Research and application of low voltage ride through capability of wind turbines in microgrid

Guanglei Li1*, Shuai Yuan2, Fei Jin3, Xiaoliang Liu3 and Peng Zhao1

1 State Grid Shandong Electric Power Research Institute, Jinan, Shandong Province, 25002, China
2 State Grid Shandong Electric Power Company, Jinan, Shandong Province, 25001, China
3 State Grid Weifang Power Supply Company, Weifang, Shandong Province, 261002, China
*Corresponding author’s e-mail: lovexjtulgl@126.com

Abstract. In order to adapt to the stable operation of microgrid operating conditions, asynchronous constant speed wind turbines need to have low voltage ride through capability. For the characteristics of a certain type of asynchronous wind turbine, the technical control of full-power back-to-back converter is proposed. The machine-side converter stabilizes the stator voltage, the grid-side converter stabilizes the DC bus voltage and controls the active and reactive decoupling. The 750 kW wind turbine simulation model is established in MATLAB/Simulink, and the rectified unit is field tested and verified to have low voltage ride through capability.

1. Introduction

In recent years, wind power generation has developed rapidly in the world, and the single-machine capacity has grown from hundreds of kilowatts to the current mainstream megawatt-class units[1]. With the development of wind power technology, in addition to large-scale development of wind power, wind power development presents the characteristics of miniaturization and miniaturization, especially in the application of wind power in microgrid[2].

As a small power system, microgrid has complete modules of generation, transmission, distribution and utilization, which can achieve power balance and energy optimization[3]. Existing research and practice show that wind power can be connected to the grid in the form of micro-grid, which can support each other with the grid[4]. This is an effective way to exert the efficiency of decentralized wind power, and is helpful for the continuous supply of power to important loads during power grid catastrophe.

The low voltage ride through capability of wind turbines is the most important basis for wind farms to achieve low voltage ride through. The fixed-speed asynchronous wind turbine itself does not have low voltage ride-through capability[5]. When the grid voltage drops, the wind turbine is disconnected from the network for its own protection. This has a negative impact on the safe and stable operation of the microgrid.

In view of the construction of the microgrid project, the asynchronous wind turbines operating in the island need to actively adapt to the functional requirements of the microgrid[6]. When wind turbines of this type are included in the microgrid system, it is difficult for wind turbines to realize...
low-voltage crossing and reactive power support to the grid during low-voltage crossing, which affects the stability of the isolated microgrid operation, and in serious cases leads to the collapse of the microgrid system and the damage of power equipment\cite{7}. Therefore, in order to ensure the reliable operation of the microgrid, it is necessary to reform the induction wind turbine to realize the reactive power and voltage support capability of the wind turbine.

2. Transformation plan

As an important power supply in the island, the changdao microgrid have great significance to ensure the high quality of power supply in the island. In changdao microgrid, the proportion of wind power installed is 75%. The grid-connected operation of wind power needs to absorb a large amount of reactive power from the grid side, which leads to inadequate reactive power capacity and difficulty in voltage regulation\cite{8}. In addition, the early wind turbines can not actively regulate the power. When the wind power fluctuates rapidly, it will easily lead to power oscillation and system disintegration in the microgrid\cite{9}\cite{10}.

In order to ensure the voltage stability of microgrid, the wind turbine needs to be reformed to add low voltage traversal and reactive power support module\cite{11}. In this paper, the wind turbine modification scheme based on full power converter is adopted, as shown in figure 1 below. Full power converter is mainly composed of four parts: grid-side converter, machine-side converter, DC discharge circuit and bypass switch. After using the full power converter, the generator stator is connected with the output of the machine side converter, so that the machine side converter can stabilize the output voltage. When the voltage on the grid side drops, the current passes through the grid side converter and the DC discharge circuit. According to the requirements of low voltage traversing control, the transformed wind turbine generates reactive current to support reactive power and maintain the voltage stability of DC bus. This control strategy will stabilize the voltage at the stator end of the generator and will not cause the motor to be disconnected.

According to the above analysis, the asynchronous constant speed wind turbines in Changdao microgrid are revamped. The rated capacity of the wind turbine is 750 kW. Considering the overload capacity of 1.1 times, combined with the influence of reactive excitation current, disturbance resistance of full power converter and stability margin, this paper chooses the weighting coefficient of 1.5 times. Therefore, the design capacity range of the full power converter is about 750 x 1.1 x 1.5 = 1237 kW, and the capacity of the final selected full power converter is 1.5 MVA.

![Diagram](image)

Figure 1. Low-voltage traversal scheme topology using full-power converter

3. Simulation analysis

Changdao Microgrid is mainly composed of wind turbine, diesel generator, power load and so on. Aiming at the modified wind turbine model, the simulation model of 750kW asynchronous wind turbine and 1.5MVA full power converter is established by using MATLAB/Simulink. In the simulation modeling, the wind turbine parameters are set as follows: the rated voltage of the asynchronous generator is 690V, the rated current is 628A, and the rated torque is 4712N.m. At the same time, the operation parameters of the full power converter are set as follows: the rated voltage of DC bus is 1100V, the DC capacitor is 28.2mF, the discharge resistance is 1.6, and the rated output voltage of the machine side converter is 690V.
With the addition of full power converter, the microgrid does not need additional reactive power compensation equipment when the microgrid is in normal operation. This solves the problem that the squirrel cage asynchronous generator must absorb a large amount of reactive power from the grid when it is connected to the grid. At the same time, wind turbines can emit or absorb certain reactive power, which can flexibly participate in the power regulation of microgrid. According to the requirements of operation conditions, when the full power converter with wind turbine runs, this paper gives 500 KVar reactive power instructions to the converter network side. Then after 0.06s, the actual output reactive power can track the given instructions. The simulation waveforms under this condition are shown in figure 2, figure 3 and figure 4.
For the low voltage traversing process, the simulation time is set to 1 s. At 0.2s, the wind turbines are loaded to full load, and then the three-phase symmetrical voltage drop is 80%. The drop starts at 0.2S and resumes after 625ms.

As shown in figure 4, when the voltage amplitude of the grid begins to drop by 80%, the DC bus will rise. Because of the DC discharge circuit through the converter, the DC bus voltage drops quickly and remains stable. When the voltage amplitude on the grid side falls in the range of 0.2S to 0.825s, the stator voltage and current fluctuate only slightly at the moment of voltage drop and recovery in the 625ms process. In this process, wind turbines can operate normally and achieve the low voltage ride-through.

4. Field test
During the process of microgrid debugging, a low voltage generator is used to simulate the voltage sag of the power grid and verify the low voltage ride-through function of the full power converter. When the full power converter outputs 1MW power, the output three-phase voltage of the low-voltage generator drops to 20% and continues 625ms.

When the output three-phase voltage of the low-voltage generator drops to 20%, the converter does not run off-line and provides reactive power support in the process. In the process of voltage sag in the power grid, the machine-side converter continuously provides energy to the DC bus, while the output power of the network side is limited. At this time, the DC crowbar input restricts the DC bus voltage and releases unbalanced power to protect the converter.

After the 1.5 MVA full power converter is connected between the grid and the generator stator, the induction wind turbine can support the generator stator terminal voltage rapidly in the process of voltage drop. This not only realizes the low voltage traversal function and reactive power support, but also effectively reduces the impact of excitation current during the soft start of the motor. Therefore, this role is particularly important for distributed generation systems and microgrid systems.

As shown in figure 5, when full power converter is not connected, the peak impulse current of 750 kW asynchronous wind turbine is 1.26KA when it is connected to the grid with soft start, which is relatively large.

![Figure 5. Impulse current of wind turbine generator without converter](image)

When the full power converter is not connected, the peak impulse current of 750 kW asynchronous wind turbines connected to the grid is 1.26KA, which is relatively large. When wind turbines are disconnected from bypass switches and connected in series with full power converters, the peak impulse current of grid-connected wind turbines is about 436A, which suppresses the impulse current. The impact on distributed generation system and other devices in microgrid system is effectively reduced.
5. Conclusion
Aiming at the operation control requirements of microgrid, this paper proposes a low voltage traversing modification scheme for 750 kW induction wind turbine. The scheme adopts the improvement measures of full power converter, carries out simulation calculation, and carries out field test under actual operating conditions. The test results verify the validity of the method and the correctness of the control strategy under three-phase symmetrical voltage sags. This scheme can adapt to the stable operation of microgrid, and has important practical significance for ensuring the security and stability of distributed generation and microgrid.

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