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Transient Stability Study of Multi-machine System with Wind Farm

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ABSTRACT. *Firstly, the speciality of the power system with wind farm, especially the speciality of fault, is briefly introduced. Then the static synchronous compensator (STATCOM) is described in detail, and the static synchronous compensator is introduced. After the basic circuit structure and working principle and the configuration of the static synchronous compensator in the transmission network, the influence of the static synchronous compensator on the stability of the power angle is analyzed. Finally, the application of the static synchronous compensator can greatly improve the wind farm. The conclusion of the system's power system transient stability.*

KEYWORDS: *wind farm; static var compensator; transient power angle stability*

1. Introduction

At present, the access of wind farms is different from the previous ones. The installed capacity of a single wind farm is getting larger and larger. A planned wind farm with multiple installed capacity of 100MW or more will directly access the 220kV transmission system. For the power system with wind farm, the grid-connected operation of the wind farm has the greatest impact on the system operation under the following two modes of operation. As long as the system is stable under these two modes of operation, the system can be guaranteed to operate in other operations. It can also run stably in the mode[1-4]:

1) The system load is the largest. In this case, there are fewer hot spares in the system. If the wind speed is reduced from the rated value to zero wind speed in a short period of time, the active power of the wind farm will be reduced to zero by the maximum output power in a short time.

2) The system load is minimal. In this case, if the wind speed is increased from zero wind speed to the rated wind speed in a short time, the active power of the wind farm will increase from zero to the maximum output power in a short time. At this time, if the generator has poor power adjustment capability. , the active increment

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generated in the system will have a greater impact on the stable operation of the system.

2. Transient power angle stability of wind farm systems

The transient power angle stability problem of power system is one of the most fundamental problems in the safe and stable operation of power systems. Research has long been conducted on a wide range of effective prevention and control strategies[5-8].

2.1 Equal area rule concept

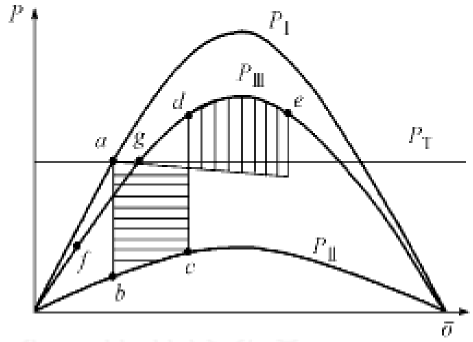

Figure 1. Power characteristics of a wind farm system

When the wind farm based on the wound asynchronous generator (WRIG) participates in the adjustment of the entire transient process of the system, Figure 1 shows the change of the power angle of the synchronous generator.

2.2 The basic physical quantities involved in the stability analysis of the power angle

The stability of the power angle is essentially the stability of the mechanical motion between the rotors of the synchronous generator. Therefore, the basic problem of the stability analysis of the power angle is the relative position between the rotors during the rotor motion, that is, the mechanical motion of the rotor[9-10].

2.3 Analysis of conceptual issues when the transient power angle is stable

1) Analyze the fundamental difference between the characteristics of the analyzed process when the power angle is statically stable and transiently stable. When analyzing the static stability and transient stability of power system power angles, there is a fundamental difference that is often overlooked. The static stability of the

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power angle is an analysis of the dynamic (dynamic) development trend of the power system in a given synchronous operation state, so it analyzes the motion state of the generator (between) at this point.

2) In the transient process after a large disturbance, only the synchronous machine electromotive force (E_q or E'_q the amplitude is considered to be constant) is sinusoidal.

The system current i_{MN} is determined by:

$$i_{MN} = \frac{e_M - e_N}{X_\Sigma} = \frac{2E_{qM}}{X_\Sigma} \cdot \cos \cdot \frac{\omega_M - \omega_N}{2} t$$
$$\cdot \sin \frac{\omega_M + \omega_N}{2} t - \frac{E_N + E_{qM}}{X_\Sigma} \sin \omega_N t$$

It can be seen that the system current ω_M is a typical non-sinusoidal wave when it is temporarily unchanged, so it cannot be represented by a phasor.

3. Particularity of wind farm system and static synchronous compensator

3.1 Large-scale wind farm operation characteristics

1) The energy density of wind energy is small. In order to obtain the same power generation capacity, the wind turbine has a wind wheel size that is several times larger than that of the corresponding turbine.

2) The stability of wind energy is poor. Wind energy belongs to process energy, which is random, intermittent, unstable, wind speed and wind direction often change, and they have a great influence on the working conditions of wind turbines. In order to obtain a more stable output power, the wind turbine must be equipped with adjustment and control devices such as speed regulation, steering and braking.

2) Wind energy cannot be stored. For wind turbines that operate independently in a single machine, to ensure uninterrupted power supply, a corresponding energy storage device must be provided.

3) The efficiency of the wind wheel is low. The theoretical maximum efficiency of the wind turbine is 59.3%, and the actual efficiency will be lower. Statistics show that the maximum efficiency of the horizontal axis wind turbine is usually 20% to 50%, and the maximum efficiency of the vertical axis wind turbine is 30% to 40%.

4) The distribution of wind farms is often remote. For example, although China's wind power resources are relatively abundant, most of them are concentrated in the “Three North Areas” in the northwest, north China and northeast.

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3.2 Static Synchronous Compensator (STATCOM) in a Wind Farm System

Static Synchronous Compensator (STATCOM) is a new type of fast dynamic reactive power compensation device developed in recent years. It can be used to improve the static and transient stability limits of the system and improve its voltage stability, thus improving the transmission capacity of the transmission line. To its thermal stability limit.

1) Basic circuit structure and working principle of static synchronous compensator. The basic circuit structure of STATCOM is divided into a voltage bridge circuit structure and a current bridge circuit structure. See Figure 2 and Figure 3, respectively.

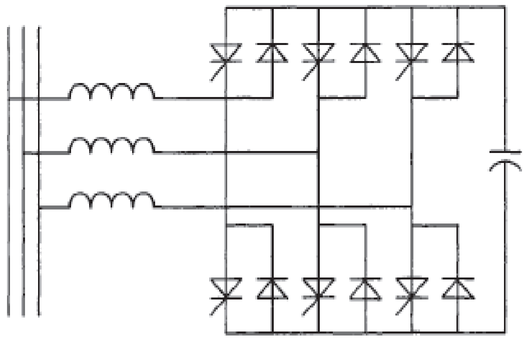

Figure 2. uses a voltage bridge circuit

The DC side of the voltage bridge circuit uses the capacitor as an energy storage component to invert the DC voltage into an AC voltage. The series reactance is connected to the grid by the series reactance, and the series reactance has the purpose of filtering ripple and damping overcurrent.

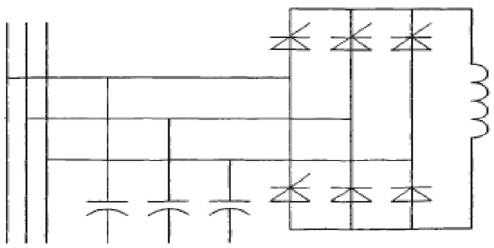

Figure 3. uses a current bridge circuit

2) Effect of static synchronous compensator on power angle stabilityThe influence of the phase angle difference at each end of each branch: Take the

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single-machine infinite system as an example, set the voltage of the terminal voltage 1 of the synchronous generator and the voltage of the infinite busbar S to be respectively, and assume transformer 1-2, tie line 2-3 and The sum of the reactances of the transformer 3-S is X, and the power delivered by the system at this time is: $P = \frac{V_1 E_S}{X}\sin\delta$

As shown in Figure 4, an ideal STATCOM is placed at the midpoint of the equivalent circuit to maintain a constant voltage. This voltage is recorded as the system is disturbed and the generator and the infinite bus are pulled apart at each other. The end point variation of the point voltage vector is shown in the solid line portion of Figure 5.

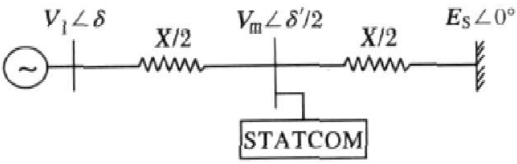

Figure 4. STATCOM compensated single-machine infinity equivalent system

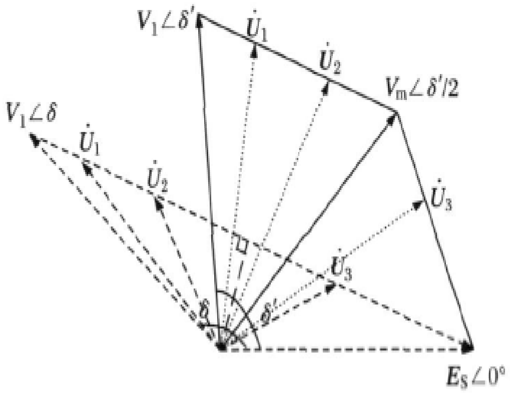

Figure 5. STATCOM compensated voltage vector diagram

The transmitted power after STATCOM compensation can be expressed as:

$$P = \frac{V_1 V_m}{X/2}\sin\frac{\dot{\delta}}{2}$$

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Influence on the accumulation of potential energy of the oscillation center branch:Taking the branches 2-3 and 3-S as examples, after installing the STATCOM parallel compensation device in the oscillation center, the voltage variation of each node is relatively small due to the disturbance of the system, especially the branch 2-3 is obvious, 3-S Second. The corresponding power angle characteristic curve is significantly higher than when STATCOM is not installed, as shown in Figure 6 $P^{`}_{2-3}$ and $P^{`}_{3-S}$ .At the same time, the transient potential energy undertaken S_2 and S_1 by the branches 2-3 and 3-S also changed significantly. Compared with the case where STATCOM is not installed, the transient potential energy of the branch 2-3 is much less than the original, and the transient potential energy of the branch 3-S is increased.

Therefore, after installing a parallel compensation device such as ST AT COM in or near the oscillation center, when the system is disturbed and the kinetic energy of the generator rotor is converted into the potential energy of each branch, the energy is no longer simply accumulated in the original oscillation center. Rather, it is more evenly distributed across the branches, greatly improving the stability of the power angle of the system.

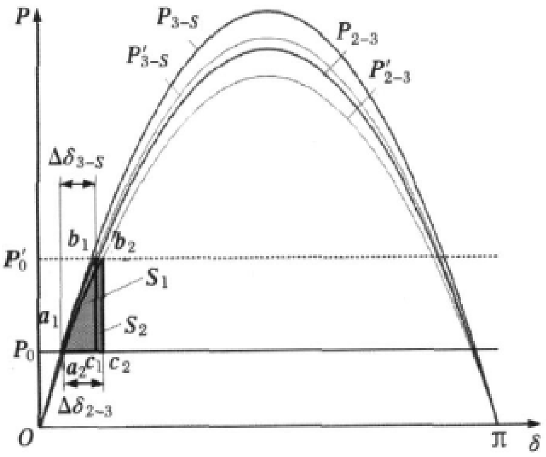

Figure 6. Change of bus characteristics and branch potential after STATOM compensation

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