Research and Analysis of Suppressing Subsynchronous Resonance Based On TCSC in Power System

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Abstract. For the subsynchronous resonance, this paper analyzes the structure, principle and operation characteristics of TCSC. The power system model and TCSC module are built by Matlab software, which is integrated and simulated. The results show that TCSC can suppress the resonance of the power system, and it can quickly stabilize the system after the power system oscillates.

1. Introduction
With the continuous development of society, the importance of large-capacity transmission and long-distance transmission has become increasingly prominent. In order to adapt to the rapid development of power systems, it is often necessary to add series compensation to reduce the influence of inductance on the line and improve the stability of the transmission line. However, adding a fixed series compensation may result in subsynchronous resonance (SSR). Subsynchronous resonance can seriously affect the operation of the generator, causing problems such as oscillation or even breakage of the motor shaft. Therefore, Controlled Series Compensation (TCSC) has emerged to provide a solution to the subsynchronous resonance problem.

2. Analysis of Power System Model with TCSC
The equivalent power system equivalent model with TCSC is shown in Figure 1:

![Figure 1. Equivalent Model of Simple Power System with TCSC](image)

In a power system, the fixed capacitor compensation in series on the line will generate a resonance lower than the grid frequency under certain conditions. The current will cause electromagnetic oscillation of the motor through the generator, which will further cause mechanical oscillation. This phenomenon belongs to the power system SSR.
3. Research method of subsynchronous resonance of TCSC system

Because the subsynchronous resonance will bring very serious consequences to the motor, it will endanger the healthy operation of the entire power grid. Therefore, studying the subsynchronous resonance of TCSC system has important significance for grid operation and technology development. So far, the academic community generally uses four methods to study the subsynchronous resonance of the TCSC system: time domain simulation, eigenvalue analysis, Prony algorithm and complex torque coefficient method.

a). Time domain simulation

The time domain simulation method can be applied to study the subsynchronous resonance of power systems under various operating modes. It can study both linear models and nonlinear models. At the same time, it can simulate the various parts of the entire power system, and can get how the specific parameters change with time, so as to make a clear and intuitive analysis of the simulation results. However, the time domain simulation method takes a long time to judge the result and is only applicable to large disturbances or faults.

b). Eigenvalue analysis

Unlike the time domain simulation method, the main application range of the eigenvalue analysis method is small disturbance. The method is to linearize the power system model, and use the state matrix to solve the eigenvalues, eigenvectors and other parameters to analyze the amplitude and damping characteristics of the shafting. The operation result of this method is very accurate, but the matrix order of solving the feature root is very high, and it is not suitable for large systems or complex systems.

c). Prony algorithm

The Prony algorithm is a method that can linearly describe complex exponential functions, and can easily find the phase, amplitude, frequency and other parameters of the sampled signal. The Prony algorithm can perform analogy analysis on the actual measured data based on the analysis of the simulation results and draw conclusions. At the same time, the Prony algorithm does not need to calculate complex system equations, and avoids the problem of “dimensionality disaster” without evasive eigenvalue analysis.

d). Complex torque coefficient method

The complex torque coefficient method is to determine the magnitude of the sum of the two by calculating the coefficients of the mechanical and electrical damping separately. If the value is greater than zero, the subsynchronous resonance of the system is stable; if the value is less than zero, the system is unstable. This method calculates the two coefficients separately, and subtly reduces the amount of calculation. The actual calculation can be applied to large systems or complex systems.

4. Establish Matlab power system simulation model

In order to analyze the effect of TCSC on suppressing subsynchronous resonance, this paper uses Matlab to establish a power system model including generator, transmission line, load and transformer. In this model, the three-phase voltage source line voltage is 10.5kV and the frequency is 60Hz. The model and parameters are shown in Figure 2 and Figure 3, respectively:
According to the circuit knowledge, all the above modules are connected to obtain a complete power system simulation model. The circuit diagram is shown in Figure 4:

5. Establish TCSC simulation model
According to the characteristics of TCSC, this paper divides TCSC into three modules: TCSC module, control module and trigger module. The TCSC module package is shown in Figure 5, and the internal structure is shown in Figure 6. The control module mainly includes a bypass breaker, which can be set to put the TCSC into use or disconnect at a specific time. The function of the trigger module is to provide a trigger pulse to the TCSC to activate the thyristor.
6. TCSC suppression subsynchronous resonance simulation

Combined with the power system model and the TCSC model, the TCSC is integrated into the power system model to obtain a power system model containing TCSC, and the three-phase ground fault is used as the interference.

In order to clearly observe the waveform, this paper sets the fault occurrence time to 0.2 seconds and returns to normal at 0.28 seconds. By observing the system voltage, active power and reactive power, the effect of TCSC on suppressing subsynchronous resonance and improving the stability of the power system is obtained. The results of the simulation when the TCSC is not connected are shown in Figures 7 and 8.

![Figure 7. Waveform of line voltage when TCSC is not connected](image1.png)

![Figure 8. Waveform diagram of active power and reactive power when TCSC is not connected](image2.png)

According to the simulation results of line power and active power and reactive power, the following conclusions can be drawn: (a). When the same simple power system is used as the research object, it can be found that the system connected in series with TCSC can recover more quickly after being disturbed by the outside world. (b). After a three-phase fault occurs, the system voltage and power are drastically reduced. After the fault is removed, it is found that the power system that is not connected to the TCSC generates power oscillations. The glitch on the image is very obvious, and it is no longer able to continue to operate smoothly. In severe cases, it may even cause power generation. The unit shaft system is broken and the system collapses; the power system of the TCSC connected in
series is stable after 0.32 seconds, and the system returns to normal and smooth operation, and there is no resonance phenomenon. Therefore, TCSC plays a very important role in suppressing subsynchronous resonance of power system and maintaining system transient stability.

7. Conclusion
The power system model was built by Matlab, and the TCSC model was built by sub-module and integrated into the power system model. It is proved that the TCSC can significantly reduce the oscillation and stabilize the whole system after the system oscillates, so as to ensure the safe operation of the power system.

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