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Research on Intelligent Microgrid and its Reliable Grid Connection

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Abstract: This paper provides an overview of operating characteristics of distributed generation, microgrid, and smart grid. Through the analysis of the basic theory of the microgrid system in grid connection, several requirements for reliable grid connection are proposed. Using matlab to model the microgrid system containing photovoltaic and wind power models, and by emulating the reliability standards of the microgrid and large-grid power grid, the power electronics equipment, power quality and control strategies were implemented for the microgrid system and the external power grid. The basic requirements for reliable grid connection. The simulation analysis results of this example system can be used as a theoretical reference to realize the reliable grid connection of the microgrid system.
Keywords: Smart microgrid, Grid-connected microgrid.

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1. INTRODUCTION

As countries around the world have included energy conservation and emission reduction in their national development strategies, research on distributed generation, microgrids and smart grids is also increasingly hot. At present, distributed generation technologies, micro-grid technologies, and smart distribution network technologies are at different levels of development. Distributed generation technologies are relatively mature and their applications are gradually expanding.

However, the bottleneck that affects the development of distributed power supply is not its own technology, but the safe and reliable grid-connected operation; micro-grid technology plays an important role in the connection between distributed energy generation and smart grid and is a reliable type of smart grid. The goal of the smart grid is to realize the intelligence of the power system so that the distributed microgrid can achieve high penetration and reliability access in large-scale power systems.

The paper introduces the characteristics, successful cases and basic operating characteristics of distributed power supply and microgrid. From the perspective of reliable grid-connected power supply, the theoretical grid-connected requirements were researched and studied. Simulations of isolated networks and grids in the microgrid were performed through matlab. The distributed power supply, microgrid isolated network, and grid-connected operation were simulated.

2. DISTRIBUTED GENERATION AND INTELLIGENT MICROGRID

2.1 Distributed generation and its operating characteristics

Distributed power supply refers to a small-sized (capacity less than 50MW) power supply to the local load and can be directly connected to the power distribution network. It includes distributed generation devices and distributed energy storage devices. Relatively small distributed power generation devices are usually within a few hundred kilowatts, and larger distributed energy storage devices can reach megawatts. However, distributed power supplies often have intermittent and random characteristics due to their own nature, such as relatively mature technologies such as wind power generation and photovoltaic power generation. Therefore, often with a certain amount of energy storage device to ensure the stability of the system, at the same time, the appropriate amount of energy storage can be in the DG unit can’t function properly under the transition.

2.2 Intelligent microgrid and its operating characteristics

Microgrid is a small-scale power generation and distribution system that is composed of distributed power sources, energy storage devices, energy conversion devices, related loads, and monitoring and protection devices. It is an autonomous system capable of self-control, protection, and management. The external grid is connected to the grid and can also be run in isolation. From the microscopic point of view: micro-net is a small self-sufficient system, which can realize the scheduling and distribution of self-energy and can also realize its own balance and energy optimization with the help of grid connection. From a macro perspective: The microgrid is equivalent to a P+jQ load in the grid system, where:

$$P + jQ = \sum_{i=0}^{\infty}(U_i * I_i)\,, \quad P \in (a,b), Q \in (c,d) \tag{1}$$

Where i is the number of system equivalent loads; Ui, Ii are the voltage and current in the reference direction of node i respectively; P and Q are the active and reactive power of the system; and intervals (a, b) (c, d) are the energy supply interval for the sum of active and reactive power vectors between the distributed power supply and load in the microgrid.

From the above, we can see that the micro-grid can not only be regarded as a small load, but also can be regarded as the equivalent combination of the grid-connected micro-power supply, with bidirectional mobility of power. However, the active power of most distributed power sources has characteristics of random changes, such as: random changes in wind power output active power with wind speed, photovoltaic solar power output power and solar light intensity. Therefore, the power fluctuation of the microgrid is more severe than that of the large power grid and brings more uncertainties to the reactive power optimization of the power grid itself.

3. SMART MICROGRID RELIABILITY AND GRID

With the widespread use of power electronic devices, harmonic pollution has become more and more serious. In addition, the random power generation and power supply uncertainty of distributed power generation have also directly led to the existence of harmonics in microgrids. The existence of a large number of harmonics will directly affect the reliability of the power after grid connection and the reliable power supply of the internal microgrid. Solving the internal harmonics of the smart microgrid is critical to achieving reliable grid-connection. The intelligent distribution network self-healing control technology has become an important method to improve the power supply reliability and safety of distribution networks, resist chain failures and large-scale power outages, solve a large number of distributed power access, and is an effective method to solve this problem.

Before grid-connected, it is difficult to adjust the frequency, voltage and phase angle of two independent systems to be completely consistent. Therefore, it is necessary to study what kind of relationship the two meets to achieve the most reliable and safe grid connection. To achieve smooth, seamless switching of voltage and frequency.

$$U_\Delta = U_1 \sin(\omega_1 t + \varphi_1) - U_2 \sin(\omega_2 t + \varphi_2) \tag{2}$$

Where $\omega_1 = 2\pi f_1, \omega_2 = 2\pi f_2$

Convert (2) to get

$$U_\Delta = 2U_1 \sin\frac{(\omega_1 - \omega_2)t + (\varphi_1 - \varphi_2)}{2} \times \cos\frac{(\omega_1 + \omega_2)t + (\varphi_1 + \varphi_2)}{2} \tag{3}$$

Let

$$U_k = 2U_1 \sin\frac{(\omega_1 - \omega_2)t + (\varphi_1 - \varphi_2)}{2} = 2U_1 \sin(\frac{\alpha t}{2} + \frac{\beta t}{2}) \tag{4}$$

Where α is the slip angular frequency, $\alpha = \omega 1 - \omega 2$; β is the initial phase difference, $\beta = \varphi 1 - \varphi 2$. Then formula (3) is expressed as

$$U_\Delta = U_k \times \cos\frac{(\omega_1 + \omega_2)t + (\varphi_1 + \varphi_2)}{2} \tag{5}$$

Confined to the interaction mechanism between microgrids and distribution networks and various types of distributed power within the microgrid, the authors used simulation analysis to reveal the reliability requirements of the microgrid and improved the power quality of the microgrid, and then proposed the criteria for grid connection.

4. SIMULATION ANALYSIS

4.1 Model introduction

Power system simulation software matlab modeling and simulation of small models. The structure of a 0.4kV low voltage system for a 20kV medium voltage distribution network and a low voltage microgrid in an external power grid is shown in Figure 3. The photovoltaic power generation can be regarded as a system consisting of a current source, nonlinear impedance, and load resistance. Intensity, battery temperature and so on all can change the voltage, current and power of solar panels; wind power can be divided into three parts: wind speed module, wind turbine and speed governor module; when isolated network is running, energy storage elements need to be added inside the microgrid to ensure the rapid balance between electrical energy.

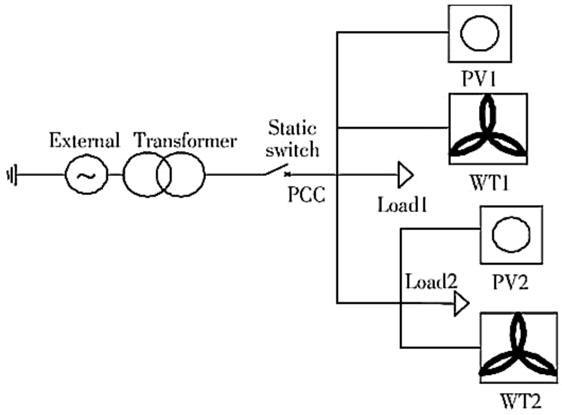

Fig. 1 Microgrid system for simulation

The microgrid is connected to the node of the medium voltage main power grid through a 20kV/0.4kV transformer and a circuit breaker is connected between the transformer and the PCC. The example is an AC microgrid. All DGs and loads are three-phase. The three-phase asymmetry is not considered in the simulation. When the external power grid fails, the corresponding PCC node's grid-connected circuit breaker detects the drop of the system frequency and voltage, and along with the abnormal flow of fault current, the circuit breaker moves in time, and the microgrid internally adopts a reasonable control strategy. Makes the smooth and stable transition of the micro-grid to ensure the safe and stable power supply of the large power grid and micro-grid.

4.2 Simulation analysis

Take the example system shown in Figure 1 as an example, perform the simulation of the isolated network and grid-connected operation respectively.

1) In the grid-connected state, the impact of the three-phase short-circuit fault on the interior of the microgrid is shown in Figure 2. It can be seen from the short-circuit fault that a long period of low voltage after a short-circuit fault will have a very negative impact on the internal load of the micro-grid. Therefore, sufficient measures must be taken within the microgrid to cope with the prolonged low voltage phenomenon that occurs due to a short-circuit fault.

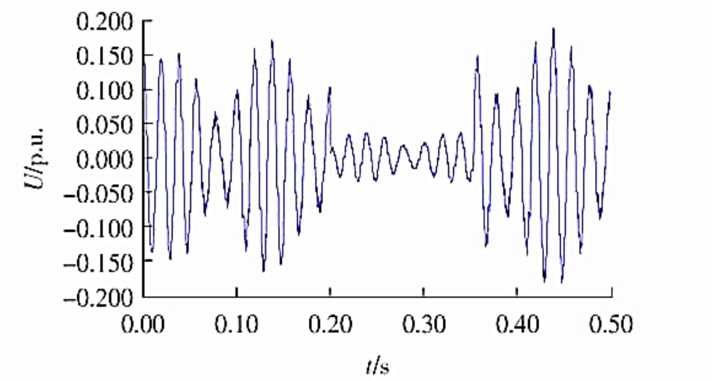

Fig. 2 Post-fault voltage curve with short-circuit fault

2) According to the IEEE 1547 standard, the frequency and voltage within the microgrid must satisfy a certain range, in which the frequency amplitude exceeds 0.5Hz, the voltage change amplitude exceeds 5%, and the duration does not exceed 0.15s. Change the internal line reactance of the microgrid before grid-connecting to change the voltage to the microgrid and perform simulation analysis. The simulation curve is shown in Figure 3 and Figure 4.

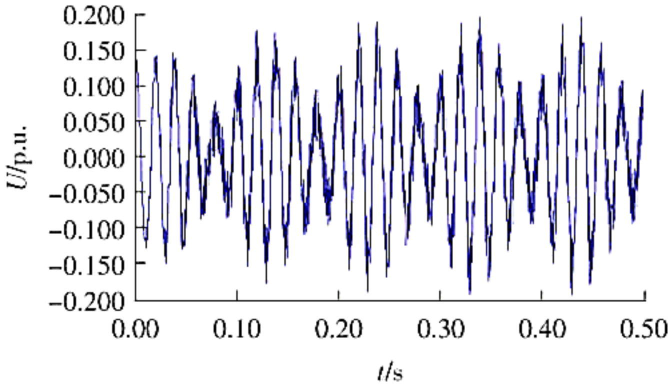

Fig. 3 Voltage curve with larger voltage difference

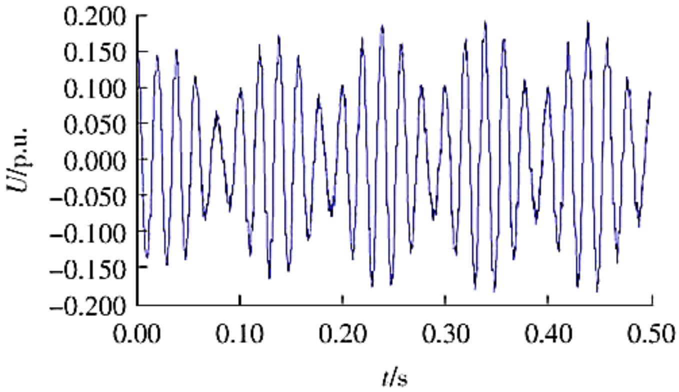

Fig. 4 Voltage curve with smaller voltage difference

5. CONCLUSION

1. For micro-grid systems, the volatility and randomness may have a strong impact. Therefore, appropriate control strategies are needed to meet the external power supply requirements.
2. In the microgrid-connected system, if a short-circuit fault occurs, the impact of the short-circuit on the parameters of the microgrid and the large power grid must be dealt with in a timely manner, and appropriate relay protection measures should be taken.

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