PAPER • OPEN ACCESS

Stability Analysis and Optimization of Grid Connected Wind Farm

View the article online for updates and enhancements.

Stability Analysis and Optimization of Grid Connected Wind Farm

Haoran Li[1, *], Changzhi Zhang[1, a], Yi Zhao[1, b], Xiaonan Cao[2, c], Weichen Ni[1, d] and Zhiyong Gan[1, e]

[1]Tianjin Electric Power Science & Research Institution, State Grid Tianjin Electric Power Company, Tianjin 300384, China
[2]State Grid (Tianjin) Integrated Energy Service Co., Ltd., Tianjin 300384, China

*Corresponding author e-mail: lihaoran2011@gmail.com, [a]13920889624@163.com, [b]zhaoyihiss@163.com, [c]15510886610@163.com, [d]13821175295@163.com, [e]13820185826@163.com

Abstract. With the rapid growth of economy, the demand for electricity is increasing. For the purpose of environmental protection, the development of new energy has become an important way. Wind power generation is an important part of the development of new energy power, wind power development has occupied a significant percentage of the grid. This requires full study of the connecting technology of large-scale wind farm to the power grid to ensure the safe and stable operation of the grid. This paper mainly studies the stability and optimization of grid-connected wind farm operation, hoping to help the relevant people.

1. Introduction

With the increasing demand for energy and the enhancement of people's awareness of environmental protection, the new generation mode has attracted the attention of people. Wind power generation has become one of the most important ways of power generation for environmental protection and renewable energy. From a global point of view, developed countries and regions have invested a lot of power in wind power generation, and continue to increase rapidly. Our country has large wind resources, but also a lot of wind power development, but because the wind farms are mostly in remote areas, the grid position is relatively weak, so it causes a grid supporting ability is poor, a serious impact on power quality. In order to ensure access to large scale wind power grid to the safe and stable operation, after the wind farm grid stability control technology and power grid coordinated control technology has become the key content for the grid connected wind farm technology. Therefore, it is very meaningful to fully study the stability and optimal operation of wind farm grid connected operation.

2. Stability analysis of wind farm connected to grid

Because the wind speed and wind power change randomly, the output of the wind farm also has random characteristics, which makes the active and reactive power dispatching of the power grid very difficult. In some situations, such as severe weather, in order to ensure the safety of wind turbine related equipment issues may occur that some wind turbines would be cut off, which brings major damage to the stability of the grid.

2.1. The influence of stability

2.1.1. The influence of static stability. The so-called static stability system refers to the system which after a certain degree of interference can also be restored to the state before interference. The influence of grid-connected wind farm operation on the static stability of power grid is mainly discussed as follows: power angle problem and synchronization problem of wind farm and power system. From the current situation, the wind farms are using variable speed constant frequency generator sets, because this unit can maximize the use of wind energy, with very high wind power utilization coefficient. Doubly fed induction wind generator will drive the coaxial rotation in the initial stage of the power generation. When the rotate speed is close, the speed changer will collect the generator output voltage and the system voltage, and compares the calculated deviation. By controlling the phase and amplitude with converter, the static stability with the synchronization of wind farm and power system is ensured.

2.1.2. Influence of transient stability. If the proportion of wind turbine in the power system is large, it will change the original line transmission power, system inertia, load distribution and so on, which will cause the change of transient stability when the wind farm is connected to the grid. When the regional power grid is relatively weak, the wind turbine can not recover to the original state after the power system fault cleared, which results in the low transient stability of the regional power grid. So in order to ensure the transient stability of power grid wind farms will be cut off from the power grid, which requires the use of dynamic reactive power compensation device, which can ensure the stability of grid voltage in fault recovery and transient process.

2.2. Countermeasures for improving the stability of the operation of the wind farm connected to grid

2.2.1. Effective improvement of power quality. From the present point of view, the compensation device can be used to improve and enhance the power quality, which comprises a static var compensator, active power filter, dynamic voltage restorer and so on, relatively static var compensator technology is relatively mature. These devices can effectively control the reactive power load fluctuations in the grid, thereby suppressing voltage fluctuations and flicker. In addition to the use of compensation devices for power quality improvement, the energy storage device is used to improve the power quality. Energy system and super capacitor energy storage system can solve the power grid voltage fluctuation and flicker, voltage sag problems etc.

2.2.2. Effective optimization of low voltage ride through problem. Mainly through two ways to optimize the low voltage ride through problem, respectively: increase the hardware circuit, optimize the control mode. By increasing the hardware circuit can deal with the fault when the voltage and current excess from the root of the problem, such as increasing the storage device in the power grid, power grid fault can be through the energy storage device will absorb excess voltage and current, can protect against wind turbine. The optimal control mode is only to reduce the excess voltage and current in the grid fault, and cannot be consumed, cannot fundamentally solve the problem.

2.2.3. Effectively improve the stability of power grid. The fast switching capacitor can be used to improve the stability of power system. Because the price of fast switching capacitor is relatively low, it has been widely used. But the problem is that such a capacitor cannot continuously adjust the voltage, and will be affected by the number of switching restrictions, so if the wind speed change more frequently, the speed is not fast transform using the same. The static var compensator can achieve fast reactive power compensation, mainly including dynamic voltage and improving the stability of the system. The static reactive power compensation device is arranged on the wind farm, to power plant voltage and grid voltage acquisition, reactive power compensation through calculating deviation, stable node voltage and lower voltage fluctuation can through this way, so as to improve the stability of power grid. In addition, device can also stabilize power to a certain extent in the wind farm installed storage, superconducting

magnetic energy storage device can also play the role of static reactive compensation device, the deviation of reactive power regulation to ensure the stability of power grid. But the superconducting energy storage device belongs to the active compensation device, compared to the static reactive power compensation device, not so much depends on the access point voltage, especially at low voltage in power grid will play a good role.

3. Optimal operation of wind farm grid connected system

3.1. Research contents of optimal power flow
The optimal power flow mainly combines the economic dispatch and power flow calculation of power system, and realizes the optimization of economy and safety, active power and reactive power by the power flow equation. The problem of optimal power flow is to optimize the system on the basis of the power flow equation and the security, so that the objective function can be optimized. The most commonly used objective function is the minimum generation cost and minimum active power loss of the system. Because the optimal power flow will be involved in the whole system of economy and security, so it can be used in the operation of the power system including:, the safe operation of the power system, power system reliability analysis, economic dispatch, network planning and so on.

3.2. Optimal power flow of wind farm

3.2.1. Minimum network loss. The minimum network loss is the most important index of the economic performance of the power system, and is also the objective function of the traditional optimal power flow. The line loss can be expressed by the lower form:

$$F_1 = \sum_{i=1}^{N} \sum_{j=1}^{N} G_{ij} \left(U_i^2 + U_j^2 - 2 U_i U_j \cos \theta_{ij} \right) \tag{1}$$

F_1 represents the total active power loss; G_{ij} represents the real part of branch admittance; U_i and U_j represent the voltage values of node i and node j; θ_{ij} represents the phase angle difference between node i and node j.

3.2.2. Reduce environmental impact. Compared with the traditional power generation mode, the process of wind power generation is cleaner and environmental protection, it is very meaningful for environmental protection. The wind is in the process of optimization, to meet the needs of power generation and load limit first, on this basis to the greatest extent to reduce the conventional power generation caused by the emission of pollutants can be represented by the following formula:

$$F_2 = \sum_{i=1}^{N_0} \rho_{Eli} G_{Eli} \tag{2}$$

$$s.t. \begin{cases} \sum_{i=1}^{N_0} \rho_{Eli} = 1 \\ 0 \leq \rho_{Eli} \leq 1 \end{cases} \tag{3}$$

Where ρ_{Eli} represents the weight factor of the i pollutant; N_0 is the total number of pollutants; G_{Eli} is the emissions of the i pollutant.

3.3. The improvement of voltage stability
One of the most important problems in the operation of power system is to ensure the stability of voltage. The voltage stability problem belongs to the dynamic aspects of the problem, but can estimate the stable operating point and voltage collapse point between the voltage differences between the static ways, so that we can estimate the voltage range of the stable operation of the system. The static state method can be used to evaluate the current running state of the system by calculating the stability index. The stability

parameters can be minimized by the corresponding calculation so that the stability of the voltage can be improved. The exponential equation can be expressed as:

$$L_{VSI} = \frac{4P_j Z \cos\theta}{[U_i \cos(\theta - \delta)]^2} \quad (4)$$

L_{VSI} is the stability index, which can reflect the operation situation of the transmission line, and can be expressed between stable operating point and voltage collapse critical point distance. $L_{VSI} > 1$ indicates that the system is not stable enough. If the network load exceeds this constraint, the voltage collapse occurs. After considering the network loss, pollutant discharge and voltage stability coefficient, the optimal power flow objective function forms the multi-objective optimal dispatch.

3.4. Constraint issues

In order to ensure that after the wind farm of the electric power system can run safely and stably, the whole power system must have the corresponding constraints, refers to the total power generation capacity of wind power control in the corresponding proportion range. Only in accordance with the constraints in this regard can ensure that the wind power generation grid will not have a greater impact on the waveform of the power line voltage. The proportion of wind power access to comply with the following formula:

$$\sum P_{WTGi} \leq \delta \sum P_{LD} \quad (5)$$

P_{WTGi} is single wind turbine capacity; P_{LD} represents the load of the whole system; δ represents the penetration coefficient of wind power. Therefore, for the multi-objective optimal power flow equations with large wind power plants, it is necessary to consider the equality conditions and inequality conditions in various aspects.

4. Conclusion

Wind power generation is a new form of power generation which is different from traditional power generation. Because of its advantages of environmental protection and renewable, it has been widely recognized all over the world. However, because wind farms are mostly located in remote areas, the access to the grid is relatively fragile, so the power grid supporting capacity is poor, which seriously affects the quality of power. Therefore, through the wind farm grid stability and optimization research can stabilize the operation of the power system, to achieve greater economic benefits, so as to further promote the construction of wind power.

References
[1]   Na Yang, Yan Zhang. Transient stability analysis of grid connected operation system of large scale wind farm [J]. hydroelectric energy science, 2014 (02): 15~17.
[2]   Lin Piao, Liye Zhao. Influence of reactive power in wind farm on grid connected stability [J]. Acta of agricultural engineering, 2015 (09): 18~19.
[3]   Hongjie Jia, Lei Wang. Study on small disturbance stability of power system with large scale wind farm [J]. power system technology, 2015 (10): 88~91.