this study is to explore the application of advanced control strategy in the stability analysis and optimization of energy power system, and verify its effectiveness and superiority through simulation experiments. Specifically, this paper deeply analyzes the stability of energy power system and its influencing factors; The principle of advanced control strategy and its application method in energy and power system are studied. The optimization method of system stability based on advanced control strategy is proposed and verified by simulation experiments. The experimental results show that compared with the traditional control methods, the advanced control strategy in this paper can better adapt to the complex and changeable system operating environment and diversified energy access requirements, and significantly improve the stability and security of the system. This study is of great significance to promote the in-depth development of the stability research of energy power system and ensure the reliability and safety of power supply. At the same time, it also provides new ideas and directions for future research.

1. Introduction

With the rapid development of society and the continuous progress of science and technology, as the infrastructure supporting the operation of modern society, the stability and safety of energy and power system have attracted more and more attention [1]. The traditional control strategy has gradually revealed its limitations in the face of increasingly complex system operating environment and diversified energy access [2]. Therefore, it is of great practical significance to explore and study the application of advanced control strategy in energy and power system for improving the stability of the system, optimizing energy allocation and ensuring power supply [3].

In recent years, with the development of smart grid, renewable energy, energy storage technology and other emerging fields, the structure and operation mode of energy and power system are undergoing profound changes [4]. These changes not only bring higher flexibility and efficiency to the system, but also bring new stability and security challenges [5]. Therefore, the purpose of this study is to deeply analyze and optimize the stability of energy power system by introducing advanced control strategy, so as to provide theoretical support and practical guidance for the safe and efficient operation of the system.

2. Theoretical basis

2.1. Overview of stability of energy power system

The stability of energy power system refers to the ability of the system to maintain or restore to the original operating state after external disturbance [6]. Stability is the basic requirement of system operation, and it is also an important prerequisite to ensure the reliability and security of power supply. According to the nature of disturbance and the response characteristics of the system, the stability of energy power system can be divided into static stability, dynamic stability and transient stability.

Static stability mainly focuses on the stability performance of the system near the equilibrium point, that is, whether the system can automatically recover to the equilibrium point after small disturbance [7]. Dynamic stability focuses on the long-term behavior of the system after large disturbance, including oscillation and instability of the system. Transient stability mainly focuses on the short-term behavior of the system after sudden large disturbance, and whether the system can return to a stable state in a short time.

In order to ensure the stability of energy power system, a series of control measures and strategies are needed [8]. The traditional control strategy is mainly based on linearization model and local feedback control, but in the face of complex and changeable system operating environment and diversified energy access, it has gradually revealed its limitations [9]. Therefore, the introduction of advanced control strategy is of great practical significance for improving the stability of the system.

2.2. Introduction of advanced control strategy

Advanced control strategy refers to control methods and technologies with higher performance, stronger adaptability and wider application range compared with traditional control strategy [10]. In the energy and power system, the application of advanced control strategy is mainly reflected in the following aspects:

(1) Intelligent control strategy: Intelligent control is a control method based on artificial intelligence and machine learning, which has the characteristics of self-learning, self-adaptation and self-optimization. In the energy and power system, intelligent control strategy can be applied to load forecasting, fault diagnosis, optimal scheduling and other links to improve the operating efficiency and stability of the system.

(2) Robust control strategy: Robust control is a control method for system uncertainty and interference, aiming at designing a controller with certain robustness, so that the system can still maintain stable performance in the face of uncertainty and interference. In energy power system, robust control strategy can be applied to restrain system oscillation and improve transient stability.

3. Methodology

3.1. Stability analysis method

In the energy and power system, stability analysis plays an important role, which is the key link to evaluate whether the system can effectively maintain or quickly recover to the scheduled operating state after external disturbance. In view of the complexity of the system and the potential operational risks, the traditional stability analysis methods may be inadequate in some scenarios. Therefore, this paper innovatively introduces NN (Neural network) model to predict and classify the stability of the system more comprehensively and accurately. In this paper, a complex nonlinear function is used to represent neurons:

$$z(x) = f\left(\sum_{i=1}^{D} w_i x_i + w_0\right) \tag{1}$$

Where $\{x_i\}_{i=1}^{D}$ is the input, $\{w_i\}_{i=0}^{D}$ is the weight coefficient of neurons to be trained, and z is the output. The formula of NN model for stability prediction is as follows:

$$F_{NN}(x) = \sigma\left(\sum_{i=1}^{n} w_i \cdot x_i + b\right) \tag{2}$$

Where F_{NN} is the output of NN, x is the input feature vector, σ is the activation function, and w_i and b are the weights and offsets respectively.

NN model, with its powerful nonlinear mapping ability and self-learning ability, shows unique advantages in dealing with the stability analysis of complex systems. By constructing an appropriate NN structure and training it with historical operation data, the model can learn the internal relationship between system stability and various influencing factors. On this basis, the model can predict the stability of the system in real time and provide valuable decision support for operators.

In addition, this paper further explores the application of reinforcement learning in the optimization of stability control strategy of energy power system. As a trial-and-error learning method, reinforcement learning learns the optimal control strategy through interaction with the environment. In this paper, the adaptive optimization of control strategy can be realized by combining reinforcement learning algorithm with the stability control problem of energy power system. Through constant trial and adjustment, the reinforcement learning algorithm can find an optimal control strategy, which makes the system maintain good stability in the face of various disturbances.

3.2. Optimization method based on advanced control strategy

The optimization method based on advanced control strategy is one of the core contents of this study. Aiming at the stability problem of energy power system, this paper puts forward the following optimization methods based on advanced control strategy: (1) MPC (Model Predictive Control): MPC is an optimization control method based on system model, which obtains the optimal control input at the current moment by solving an optimization problem in a finite time domain online. In this study, MPC method will be used to design the stability optimization controller of energy and power system, so as to realize real-time optimization and control of system stability. (2) Robust optimal control: Considering the uncertainties and interference factors in the energy and power system, this study will adopt robust optimal control method to design a stability optimal controller with certain robustness. By introducing robust performance index and constraint conditions, the controller can still maintain excellent performance in the face of uncertainty and interference. (3) Distributed collaborative optimization control: For distributed energy power system, this study will adopt distributed collaborative optimization control method to realize collaborative work and information sharing among multiple controllers. By constructing a distributed optimization model and solving it by using a distributed algorithm, the overall performance of the system is optimized and improved.

If the system shows strong nonlinear characteristics and is disturbed by many uncertain factors, this paper will choose the robust optimal control method to ensure the stability of the system in all cases. If the system needs to respond to external changes quickly and has strict real-time requirements, MPC is a better choice because it can solve optimization problems online and adjust control strategies in real time. In this paper, according to the specific system characteristics and analysis requirements, the appropriate method is selected for stability analysis, and accurate stability evaluation results are provided for subsequent optimization methods.

4. Simulation experiment

In order to verify the effectiveness and superiority of the proposed stability optimization method based on advanced control strategy, corresponding simulation experiments are designed. The main steps of experimental design are as follows:

(1) System modeling and parameter setting: According to the research objectives and experimental requirements, the detailed mathematical model of the energy and power system is constructed, and the corresponding system parameters and operating conditions are set. Ensure that the model can accurately reflect the dynamic characteristics and stability of the actual system.

(2) Design and implementation of controller: According to the selected optimization method, design and implement the corresponding stability optimization controller. Ensure that the controller can meet the experimental requirements and has good performance and stability.

(3) Simulation scenarios and disturbance settings: In order to comprehensively evaluate the performance and stability optimization effect of the controller, various simulation scenarios and disturbance conditions are designed. Including different types and amplitudes of load disturbance, fault disturbance and renewable energy access scenarios.

(4) Data acquisition and processing: During the simulation experiment, collect and record the key operation data and performance indicators of the system. Including voltage, frequency, power and other electrical quantities, as well as the output signal of the controller. The collected data are processed and analyzed to evaluate the performance and stability optimization effect of the controller.

By comparing the system stability index and dynamic response curve before and after the simulation experiment, the improvement effect of the proposed optimization method on the system stability is evaluated. Figure 1 shows the dynamic response curve of the system. Figure 2 shows the stability of the system.

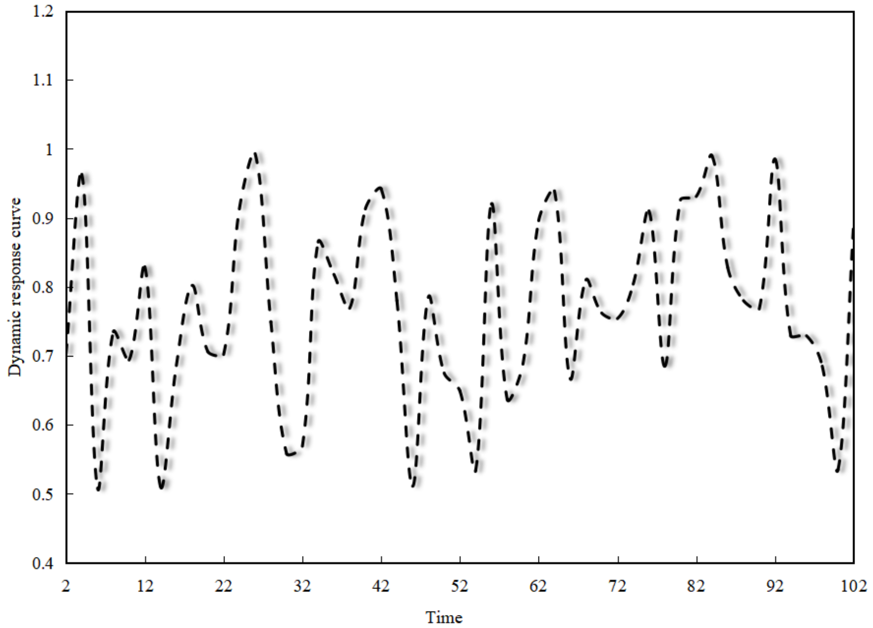

Figure 1: Dynamic response curve of the system

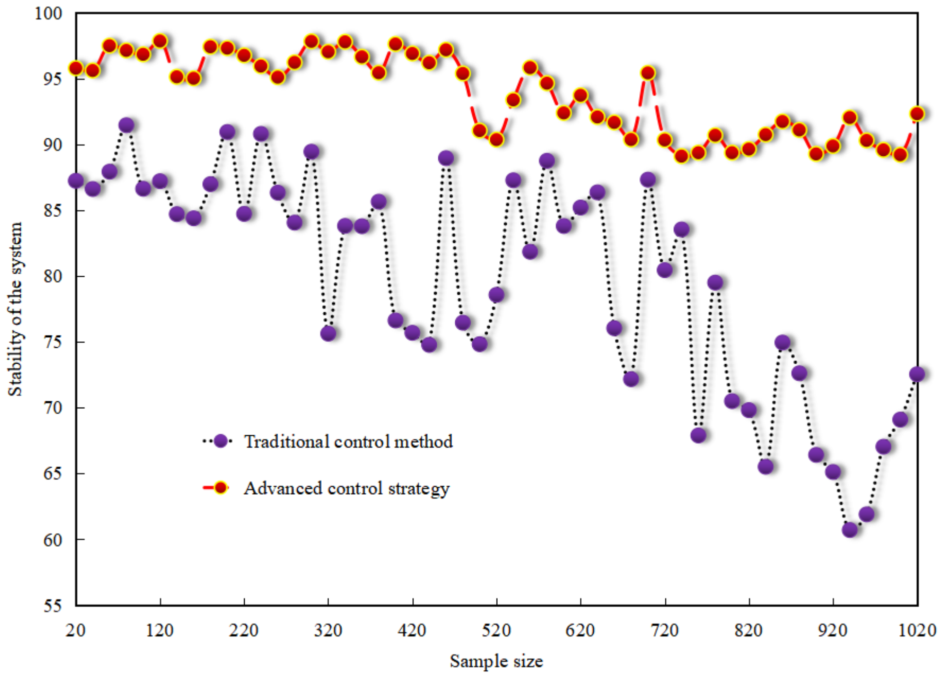

Figure 2: The stability of the system

This section verifies the effectiveness of the proposed stability optimization method based on advanced control strategy, and provides useful reference for the safe and stable operation of the actual energy power system.

5. Conclusions

Aiming at the stability of energy power system, this paper deeply discusses the application and optimization method of advanced control strategy in it. Through theoretical analysis and simulation experiments, this paper draws the following main conclusions:

First of all, advanced control strategy has important application value in the stability analysis and optimization of energy power system. Compared with traditional control methods, advanced control strategy can better adapt to the complex and changeable system operating environment and diverse energy access requirements, and significantly improve the stability and security of the system.

Secondly, the stability optimization method based on advanced control strategy proposed in this study has achieved remarkable results in practical application. The simulation results show that these methods can effectively reduce the oscillation amplitude of the system, shorten the recovery time and improve the system's resistance to external disturbances.

Finally, this study provides useful theoretical support and practical guidance for the safe and efficient operation of energy and power systems. By introducing advanced control strategy, it not only enriches the analysis method and optimization theory of energy power system stability, but also provides useful reference for the operation and maintenance of the actual system.

With the continuous development and reform of energy and power system, new stability and security challenges will emerge constantly. Future research can focus on the application potential of emerging technologies in the stability analysis and optimization of energy and power systems, and explore more efficient and intelligent stability control methods and strategies. At the same time, strengthen interdisciplinary cooperation and exchanges to jointly promote the in-depth development of energy and power system stability research.

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