Grid-connected power oscillation study of hybrid storage direct-drive wind farms based on SVG

Chao Zhang 1,*, shaojie Xin 2, b and Cong Xu 3, c

1 School of Mechanical Engineering, Shanghai Dianji University, Shanghai, China
2 School of Mechanical Engineering, Shanghai Dianji University, Shanghai, China
3 School of Mechanical Engineering, Shanghai Dianji University, Shanghai, China

a 1742587652@qq.com, bxinsj@sdju.edu, c 1315040634@qq.com

*Xinshaojie: xinsj@sdju.edu

Abstract. This paper studies the control strategy of hybrid energy storage to suppress power fluctuation of direct-drive wind turbine based on static var generator, and proposes a grid-connected power oscillation suppression of hybrid energy storage direct-drive wind turbine based on static var generator (SVG). Method, the static var generator is mainly to solve the reactive current generated by the large and impact load and the resulting reactive power, and the SVG connected in parallel with the fan outlet busbar performs reactive power coordinated control to support the grid voltage. This control strategy control The lead-acid battery compensates for the intermediate frequency power fluctuation and the super capacitor (SC) quickly absorbs the high frequency power fluctuation, thereby smoothing the wind power and improving the power quality. sexual demands. Finally, a system simulation model is established in the Matlab/Simulink environment to verify the effectiveness of the proposed method.

1. Introduction

As the most promising renewable and clean energy power generation method, wind power generation has received extensive attention from countries all over the world. However, in the process of rapid development of wind power generation, some bottlenecks and problems inevitably appear. Due to the influence of factors such as climate and geographical environment, the randomness and intermittence of wind turbines cause fluctuations in the output power of direct-drive wind turbines. Large-scale fluctuating wind power is directly integrated into the power grid, which will adversely affect the power quality, voltage stability and grid dispatching of the power grid. A control strategy of a hybrid energy storage system that takes the DC bus as the control object and takes the constant DC voltage as the control target to suppress the effect of wind speed changes on the operation stability of the wind turbine. In addition, a static var generator is added to the public AC bus to compensate the reactive power of the system, which can not only improve the power factor of the system, but also improve the grid-connected stability of the system. Alleviate the energy fluctuation of the wind power generation system and reduce the impact on the system when it is connected to the grid. In this paper, the supercapacitor-battery hybrid energy storage system is applied to a small wind power generation system to form a microgrid system to improve the stability of the system operation. This research has extremely important practical significance for the application and improvement of wind power generation systems. Reference [2] uses the empirical mode decomposition (EMD) algorithm to realize the power distribution between hybrid
energy storages and smooth the wind power fluctuations. Strategies are not universal. Reference [3] proposes that on the basis of the variable filtering algorithm, the dynamic adjustment of the energy storage system can be realized, the service life of the energy storage device can be optimized, and a better wind level suppression effect can be achieved. Reference [4] proposes an additional damping suppression scheme based on STATCOM. By increasing the real part of the admittance at the resonant frequency, the oscillation power is consumed, and the damping sub-synchronous interaction of the DFIG system with fixed series compensation is enhanced. (sub-synchronous control interaction, SSCI) capability. Reference [6] proposed to add SSDC at the source side of the PV system to suppress the SSO caused by the PV sending through the weak AC system.

2. Topology structure of direct-drive wind power system based on hybrid energy storage

The topology of the hybrid energy storage based direct-drive wind power generation system is shown in Figure 1. The direct-drive wind turbine is connected to the grid through a transformer with a variable ratio of 0.69 kV/35 kV. The supercapacitor and lead-acid battery are connected to the DC side through bidirectional DC/DC, respectively, and the lead-acid battery is controlled to absorb medium-frequency power fluctuations while the supercapacitor absorbs high-frequency power fluctuations, thus smoothing out the fluctuations of the electric power of the direct-drive wind power system and improving the power quality.

![Figure 1: Topology of direct-drive wind turbine power generation system with hybrid energy storage](image)

3. Basic Analysis of Static Var Generators

As a reactive power compensation element, the static var generator is usually connected in parallel to the wind farm bus, and maintains the voltage stability of the wind farm bus by supplying or absorbing inductive reactive power. Its working principle is to use the self-commutation method in the circuit to connect to the power grid system through the reactor or directly, and then change the amplitude and phase of the output voltage of the circuit, or directly adjust the current on the AC side, so that the static reactive power generator obtains or generates the reactive current required by the grid to achieve dynamic compensation of reactive power.

Figure 2 shows the SVG structure. From Figure 2, it can be seen that the current absorbed by the static var generator is

\[
I = \frac{\dot{u}_x - \dot{u}_l}{jX}
\]

The active and reactive power absorbed by SVG is
\[ Q = \frac{U^2}{2R} \sin 2\delta \]  
\[ P = \frac{U^2}{2R} (1 - \cos 2\delta) \]

In the formula: \( X \) is the reactance of the connected reactor, and \( \alpha \) is the grid voltage vector, which \( U_1 \) is the phase angle difference relative to the \( U_s \) voltage vector of the static var generator.

Ignoring the various losses of the static var generator and its influence on the active power, it can be obtained:

\[ Q = \text{Im} \left( \frac{U_s \cdot \dot{U}_s - \dot{U}_1}{-jX} \right) = \frac{U_s - U_1}{X} U_s \]

Figure 2 SVG structure
The d-axis voltage outer loop is based on the difference between the dc voltage reference value $U_{dc}^*$ and the actual $U_{dc}$ value and is then composed by the PI controller. For the q-axis voltage outer loop, it is mainly based on the reference value of reactive power output corresponding to the parallel network point, i.e. $Q_{sref}$, and then the difference between $i_q^*$ and the actual feedback value $i_q$ is obtained to output the corresponding reactive power.

### 4. Hybrid energy storage and SVG combined to improve the grid stability of wind turbines

Supercapacitors and lead-acid batteries are connected to the DC side through bidirectional DC/DC respectively, controlling the all-vanadium redox flow battery to absorb intermediate frequency power fluctuations, while the supercapacitor absorbs high frequency power fluctuations, thereby smoothing the fluctuations of the electric power of the direct-drive wind power system and improving the power quality.
bus, and the hybrid energy storage system stabilizes the voltage at the AC bus. SVG only needs to increase reactive power support to the grid-side converter.

5. Simulation Analysis

In order to verify the correctness of the hybrid energy storage system and static var generators proposed in this paper to suppress power fluctuations of direct-drive wind turbines, a system simulation model is established in the MATLAB/Simulink environment, and simulation research is carried out.

5.1 Simulation analysis

It can be seen from Figure 5 that the active power output by the wind turbine is seriously reduced during the fault period. The traditional control cannot suppress the oscillation of the active power very well, which will have a great impact on the power grid. When the system control strategy is adopted, the ability of the fan to output active power is improved during the fault period, and the active power recovery of the fan is faster and more stable after the fault is removed.

![Figure 5 Active power output of the wind turbine](image)

6. Conclusion

Based on the active power oscillation mechanism of the direct-drive fan connected to the weak AC power grid system, this paper proposes a method to suppress the active power oscillation by the hybrid energy storage control strategy of SVG, supercapacitor and lead-acid battery. By making the SVG at the grid connection point equivalent to a positive resistance at the active power frequency of the parallel connection system, the oscillation energy is consumed to achieve the suppression effect, and at the same time, the reactive power is compensated for the system, the power factor is improved, and the power quality is improved. The model verifies the effectiveness of the control strategy proposed in this paper, and is suitable for a variety of working conditions. Based on the proposed strategy, centralized governance can be achieved when active power oscillation occurs, which is easy to implement and has certain economic advantages.

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