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A Survey on Problems in Smart Grid with Large Capacity Wind Farm Interconnected

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Abstract

The basic concepts and development of smart grid is described. The influence of large capacity wind farm interconnected on the smart grid is analyzed particularly, following contents are emphatically presented: model of wind farm, basic operation performance, output forecasting of wind farm, power flow in smart grid including wind farm, balance of voltage and reactive power, small disturbance stability, transient stability, faults and reliability, etc., in the hope of offering references for the fast development of smart grids absorbing more capacity of wind power.

Keywords- smart grid;power system;wind farm; stability

1. Introduction

With the rapid development of society, economic and information automation, as with the shortage of resources and the serious environmental pollution ,the development of power system will face the new challenges. Relying on modern communication technology and control technology, developing smart grid have reached a consensus throughout the world. Smart grid is not only the upgrading of the modern electric power network composition, it's the depth reform of the global power industry[1-2].State grid corporations of China with its basic situation and the development of extra high voltage, have set the goal to develop the smart grid, of which is the backbone of extra-high voltage grid . How to effectively solve

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the large-scale renewable energy development, access and long-distance transmission are the key technology to smart grid[3].

Among the renewable energy, wind power is the most mature technology, so large-scale wind power generation access to grid is the inevitable trend. Based on the random and undulant characteristics of wind power generation output, so accessing to grid will influence the stable operation of power system. Some necessary problems of smart grid after large capacity of wind power got accessed is analyzed systematically in this paper, such as the basis of wind farms, the basic operating characteristics of wind farms or the stability of smart grid after wind power accessed.

2. The Basis of Wind Farms

2.1 Modeling of Wind Farms

Actually large-capacity of wind farm often contain dozens, hundreds or even thousands of wind generators. All wind turbines in wind farm could be the equivalent of several or one units which access to the equivalent of wind generators. The premise of equivalent value is to be the same with the equivalent of wind turbine model number and run on the same wind conditions, small deviation of slip in the transient in the generator is allow[4].Wind farm is a complex system involving multi-disciplinary, primarily consist by three parts, such as wind turbines, driving system and generators, as shown in figure 1.

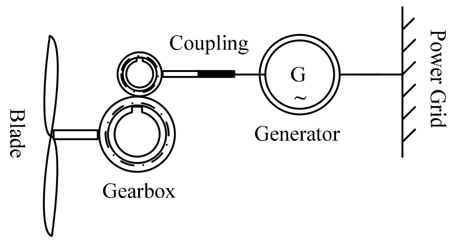

Figure 1. wind turbine model diagrm

1) Wind Turbine Model

Wind turbines get power through the blades and produce certain torque, then wind turbines obtain the wind energy P_M and torque T_M are expressed as:

$$P_M = \begin{cases} 0 & V < V_{in} \\ \frac{1}{2}\rho\pi R^2 V^3 C_P(\lambda,\beta) & V_{in} < V < V_n \\ P_N & V_n < V < V_{out} \\ 0 & V_{out} < V \end{cases} \quad (1)$$

$$T_M = \frac{P_M}{\omega_M / p} \quad (2)$$

There into: P_M signify Wind generator obtain the wind energy, W; T_M signify Wind generator input torque, $N \cdot m$; V signify Wind speed, m/s; V_{in} signify Cut-in wind speed; V_n signify Rated wind speed; V_{out} signify Cut-out wind speed; ρ signify Air density in wind farm, Kg/m^3;R signify Blades radius, m;

C_p signify Power coefficient; λ signify Tip speed ratio, $\lambda = \omega_M R / V$; β signify pitch Angle, ω_M signify Turbine mechanical angular velocity, rad/s.

Power coefficient C_P is a nonlinear function about λ and β, it stands for Wind generator efficiency of absorption of the important parameters of wind energy, according to Betz theory [5],the maximum of C_P is 0.593.

2) Driving System Model

As the two systems is flexible connected ,there is a big difference between wind turbine rotor speed and generator rotor speed , so it needs a certain ratio rise speed gearbox which connected to turbine and generator to make a driving. Therefore the driving system of wind power generation need at least two quality blocks to simulate it. Here, the drive system is equivalent to two quality blocks: one for Wind turbines and low-speed shaft, called turbine quality block; another for generator rotor and high-speed shaft, called generator quality block, the model also known as flexible model of transmission system. Specific mathematical model are as follows [6]:

$$\begin{cases} H_M \dfrac{d\omega_M}{dt} = T_M - K_S\theta_S - D_M\omega_M \\ H_G \dfrac{d\omega_S}{dt} = K_S\theta_S - T_E - D_G\omega_S \\ \dfrac{d\theta_S}{dt} = \omega_0(\omega_M - \omega_S) \end{cases} \tag{3}$$

There into: H_M and H_G signify wind turbines and generator time constant; D_M and D_G signify wind turbine and generator damping coefficient; ω_M , ω_S and ω_0 signify wind turbine rotor angular velocity, wind turbine rotor angular velocity, angular velocity of generator rated; T_M and T_E signify wind turbine mechanical torque and wind turbine torque; K_S signify transmission shaft stiffness coefficient; θ_S signify transmission shaft torsion angle.

3) Wind Generator Model

Wind generators are mainly consist by asynchronous generators with constant speed and doubly-fed induction generators with variable speed and constant frequency in wind powe systems, though the main difference between two models is the different control system, they have the same essentially, In the article, let's take constant speed asynchronous wind generators as an example to establish the mathematical model. When taking account of the rotor windings of electromagnetic transient, please establish three-order model of mathematical model of the asynchronous. In view of the stator electromagnetic transient ,the mathematical model of the asynchronous are as follows [6]:

$$\begin{cases} u_d = -ri_d + x'i_q + E'_d \\ u_q = -ri_q + x'i_d + E'_q \\ T'_0 PE'_d = -E'_d - (x' - x)i_q - 2\pi f_0 s T'_0 E'_q \\ T'_0 PE'_q = -E'_q - (x' - x)i_d - 2\pi f_0 s T'_0 E'_d \end{cases} \tag{4}$$

There into: subscript d signify Direct-axis quantity, subscript q signify Cross-axis quantity; x signify Synchronous reactance; x' signify Transient reactance; T'_0 signify Rotor time constants; s signify Slip induction generator; f_0 signify Standards system frequency.

Equation of motion for the generator rotor:

$$\begin{cases} \dfrac{d\omega}{dt} = \dfrac{1}{T_{\mathrm{j}}}(M_{\mathrm{T}} - M_{\mathrm{E}}) \\ \dfrac{d\delta}{dt} = 2\pi f_0(\omega - 1) \end{cases} \tag{5}$$

There into: M_{T} and M_{E} signify Induction generator mechanical torque and electromagnetic torque($p \cdot u$); T_{j} signify inertia time constant of induction generator (s); ω signify Angular frequency($p \cdot u$); δ signify Power angle(red).

In order to accurately analysis the impact when large capacity wind farms access to the smart grid, researchers have to based on these models, embark from the reality, combine with the relevant technology and smart grid, and establish pragmatic mathematical model which is applicable to different wind condition. This will play an important role in smart grid operating system.

2.2 Wind Farm Output Forecasting

Wind power is an intermittent energy .Its output power has great random and uncontrollable nature, fluctuating in a large range and a large velocity is included. Thus, it's hard to control the peakload, reactive power and voltage, making it difficult to dispatch and stability operation to the grid[7]. So, making a reasonable accurately forecast of wind power, It helps solve problems such as power system stability and dispatch, reducing the impact on the smart grid, reducing the operation cost and spinning reserve and Increase penetration limitation in wind farm.

Uncertainty of wind power output is influenced by many factors. So, many scholars do the forecast mainly focused on wind velocity [8-11], researches of forecasting for the output is still less. It's hard to describe the deterministic model as too many influence factors of wind power output exist. Therefore, we should establish a real-time dynamic and more useful models and algorithms for smart grid according to the wind power output of the actual situation, offering references for effective recruit wind resources.

3. The Basic Operation Characteristic Analysis of Wind Farm

3.1 Power Flow in Smart Grid Including Wind Farm

Because of the random characteristic of wind power system, access to power system will influence the distribution of power flow, the conventional calculation method of power flow is not practical, solving the power flow with wind farm must consider the features of wind turbine generators. The asynchronous generator itself hasn't excitation adjuster, it hasn't voltage adjustment ability, therefore not like the regular synchronous generators can be as PV nodes, asynchronous generator inject active power to system and absorb a certain of reactive power at the same time, join in reactive power compensation devices at access point is necessary, the size of absorption of reactive power is related with voltage of machine, developed active power and the sliding closely, therefore can not be treated as PQ nodes simply[12].

At present, including the power flow calculation models which contain wind farm, the most commonly used is PQ model and RX model [13-14]. However, the calculation deviation exist in PQ model, RX doesn't consider the influence of output character of the sliding. Therefore, it is necessary to further study power flow models and calculation methods of wind farm, in order to make the consequence of power flow more accurate, be tally with actual situation, and for the stability analysis of wind farm with calculation lay the foundation.

3.2 Voltage and reactive power balance

large wind turbine generators interconnected power grid has significant influence to secure state and stable operation of the power system, one of the most prominent problems is caused of the decrease of voltage quality of surrounding area seriously, because of the change of power output of wind farm interconnected power grid can cause the change of reactive power of the system, and then affect system voltage, even lead to voltage collapse [15]. Therefore, we should adopt reasonable of reactive power compensation scheme, otherwise, the voltage-reactive power stability problem of wind farm the will hinder the development of the wind power, especially the limit of construction of large capacity of wind farm.

At present, we usually adopt parallel capacitor in the generator terminal as reactive power compensation. However, the reactive power of compensation capacitor in lower voltage decrease significantly, blocks the speed of the asynchronous generator and recovery of voltage, eventually lead to destruction of voltage stability. Therefore, the research of putting large capacity of wind farm in power system then the voltage stability is of significance, find out the mechanism of the voltage instability, provide a reasonable compensation reactive power optimization scheme, propose the agile voltage control strategy, To reduce the influence on smart grid, ensure voltage stability, improve the quality of electric energy, improve absorption capacity of the smart grid accessing in wind power.

4. The Stability Problem of Wind Farm Access in Smart Grid

4.1 The Transient Stability of Smart Grid Including Wind Farm

The proportion of the wind capacity in the power grid is increasing rapidly, the problem about transient stability of parallel in system is more prominent. Power grid failure, the change of the wind speed all can make disturbance to system, these disturbances will affect generator unit stable running, relative Angle can keep stable in the range.

Domestic and overseas have made certain work for transient stability of large-scale wind farm which is connected in power grid, and made a series of achievements [16-19]. However, most of the current researches focus on wind power system stability and the influence of its model of itself of the stability, lack of systematic analysis of the transient stability with large capacity of wind farm in power grid. In order to build a strong smart grid, smart grid guarantee acceptance of large capacity wind farm effectively, should make a comprehensive analysis of the stability problem of wind farm put in smart grid, mainly includes: three-phase short-circuit fault occurred in different positions for power grid and the influence of wind turbine generator; when single-phase fault occurred in power grid, wind power output of grid and wide fluctuations of wind generator, when cascading failure occurs in wind power grid whether wind turbine generator system can be stable operation, etc. Overall demonstration the influence of wind farm put in power grid stability, and put forward the corresponding measures to improve the wind power of transient stability.

4.2 The Small-Signal Stability of Smart Grid Including Wind Farm

The wind resources are rich in remote areas of the backward area, far from the load centers, with the installed capacity of the wind farm is more and more big, access to the voltage grade begin by long distance to power grids and load centers. China Internet network system after region appears low frequency oscillation phenomena [20], therefore, in the wind power system small signal stability analysis and damping characteristics as very urgent issue. It's in this topic, there have been few studies on comprehensive analysis of wind power system, including the small signal stability analysis is only, the lack of wind power generator control system model research.

In the construction of strong smart grid operation of framework, set up detailed small signal stability analysis model, Small signal stability analysis method used in wind power system, comprehensive analysis of small interference stability mechanism which include wind farm of power system, make comprehensive study of the influence of large-scale wind farm to the damping characteristics, put forward corresponding measures to improve the power system with wind damp and enhance the system dynamic stability.

4.3 Power Grid Faults and Reliability

With the expansion of the power generation capacity and the scale of the wind farm, Urgent need research large capacity of wind farm put in power grid then the influence to the system reliability and troubleshooting. When the system disturbance or fault, the uncertainty of the wind power can reduce reliability of the system.When make reliability assessment on smart grid which contain wind farm, it needs to consider the way that wind farm access in, operation mode and state policies, geography, establish applicable reliability calculation model, to ensure that the system reliability requirement, build the most applicable reliability evaluation system.

Under the strong smart grid, should combine wind power system, the analysis theory of the smart grid security, the self-healing control framework, automatic control equipment, etc, in order to ensure safety and reliability of the wind power grid access in intelligent power grid.

5. Conclusion

Under the background of the smart grid, large-scale wind power generation access problems still need further study, involving wind power generation system planning, operation, management, etc. Combined with the actual situation of the national power grid in china, start with the basic problems, and intelligent network analysis in the optimization problem of utilization of wind power, realize information and intelligence control of the wind power, ensure all kinds of condition of the safe and stable operation of the system, and promote the rapid development of smart grid.

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