Study on the Impact of Renewable Energy Power Generation Transient Characteristics on System Stability in Weak Grid

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Abstract. With the large-mound access of renewable energy to the electric power grid, the unique seasonal and day and night output fluctuation of renewable energy power generation has brought new challenges to the stable and safe operation of the power system. These challenges mainly include the impact on power grid voltage stability, frequency stability and power angle stability. Therefore, the impact of renewable energy power generation on the stable and safe operation of power system should be be paid enough attention. Due to the characteristics of long-distance, large-scale and high concentration of grid connected renewable energy, the ability of AC system to connect to power grid is relatively weak, which is a typical weak current network. With the continuous expansion of renewable energy grid connection scale, the dynamic characteristics of weak current power grid become more complex, which brings great challenges to the stability and security of power grid. However, in the calculation of power system security and stability, more conservative renewable energy generation model parameters are often used to fix the power grid operation reliability. For better improve the renewable energy acceptance capacity of the system, the proportion of renewable power generation will be further increased. Therefore, establishing an accurate and reasonable renewable energy model is the basis of large-scale renewable energy grid connection security and stability calculation. Further study on the control strategy and parameter adaptability of renewable energy model could be reduced stability risk of high proportion of renewable energy connected to weak current network.

1. Introduction

In December 2016, the "Energy Production and Consumption Revolution Strategy (2016-2030)" issued by the National Development and Reform Commission and the National Energy Administration clearly stated that by 2030, in total power generation, the non-fossil energy power generation proportion will be reached 50%. Correspondingly, the primary energy of the power system would be undergo tremendous changes, and the consumption of growing renewable energy will become one of the very important main goals of power system operation in China. In October 2018, the National Development and Reform Commission and the National Energy Administration issued "Clean Energy Consumption Action Plan (2018-2020)". A clear goal for clean energy consumption was established: by 2020, ensure that the light rate is less than 5%. Since 2010, renewable energy industry has experienced explosive growth in China, with cumulative installed capacity ranking first in the world for many years and maintaining a strong momentum of development. However, as large mount renewable energy is connected to the power grid, the seasonal, day and night power output volatility
unique to renewable energy power generation itself has brought new challenges to the stable and safe operation of the power system. These challenges mainly include the impact on voltage stability, power grid frequency stability, and power angle stability. Therefore, the impact of renewable energy power generation on the stable and safe operation of the power system requires sufficient attention.

The northwest region has unique resources and vast land resources. In recent years, large-scale centralized renewable energy has been connected to the grid, and the grid load is mainly concentrated in the eastern region, making it difficult to absorb renewable energy locally. For the load demand meeting in the eastern region, power transmission of long-distance and centralized has become the main development mode of renewable power generation in the northwest. As the grid-connected renewable energy presents the characteristics of long-distance, large-scale, and high concentration, the AC system connected to the grid is relatively weak, which is a typical weak grid. As the increasing number of grid connection of renewable energy, the dynamic characteristics of weak power grids become more complex, which poses huge challenges to the stability and security of power grids. Power system security and stability calculations could reflect the degree interaction between the power grid and renewable energy generation under different kinds of operating conditions, and are the basis for rationally formulating grid operation and dispatching control strategies and ensuring the safe and stable operation of the grid under the condition of large mount renewable energy generation access. Among them, accurate renewable energy power generation models and parameters are the key to the stability and safety calculation of the power grid. However, when carrying out power system security and stability calculations, more conservative parameters of renewable energy generation models are often used to ensure the power grid operation reliability. For the renewable energy absorption capacity improvement, the proportion of renewable energy generation will be further increased. Therefore, the renewable energy generation control characteristics will have an important impact on the stability of the grid. Unreasonable renewable energy power generation control strategies are not only not conducive to the elimination of faults, but also cause chain disconnection and expand the scope of accidents. Therefore, the establishment of an accurate and reasonable renewable energy model is the basis for the safety and stability calculation of the power grid with large-scale renewable energy connection. In-depth research on the control strategy and parameter adaptability of the renewable energy model could reduce the stability risk of large mount of renewable energy access to the weak system.

2. Development of Research Work in the World
In the world, the study on the grid-connected control characteristics of renewable energy generation is still mostly at the level of grid operation agencies or research institutes to formulate grid-connected standards. The design and self-control of renewable energy grid-connected equipment is aimed at meeting the grid-connected standards. For meet the operating conditions of different power grids, the current grid operation agencies have relatively broad grid connection standards for renewable energy power generation, and they have not taken full advantage of the rapid characteristics of renewable power stations controlling to improve the dynamic characteristics of the power system.

2.1. Renewable Energy Generation Fault Ride-through
When the voltage drops for some reasons in the power grid, the renewable energy system can maintain the grid-connected state and operate normally, and support the restoration of the grid voltage to the normal value. This transition technology in the low-voltage area is the low-voltage renewable energy fault ride-through technology (LVRT). Most of the study on the LVRT characteristics of renewable energy is carried out from the perspective of the operating characteristics of inverters or renewable energy power stations. Literature [1] studied the LVRT control strategy of the inverter. The control strategy switched in real time at different stages, limiting the injecting the reactive current and active current during the fault. Literature [2] derives the calculation formula of the inverter's steady-state short-circuit current according to the power control target. Literature [3] analyzed the premise and applicability of using a
steady-state fault current model to equivalently replace renewable energy sources. Most of the related researches on the grid-connected inverters stability are based on detailed state-space models, using related control theories for analysis. Literature [4] established a small signal model for the parallel system of two units with renewable energy power generation, and analyzed the influence of the power grid strength, the operating conditions of each unit with renewable energy power generation, and the parameters of the phase-locked loop controller of each inverter on the system stability o. Literature [5] focused on the interaction between the inverter's output impedance and the grid equivalent impedance, and the model of impedance analysis is established, the purpose of obtaining a simple impedance stability criterion is realized. Literature [6] established a single-phase LCL grid-connected inverter model with a phase-locked loop small-signal, and deduced the grid-connected inverter stability criterion.

2.2. Renewable Energy Generation under Weak Grid Conditions

The research of renewable energy generation control strategy is carried out on the basis of strong power grid. In fact, large-scale renewable energy power generation areas and load centers mainly adopt long-distance and long-distance transmission methods.

In the case of a high proportion of renewable energy connected to the weak grid, because the coupling of the inverter and the grid [7], the influence of the inverter control link on the stable and safe operation of the power grid is different. The research on analyzing the operating characteristics of renewable energy power generation in weak power grid conditions is mostly based on the analysis of control theory, and it is roughly concluded that the grid-connected inverter stability decreases as the decrease of the access point system short-circuit ratio [8]. Literature [9] shown that the control parameters of the phase-locked loop in the weak grid have an effect on the stability of the system. Literature [10] pointed out that the hysteresis adjustment characteristic of the AC voltage outer loop leads to the formation of negative damping in the DC voltage outer loop, which deteriorates the stability of the system.

2.3. Stable Power System with DC

Literature [11] studies and analyzes the relationship between the coupling admittance between inverter stations of the DC transmission system with multi-infeed and whether each inverter station will fail to commutate simultaneously or successively. Literature [12] uses the multi-infeed interaction factor as the criterion to analyze whether the DC system with multi-infeed would fail to commutation at the same time. Literature [13] derives the critical impedance boundary for simultaneous commutation failure of multiple feed-in systems at the base of node voltage interaction factor. The research on multi-infeed systems simultaneous commutation failure is mostly based on interaction factors with multi-infeed and short-circuit ratio indicators.

However, most of this analysis only considers the voltage amplitude drop influence on the commutation failure, and is generally verified at the base of electromechanical quasi-steady-state simulation program, and the results are biased towards idealization. In addition to the voltage drop, the main factors that could affect the commutation failure of the DC system include the distortion of the commutation voltage waveform and the commutation voltage phase angle forward shift [14].

3. Key Technology

The key technology is shown in figure 1.
3.1. Differences in Short-circuit Ratios of Weak Grids with Different Proportions of Renewable Energy and their Impact on Transient Stability

It is necessary to adjust various operating modes such as the proportion of different renewable energy sources and different loads to provide a basis for adaptability analysis for the optimization method of renewable energy power generation parameters. However, due to the poor stability of the weak power system grid, it is difficult to find a weak power system grid under multiple operating modes, as shown in figure 2.

3.2. Influence of Fault Ride Through Control Parameters of Renewable Energy Generation on the Transient Stability of Weak Grid Voltage, Frequency and Power Angle and Its Correlation

- Establish a weak grid model with renewable energy generation and conventional synchronous generators
- Comparative study of the difference in short-circuit ratio of weak grids with different renewable energy proportions
- Study the impact of different renewable energy generation ratios on the transient stability of weak power system grids
• Comparative study of the impact of key parameters of the renewable energy model low voltage ride through on the voltage, frequency, and power angle transient stability of a weak grid containing a large mount of renewable energy
• Analyze the correlation between key parameters and voltage, frequency, and power angle

3.3. Renewable Energy Generation Fault Ride-through Parameter Optimization to Meet the Stable Demand of a Large Mount of Renewable Energy Access to the Weak Grid
It is required to combine the characteristics of different operation modes of weak grids, extract the low voltage ride-through parameters of renewable energy that have obvious influences on the power grid transient stability, and analyze their correlations to obtain conclusions applicable to different operation modes.
• Analyze the correlation between the fault ride-through parameters of renewable energy power generation and the safe and stable operation of the weak power grid based on the stability of renewable energy connect to the weak grid
• Study on the optimization method of renewable energy power generation parameters that adapt to the stable demand of a large mount of renewable energy access to the weak grid
• Study the adaptability of renewable energy generation parameter optimization methods to the stable and safe operation of the power system grid in weak grids with different short-circuit ratios

The research plan will adopt the technical route that combines theoretical analysis and simulation calculation, carry out theoretical research on the basis of simulation analysis, and apply simulation calculation for theoretical verification. According to the analysis result, formulate the control strategy optimization method of the renewable energy model and apply it to the simulation calculation. In the process of continuous verification and analysis, the optimization method of low-throughput control parameters of renewable energy power generation is gradually optimized.

4. Conclusion
To sum up, the current domestic and foreign research on the fault ride-through control of renewable energy power generation is mainly considered from the perspective of power station operation, and does not involve the power grid transient stability requirements. Renewable energy generation parameter optimization method. There are only a few studies on the impact of renewable energy generation control strategies on the transient stability of the grid. Considering that the large-scale renewable energy access to the grid in China is mostly a weak grid, the research in this area is not sufficient. Therefore, there is an urgent need to study the control strategy and parameter optimization of renewable energy power plants in actual power grids, considering the characteristics and operation modes of weak power grids. Based on the influence and correlation of key parameters of renewable energy generation fault ride-through control on the transient stability of weak grids, this thesis conducts a research on the optimization of renewable energy fault ride-through parameters for a large mount of renewable energy connected to the weak grid. Research on the optimization method of renewable energy power generation parameters that adapt to the stable demand of a large mount of renewable energy connected to the weak grid can effectively solve the problem of weak grid stability when a large mount of renewable energy is connected. It could improve the power grid transient stability and provide theoretical support for solving the problem of renewable energy consumption. It has a strong forward-looking and technologically advanced nature.

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