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The control strategy of photovoltaic energy storage system based on virtual synchronous generator

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Abstract. With energy crisis and environmental crisis become more serious, photovoltaic energy storage system has increase development. In this article, the virtual synchronous generator second order model is introduced to provide control strategy for photovoltaic energy storage system. The simulation model is established to simulate control strategy. The case study is present to verity the effectiveness of virtual synchronous generator model.

1. Introduction

With the increasingly serious energy crisis and environmental crisis, photovoltaic grid power generation technology has rapid development. Photovoltaic power generation is clean and inexhaustible which are achieved by fossil fuels and make environment develop sustainably. In recent years, in order to solve the problems of the efficient utilization of photovoltaic cells and the friendly access to the power grid, the photovoltaic micro-grid has become a hot spot in the research of institutions and scholars.

In order to store the electrical energy, electrical energy is stored by energy storage system in the situation that the renewable energy power is greater than the load required. When he renewable energy power are not able to meet the needs of the load, energy storage system provide power supplement to maximize the collection and use efficiency of renewable energy. At present, there are many types of energy storage technology. According to the different principles and forms of energy storage, energy storage systems can be divided into mechanical energy storage and electromagnetic energy storage.

Due to the intermittent nature of renewable energy source, energy storage is supposed to provide technical support for photovoltaic generation system on the isolated operation state. The battery energy storage technology is mainly applied in independent photovoltaic power generation system. For the widely photovoltaic integrated power generation system, various energy storage technology can be used[42].The combination of photovoltaic with energy storage system is constructed to expand the scale of distributed photovoltaic applications. Meanwhile, photovoltaic energy storage can improve acceptance ability of the distributed photovoltaic power grid and reduce the influence of photovoltaic power generation for power grid.

2. The control structure and strategy of the photovoltaic energy storage system

Photovoltaic energy storage combined power generation system consists of three parts. The first part include photovoltaic power generation and maximum power tracking control. The second part include energy storage device and charge and discharge control links. The third part include three-phase inverter and control links. Each part of system operation coordinate to realize the conversion of light energy into electrical energy and provide reliable power supply quality. This chapter provides a brief introduction to the various parts of the photovoltaic energy storage power generation system.

2.1 Solar photovoltaic power generation and control strategy.

As the output of photovoltaic battery voltage and current are greatly influenced by factors such as light intensity, the photovoltaic cell shows the typical nonlinear characteristics from the external characteristic. In order to improve the utilization of solar energy, some control methods are adopted to make solar battery in the mximum power point(MPP).The commonly maximum power point tracking (MPPT) control methods include the constant voltage tracking method, short circuit current ratio coefficient method, interpolation method, disturbance observation method, the incremental conductance method[41] and other intelligent MPPT control algorithm.

As a a kind of control method based on photovoltaic battery output characteristic curve, disturbance observation method regulate the output voltage near the maximum power point by the disturbancing photovoltaic battery output voltage and observing the changing direction of the power. Owing that the principle is simple and easy to implement, the MPP is tracked by disturbance observation in the paper.

2.2 Energy storage system control strategy.

The Control strategies of the energy storage system, contains fixed power control strategy and definite voltage control. In this article, the inverter is required to be independent on load in the isolated system running state, so the inverter is required to provide in the output voltage frequency for the system. And the MPPT control strategy is applied in the photovoltaic power generation before class USES, which requires energy storage device maintain DC bus voltage constant. Therefore, the constant voltage control is adopted in the storage energy device. When the output of the solar photovoltaic cell is less than the output power of the inverter, the the battery is discharged and the output is pointed to the bus. When the output of a solar photovoltaic cell exceeds the output of the inverter, the battery is charged because of the constant bus voltage. The voltage current dual closed-loop control is introduced in this paper, as shown in figure 1.

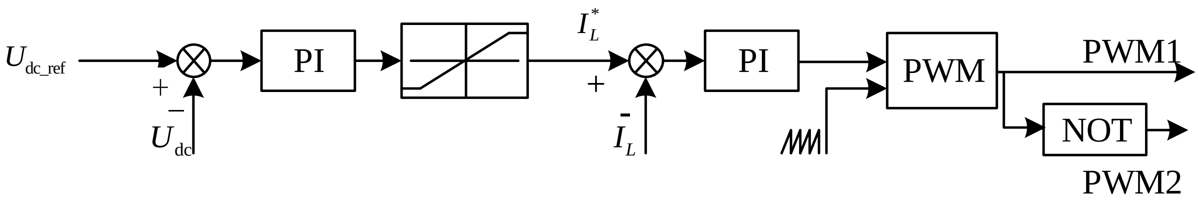

Figure 1. voltage outer ring current control principle diagram

The voltage and current double closed-loop control is established, U_{dc_ref} is the given DC voltage value in the outer ring. The given value is compared with the actual measured capacitance voltage through the PI controller to get the current reference value in the inner ring. The current reference value I_L^* is compared with actual measured capacitance current I_L through the PI controller to get the control signal, which is combined with PI regulator to carry modulation signal to control the on-off of the bidirectional DC/DC converter switching devices. The voltage and current double closed loop control is introduced in the bidirectional DC/DC converter. When the bus capacitance voltage U_{dc} is less than the DC given voltage value U_{dc_ref}, the inner current loop given value I_L^* is greater than zero. Under the control of the inner current loop, the inductance current with current ring is given, and the bidirectional DC/DC module of input connected the battery provide power. When the bus voltage capacitance value U_{dc} is greater than the voltage control loop given value U_{dc_ref}, the inner current loop given value is less than zero.Therefore, the inductor current is less than zero and the battery absorb power.

3. Virtual synchronous generator model

3.1 Synchronous generator classical second order mathematical model.

The mathematical model of synchronous generator contains second-order, third-order and five order model [44]. The mathematical model of high order model is more accurate, but the transient process is more complicated. In this paper, we use the classical second order model of synchronous generator, and assume that the polar logarithm is 1, and the equation of the rotor motion equation (2-3) is shown.

$$\begin{cases} J\dfrac{d\omega}{dt} = \dfrac{P_{\mathrm{m}} - P_{\mathrm{e}}}{\omega} - D\Delta\omega \\ \dfrac{d\theta}{dt} = \omega \end{cases} \tag{1}$$

In the formula, P_{m} 、P_{e} is the mechanical power and electromagnetic power respectively; ω is the actual electric angular velocity; $\Delta\omega$ is the difference between the actual electric angular velocity and the angular velocity of the electric grid; θ is the electric angle; D is the constant damping coefficient; J is the moment of inertia.

The stator electrical equation is shown in the formula (2-4):

$$\dot{E} = \dot{U} + \dot{I}(r_{\mathrm{a}} + \mathrm{j}x_{\mathrm{a}}) \tag{2}$$

In the formula, r_{a} is the armature resistance, x_{a} is the synchronous reactance, $\dot{U}$ is the voltage of the synchronous generator machine, $\dot{I}$ and is the stator current.

3.2 Virtual synchronous generator algorithm.

In order to decrease the volatility response speed of the power electronic devices, the classic second order model of the synchronous generator is introduced to the control strategy to simulate the rotor mechanical properties of the synchronous generator. The control block diagram is shown in figure 2-7.

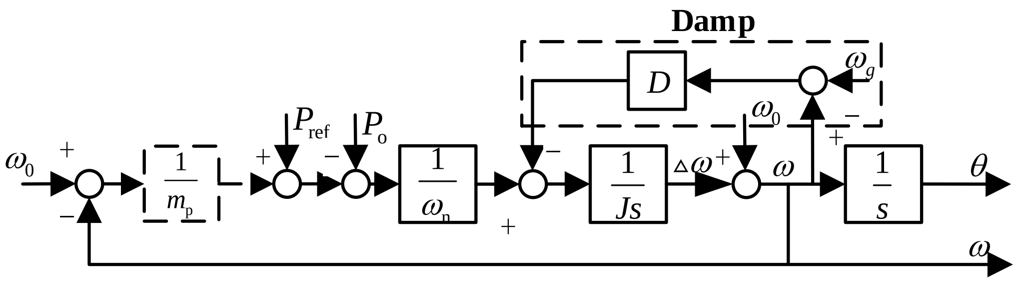

Fig.2 the active power control block diagram

In Fig.2, ω_{g} is the frequency of the grid, ω_0 is reference angular frequency, m_{p} is the sag coefficient, P_{ref} is the reference value for the active power, P_{o} is the active power feedback. Due to the small deviation of the angular frequency deviation, it is supposed that the actual angular frequency is equal to the nominal angular frequency in transformation formula of the power and mechanical torque.

3.3 Case Study.

In the single machine load, the rotational inertia of the virtual synchronous generator is set to $0.1\,\mathrm{kg{\bullet}m^2}$, $1.1\,\mathrm{kg{\bullet}m^2}$, $2.1\,\mathrm{kg{\bullet}m^2}$, $3.1\,\mathrm{kg{\bullet}m^2}$, $4.1\,\mathrm{kg{\bullet}m^2}$ and a load mutation is set up in 2 seconds. The results of the angular frequency diagram as shown in figure 2-8.

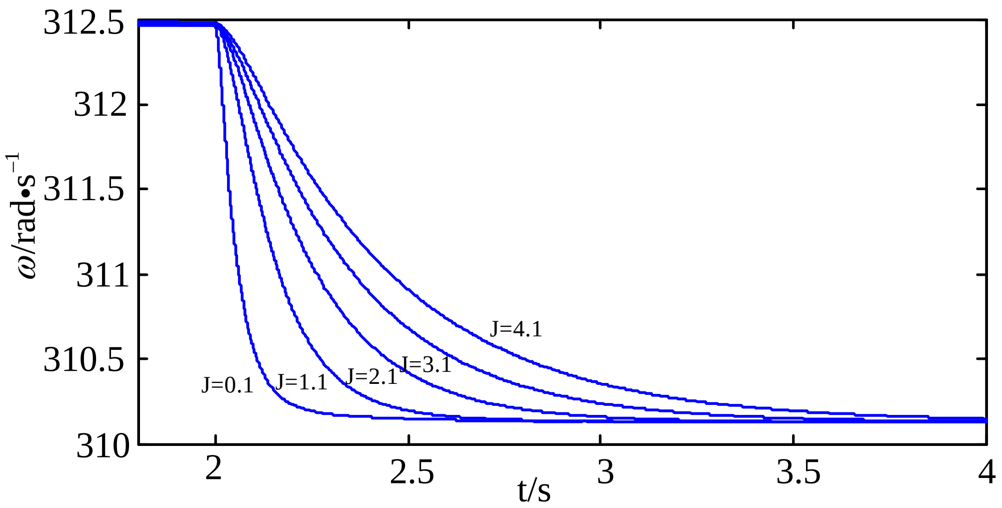

Figure 3. angular frequency variation

It can be observed that with the change of power and the frequency, virtual rotational inertia can change the speed of the frequency. It is validated with the inertia become the greater, the frequency is slower.

4. Summary

This paper respectively introduces the mathematical model of photovoltaic cells in DC side, maximum power tracking control strategy, control strategy of energy storage and the virtual synchronous generator control strategy. The virtual synchronous generator second order model is established to simulate the control strategy. The corresponding simulation model is set up in Matlab, and the function of each module is verified. Finally the simulation results show that with the change of power and the frequency, virtual rotational inertia can change the speed of the frequency.

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