Frequency Modulation Method and System of Photovoltaic Virtual Synchronous Generator Based on Computer Technology

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Abstract. With people's attention to environmental protection, clean energy has become an important research and development direction. Among them, photovoltaic power generation has many advantages, such as simple process, no fuel consumption, no noise, no pollution and so on. The power grid capacity is becoming larger and larger, and has a great impact on the environment. Therefore, the grid connection of photovoltaic power generation will cause major problems for the planning, operation and dispatching of power grid. Virtual synchronous generator (hereinafter referred to as VSG) technology can simulate the inertia, primary frequency regulation and voltage regulation characteristics of synchronous generator, which has become an important way to improve the dynamic frequency response ability of the system. Therefore, VSG technology has become an important research technology of photovoltaic grid connected system, among which FM method will also become an important research direction. Firstly, this paper analyzes the VSG algorithm and its basic characteristics. Finally, this paper analyzes the control scheme of overall primary frequency regulation of photovoltaic power station (hereinafter referred to as PPS).

Keywords: Computer Technology, VSG, Frequency Modulation Method

1. Introduction
China's photovoltaic industry started late, but developed very rapidly. At present, a large number of megawatt PPS projects have been built in China [1]. Among them, the PPS of Shenzhen International Garden and flower expo park provides a significant reference value for China's photovoltaic power generation system, which has become a major symbol of clean energy [2-5]. The working stability of grid connected photovoltaic power generation will be affected by weather factors, which requires us to improve the stability of distributed generation under the condition of high penetration [6]. Based on distributed inverter, we can realize flexible control, which can simulate the dynamic and static characteristics of synchronous generator [7].

2. VSG algorithm and basic characteristic analysis
2.1. Overall structure of VSG

The control strategy of VSG can make the whole photovoltaic power supply device connect to the power grid with the external characteristics of synchronous generator [8]. A photovoltaic power generation system device based on VSG is developed, as shown in Figure 1. The system includes photovoltaic power generation device, energy storage system and steam turbine generator device [9]. Photovoltaic power generation units are often easily disturbed by external factors and stop working. According to the fluctuation, we can adjust our power input and output in real time. During grid connection, the inverter can output power to supplement the required load according to the preset distribution rules, which can reduce the impact of load fluctuation on the power grid [10].

![Figure 1. Photovoltaic grid connected power generation system based on VSG](image)

2.2. Establish VSG ontology algorithm model

The second-order, third-order and fifth-order models are commonly used in the dynamic characteristic analysis of synchronous generators. The model mainly includes rotor motion equation, as shown in Formula 1. When ignoring the influence of salient pole effect, we make the pole pair \( P = 1 \). Therefore, the electrical angle is equal to the mechanical angle.

\[
\begin{align*}
J \frac{d\omega}{dt} &= \frac{P_m - P_e}{\omega} - D(\omega - \omega_s) \\
\dot{E}_e &= V + IR_s + j\dot{X}_s \\
\omega &= \frac{d\theta}{dt}
\end{align*}
\]  

(1)

Where, \( J \) is the moment of inertia, \( D \) is the damping coefficient, \( \omega \) representing the action of damping winding, \( \theta \) is the rotor angular frequency, \( e \) is the electrical angle, \( \dot{E} \) is the electromotive force in the stator, \( R_s \) and \( X_s \) are the stator resistance and synchronous reactance respectively.

According to equation 1, the algorithm block diagram of VSG can be obtained in this paper, as shown in Figure 2. The block diagram shows the VSG algorithm model for three-phase system, which can become the VSG ontology algorithm.
According to figure 2, we can get multiple signals, including: electromotive force $e_a, e_b, e_c$ in three-phase stator, three-phase stator currents $i_a, i_b, i_c$, $P_{\text{VSG}}$ is the output active power, $Q_{\text{VSG}}$ is the output reactive power.

3. Overall primary frequency modulation control scheme of PPS

3.1. Design ideas
The project plans to adopt the primary frequency modulation device. When the frequency exceeds the limit, the system can start adjustment through the primary frequency modulation control system. By superimposing AGC commands, the system can send commands to the communication unit. Through the inverter command, we can monitor the power regulation results, which will better form a closed-loop control. The system architecture is developed in this paper, as shown in Figure 3.

3.2. Implementation plan
Through the measurement and control of box transformer, the system can add primary frequency modulation communication interface. By forwarding the primary frequency modulation active power
command allocation strategy, we can enable the inverter to quickly adjust the active power output according to the change of load command. The primary frequency modulation device directly collects and calculates the real-time frequency of the power grid with high precision Pt, CT and other signals. The total active power regulation value is calculated according to the parameters such as frequency dead band, regulation difference rate and dispatching AGC setting value. The primary frequency modulation control system can reasonably distribute the total active power regulation value to each photovoltaic inverter. The inverter adjusts the load according to the issued active power value, which will achieve the purpose of frequency regulation. The primary frequency modulation device interacts with the dispatching master station through the telecontrol device. The station related data is collected by AGC device from the energy management platform and sent to the dispatching master station. The structure is shown in Figure 4.

![Figure 4. Structure diagram of fast frequency modulation control of PPS](image)

3.3. **VSG control block diagram**

This paper formulates the VSG control block diagram, as shown in Figure 5. When the system frequency changes, different adjustment coefficients determine the power response of the unit. The smaller the adjustment coefficient is, the more obvious the output improvement is.

![Figure 5. VSG control block diagram](image)
4. **Conclusion**

This paper designs a new energy frequency intelligent control system, including voltage transformer, voltage data and so on. Through the active power regulation module of PPS, we can adjust the active power of grid connected output of PPS. Through the frequency control module, we can determine the regulation amount of grid connected active power according to the frequency active power droop curve, which will distribute the regulation amount of active power to the active power regulation module of wind farm and the active power regulation module of PPS. By using the VSG control strategy to control the energy storage unit inverter, this paper avoids the disadvantage that the traditional photovoltaic inverter does not have frequency modulation characteristics.

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