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Microgrid Control Strategy Based on Group Search Optimization Algorithm

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Abstract

This paper uses the virtual synchronous generator (VSG) control technology. The VSG simulates the working characteristics of a synchronous generator and has the same properties of system control parameters. A microgrid model based on VSG control was established. Because of the influence of control parameters on system stability, a group search optimization algorithm (GSO) was proposed to optimize several important control parameters of the system. Finally, the simulation of the model and algorithm is completed in MATLAB / Simulink.

Keywords

Microgrid, Virtual Synchronous Generator, Group Search Optimization, Stability.

1. Introduction

With the continuous deterioration of the global environment, countries around the world have begun to pay attention to the regional decentralization and economic development of renewable energy. Distributed generation (DG) technology has become the main method of using new energy to build microgrids [1]- [2]. This paper introduces and deeply analyzes the virtual synchronous generator control model and system structure and its MATLAB simulation. The voltage amplitude deviation constraint is used as a tool for evaluating the stability of the microgrid system, and a group search optimization algorithm is used to obtain the expected response values of certain parameters affecting the stability of the microgrid.

2. Basic principle of virtual synchronous generator

The model of the virtual synchronous generator is based on the mathematical model of the synchronous generator. A synchronous generator is a device that converts mechanical energy into electrical energy. Its mathematical model is divided into the winding electromagnetic equation of the electrical part and the rotor motion equation of the mechanical part, and the latter is the core of the virtual synchronous generator. With the help of the mathematical model of the synchronous generator, the rotor motion equation of the virtual synchronous generator can be obtained as:

$$\begin{cases} P_m - P_e = J\omega_{ref}\dfrac{d\omega}{dt} + D\omega_{ref}(\omega - \omega_{ref}) \\ \dfrac{d\theta}{dt} = \omega \end{cases} \tag{1}$$

In the formula is the virtual moment of inertia, the damping coefficient, the virtual mechanical power, the virtual electromagnetic power, the actual angular velocity, the angular velocity corresponding to the reference frequency, and the virtual electrical angle. Due to the virtual moment of inertia,The

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inertia of VSG in dynamic response is the same as that of synchronous generator, and the ability of VSG to damp power oscillation is determined by the damping coefficient.

2.1 Power frequency controller

The model of the virtual synchronous generator is based on the mathematical model of the synchronous generator. The mathematical model of the synchronous generator is divided into the electromagnetic equation of the winding of the electrical part and the rotor motion equation of the mechanical part, and the latter is the core of the virtual synchronous generator [3]. According to the mechanical power input by the prime mover of the synchronous generator, a droop mathematical model is established;

$$P_m = P_{ref} + \Delta P = P_{ref} + K_m\left(f_{ref} - f\right) \tag{2}$$

The above formula P_{ref} is the reference value of the active power, ΔP the relative change value of the frequency, and K_m the frequency modulation coefficient value.

2.2 Excitation controller

Establish a mathematical model of reactive-voltage modulation:

$$E = U_0 + K_2\left(Q_n - Q_e\right) \tag{3}$$

In the formula Q_n is the reference value of reactive power， Q_e is the system output reactive power， U_0 is the reference voltage value， K_n is the scale factor.

3. The overall structure of virtual synchronous generator microgrid

This paper constructs a VSG-based microgrid model including several parts: distributed power supply part selects three-phase voltage source inverter, active and reactive power calculation output module, virtual synchronous machine control, voltage and current double closed-loop control, carrier-based The PWM pulse width modulation module, PLL phase-locked loop, etc., some parameters in the model are presented in Table 2-1.

Table 2-1

DC Voltage Source	700 V
Reference active power (P_0)	15 kW
Reference reactive power (Q_{ref})	5 kvar
Resistance(R)	0.135 Ohms
Inductance(L)	1.5e-3 H
Capacitance(C)	20e-6 F
Reference voltage (U_{ref})	311 V

4. Selection of fitness function and parameters

In the traditional power system, the difference between the rotor angle of the synchronous generator and the central angle of inertia (COI) is usually observed to achieve system stability and optimization. If the relative rotor angle of the synchronous generator exceeds a certain range, it is considered that the system is prone to instability. The optimization method tends to find and find the best parameter values of some parameters that affect the stability of the system, so that the rotor angle deviation value is within the boundary.

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In this paper, the weighting function of time multiplied by absolute value of error (ITAE) and harmonic distortion rate (THD) is adopted as the objective function to control the grid connection performance of VSG system [4]. The formulas for ITAE and THD are as follows:

$$\begin{cases} ITAE = \int_0^t t\left|e(t)\right|dt \\ THD = \dfrac{\sqrt{\sum_{n=2}^{\infty} U_n^2}}{U_1} \times 100\% \end{cases} \tag{4}$$

In the formula U_1 represents the fundamental amplitude of the output voltage, U_n refers to the nth harmonic amplitude of the output voltage, $e(t)$ represents the error value.Here the voltage error is used as the optimization object, then the fitness function expression can be expressed as:

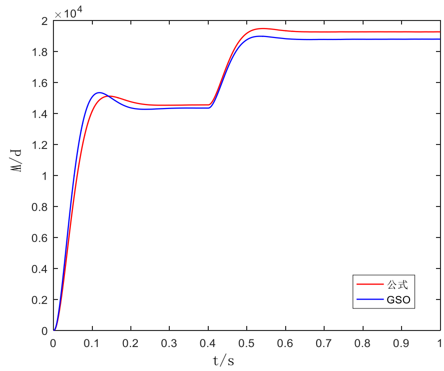
$$fit = THD + \int_0^t t\left|u_d(t)\right|dt + \int_0^t t\left|u_q(t)\right|dt \tag{5}$$

In formula (5) fit represents the value of the fitness function of an individual parameter, u_d and u_q indicates the d-axis and q-axis values of the grid-connected capacitor voltage, respectively.

In this chapter, the virtual moment of inertia, damping coefficient, frequency modulation coefficient and voltage regulation coefficient are selected. In order to evaluate the stability performance of the above system, the parameter design formula of virtual synchronous generator is proposed [5]. In the system established this time, the value of the time constant is set to 0.05. According to the data in Table 1, the value of the damping coefficient is 30.427, the value of the rotational inertia is 1.521. The value of the coefficient is 160.771.

5. Group search algorithm optimization

The group search algorithm is derived from the foraging phenomenon of social animals and is an algorithm that can achieve multi-dimensional search behavior [6]. The group search algorithm uses a fitness objective function to achieve the two goals of the model: the first is to maintain the amplitude of the system voltage and frequency within a specific range; the second is to be able to smoothly transition when the load increases. The transition is faster and there is less turbulent transition. The fitness function is embedded in the PSO algorithm to see if the constrained moment of inertia scheduling improves the stability of the system. The following is the result of optimizing several parameters through the group search algorithm. The fitness function is embedded in the group search algorithm, and the parameter junctions obtained after operation are: damping coefficient 50.135, rotational inertia 3.152, frequency modulation coefficient 10707.5097, voltage adjustment coefficient 313.0391. Enter parameter from the two methods into the model, and the resulting active and reactive waveforms are shown in Figure 1:



（a） Variation in active power

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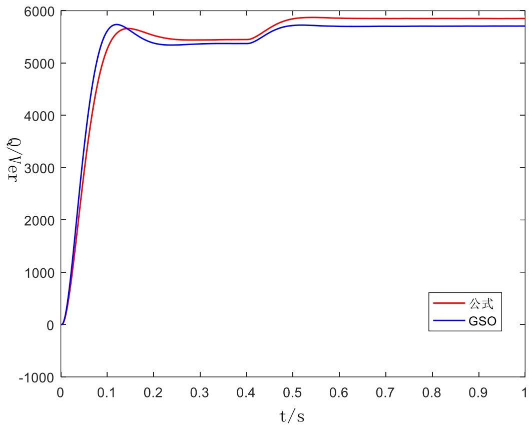

(b)Variation in reactive power

Fig.1 Optimized output waveform comparison under voltage and frequency change

The blue line in the figure is the active and reactive simulation results of the system optimization optimized by the group search optimization algorithm. It can be seen that the simulated waveform of the group search algorithm has a faster response speed and better results.

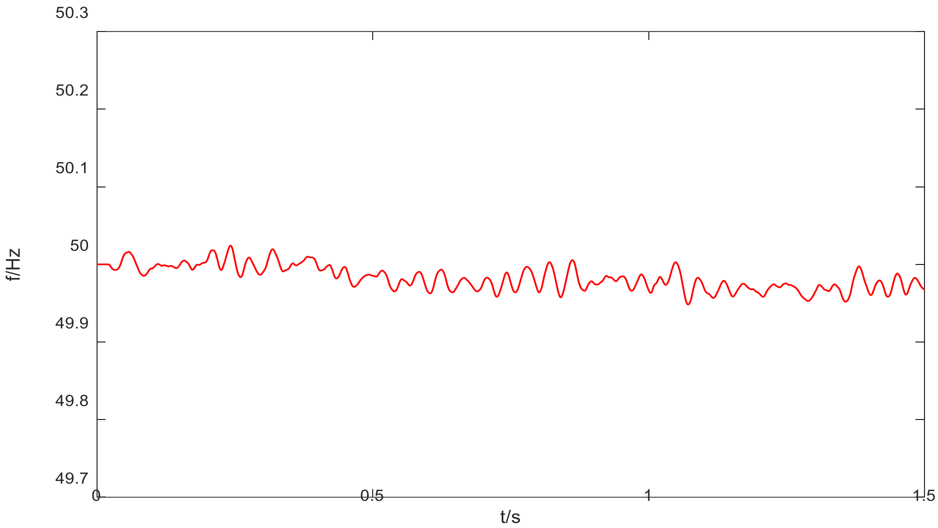

Fig.2 Optimized frequency waveform

It can be seen from Figure 2 that the optimized frequency waveform has a certain oscillation, but its amplitude is very small, and only the percentile changes. In summary, after being optimized by the group search optimization algorithm, the system is in a more stable state. It can also be in a stable state when the microgrid is connected to the grid in 1s, and the frequency does not change suddenly.

6. Summary

This chapter is based on the advantages of the virtual synchronous generator, imitating the mathematical model established for the synchronous generator, including the real-time variable physical model parameters. The first is to establish a microgrid model based on the virtual synchronous generator control method. The calculation method of fitness function is simply selected. Finally, according to the general calculation formula and GSO, according to the objective function, the optimal value of the virtual rotational inertia, damping coefficient and voltage and frequency modulation coefficient is compared to the effect of the system waveform. The parameter value optimized by GSO is calculated than the usual formula. The parameter simulation effect is better, and the response time is faster.

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