Impact of Wind Power and Photovoltaic Grid Connection on Subsynchronous Oscillation of Thermal Power

Chen Dai*, Tao Xu

School of Electric Power, Inner Mongolia University of Technology, Hohhot, China

*Corresponding author e-mail: 1441434665@qq.com

Abstract. Wind power, photovoltaic and thermal power bundling are the main forms of large-scale new energy grid connection and power transmission. Based on the IEEE’s first standard model, this paper incorporates direct-drive fans and photovoltaic systems. The transform method analyzes the effect of direct-drive wind turbines and photovoltaic grid-connected power on subsynchronous oscillation of thermal power. Simulation results show that appropriately increasing the photovoltaic grid-connected capacity can increase the electrical damping of thermal power in the wind, solar and fire delivery system.

1. Introduction

The problem of sub-synchronous resonance belongs to the oscillation instability of the system, because the mutual vibration of the mechanical part and the electrical part of the system will cause serious damage to the shaft system of the turbine generator. According to the oscillation mechanism, it can be divided into induction generator effect and torsional vibration interaction. The addition of new energy will make sub-synchronous oscillation in thermal power more complicated. The methods of analyzing the sub-synchronous oscillation problem are time domain simulation analysis method, complex torque coefficient method, eigenvalue method and parameter identification method[1].

In our country and abroad, there are studies on wind-fire bundling and light-fire bundling subsynchronous oscillation. But there is no research on the sub-synchronous oscillation of the wind-light-fire AC delivery system. Reference [2] used a combination of time-domain simulation and identification of Prony damping ratio to analyze the effect of the double-fed fan connection on the thermal resistance. The damping controller was added to the fan to achieve the suppression effect. Reference [3] introduced that the integration of direct-drive wind turbines into the power grid will aggravate the sub-synchronous oscillation of the turbine generators in thermal power plants. Literature [4] concluded that the incorporation of photovoltaics will increase the electrical damping of thermal power by using the complex torque coefficient method. Literature [5] carried out an in-depth analysis of the sub-synchronous oscillation mechanism of wind-fired bundling via a DC transmission system, and it was concluded that the sub-synchronous oscillation of thermal power is still the main in the DC transmission system. Based on IEEE’s first standard model, this paper establishes a system for the impact of wind power and photovoltaic grid-connected power on sub-synchronous oscillation in PSCAD / EMTDC. Obtain the effect on the system damping by changing the capacity of wind, light and fire. The combined method of time-domain simulation and Hilbert-Huang transformation method is used to study the influence of wind power and photovoltaic on grid power.
2. Modeling of direct-drive wind turbine photovoltaic fire power bundling delivery system

The simulation model shown in Figure 1 is built in PSCAD, and the electromagnetic transient model of the direct-drive wind turbine, photovoltaic and thermal power transmission system via series compensation. The rated capacity of the generator is 700MW, and the main parameters refer to [4]. The typical turbo-generator shaft system is shown in the figure, which includes high-pressure cylinder HP, medium-pressure cylinder IP, low-pressure cylinder LPA, low-pressure cylinder LPB, generator and excitation. Machine six shaft segments. The direct-drive fan includes the generator-side grid-side converter part, the pitch distance control part, and the fan shaft system part. The specific parameters are shown in Table 1. The photovoltaic model consists of a photovoltaic array and a grid-connected inverter. The photovoltaic parameters are shown in Table 2.

![Figure 1. System structure diagram.](image)

Table 1. Direct drive fan parameters.

| Parameter                  | Value  | Parameter                  | Value  |
|----------------------------|--------|----------------------------|--------|
| Paddle diameter            | 29.9m  | Stator inductance          | 0.028mH|
| Generator pole pairs       | 48     | Rated power                | 1.5MW  |
| Rated voltage              | 690V   | Frequency                  | 60Hz   |

Table 2. Photovoltaic parameters.

| Parameter                          | Value  | Parameter                          | Value  |
|------------------------------------|--------|------------------------------------|--------|
| Number of modules in series per array | 110    | Short-circuit current              | 2.5A   |
| Number of parallel modules per array | 88     | Number of units in series in each module | 4     |
| Reference temperature              | 25°C   | Number of units in parallel per module | 10 |

3. Simulation analysis

This paper uses a combination of time-domain simulation and Hilbert-Huang transform[6] to analyze. In order to be able to study the influence of wind and solar grid-connected capacity on the sub-synchronous oscillation of thermal power, the following five operating conditions are set, as shown in Table 3. The wind speed is 11m/s, the light intensity is 1000W/m² and the distance between the grid-connecting points remains unchanged, and the string compensation is 74%.

Table 3. Working condition design.

| Working condition | Thermal power capacity (MW) | Wind power capacity (MW) | Photovoltaic capacity (MW) |
|-------------------|-----------------------------|--------------------------|---------------------------|
| 1                 | 700                         | 300                      | 300                       |
| 2                 | 700                         | 300                      | 400                       |
| 3                 | 700                         | 300                      | 200                       |
| 4                 | 700                         | 400                      | 300                       |
| 5                 | 700                         | 200                      | 300                       |
As shown in Figures 2, through simulation waveforms, it is found that the shaft system torque oscillations of the turbo-generator units are all diverging. When the photovoltaic capacity is increased, the amplitude of the shaft system torque oscillation of the thermal power unit becomes smaller. The torque oscillation amplitude of the shaft system of the thermal power unit becomes larger. Increasing the photovoltaic capacity can increase the electrical damping of the generator, thereby improving the sub-synchronous resonance problem of the thermal power unit.

![Figure 2. Comparison of shaft torque between GEN-EXC](image)

As shown in Figures 3, when the wind power capacity increases, the amplitude of the shaft system torque oscillation of the thermal power unit becomes larger, and the spectrum analysis chart also shows that the oscillation amplitude of the fourth condition is the largest. Increasing the capacity of wind power will reduce the electrical damping of the generator, thereby making the sub-synchronous resonance problem of thermal power more serious.

![Figure 3. Comparison of shaft torque between GEN-EXC](image)

Calculate the frequency and damping of the main vibration modes in conditions 1 to 5 based on the Hilbert Yellow Transform, as shown in Table 4.

| Working condition | Oscillation frequency | Damping ratio |
|-------------------|-----------------------|--------------|
| 1                 | 20.2600               | -0.00353579427 |
| 2                 | 20.2000               | -0.00341841231 |
| 3                 | 20.3000               | -0.00370414898 |
| 4                 | 20.2600               | -0.00422982435 |
| 5                 | 20.2600               | -0.00285754822 |

According to the value of the damping ratio, it can be seen that an increase in wind power capacity will reduce the electrical damping of thermal power, and an increase in photovoltaic capacity will increase the electrical damping of thermal power.

### 4. Conclusion

In this paper, a model of sub-synchronous oscillation of direct-drive wind turbines and photovoltaic grid-connected thermal power generation is established based on IEEE. The method of time-domain simulation and Hilbert Yellow Transform is used to study and analyze. The conclusion is that damping and increasing photovoltaic capacity will increase the electrical damping of thermal power. In this paper, by studying the sub-synchronous oscillation of thermal power in the AC delivery system of wind, light,
and fire, establishes a theoretical basis for the subsequent suppression measures of the sub-synchronous oscillation.

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