ISSN 2706-655X Vol.3, Issue 3: 44-49, DOI: 10.25236/IJFET.2021.030308

Application of an improved droop control strategy in micro-grid system

Zhao Xiaoliang

Institute of Electrical Engineering, Henan University of Science and Technology, Luoyang 471023, China

Abstract: *droop coefficient of the traditional droop control strategy in micro-grid is fixed, and lead to the contradiction between speed of dynamic response, frequency and voltage stability of the system. In order to solve this problem, a nonlinear dynamic droop control strategy is proposed. By utilizing the characteristics of the slope of hyperbolic tangent curve, the droop coefficient is constantly changing. The droop control is carried out by replacing the traditional droop line with hyperbolic tangent curve, which makes the droop coefficient adjust dynamically with the change of the system, and makes the micro-grid adopt droop control strategy to adjust the stability of frequency and voltage. The simulation model of traditional droop control strategy and improved droop control strategy is built on Matlab/Simulink platform, and the simulation comparison is carried out under the same conditions. The simulation results verify the feasibility of improved droop control strategy.*

Keywords: *micro-grid; Droop control; Hyperbolic tangent; Nonlinear*

1. Introduction

With the increasing demand of energy over the world and the increasingly tense environmental problems, the importance of distributed generation mode based on clean energy is becoming increasingly obvious. Distributed power generation system has the advantages of flexibility and efficiency, and also has the disadvantages of high cost and instability. Under this premise, in the early 21st century, experts and scholars proposed the concept of micro-grid and introduced the structure of micro-grid into the power system. The diversified energy coordination and complementation are adjusted by the function of the micro-grid to realize the effective management of load and the support of energy storage equipment, thus reducing the impact of distributed power supply and load change on the stability of the grid, and making the effect of distributed energy used efficiently[1].

Droop control as the main traditional strategy of micro-grid control, adopts fixed droop coefficient, which lead to the contradiction between the speed of dynamic response and the stability of frequency and voltage. When the droop coefficient is too large, the distributed power output has a fast dynamic response, but the frequency and voltage will generate a large offset, which reduces the stability of the system. When the droop coefficient is small and the system stability is high, the dynamic response of the output power output of distributed power supply is slow. When there is sensitive load in the micro-grid or the load suddenly increases or decreases a lot at a certain time, the voltage and frequency in the micro-grid will show a larger offset and fluctuation[2]. At this time, the traditional droop control can not be adjusted to a stable state in time. Therefore, a nonlinear dynamic droop control strategy is proposed. The nonlinear curve is used to replace the linear curve of traditional droop control, so that the droop coefficient can be adjusted dynamically with the change of the system, and the droop control strategy is applied to adjust the stability of frequency and voltage in micro-grid. When the load increases, the interface inverter with more active power tasks is used. By adjusting the nonlinear dynamic droop control strategy, the larger droop coefficient is adopted to respond to the change of the system quickly. The interface inverter with more active power task adopts the regulation function of nonlinear dynamic droop control and adopts the smaller droop coefficient to cope with the change of the system, The interface inverter can adjust the system by dynamic droop coefficient, which can alleviate the contradiction between the fast and slow response speed and the frequency and voltage fluctuation range because of the fixed droop coefficient.

The simulation model of droop control micro-grid is built on Matlab/Simulink platform. The simulation results show that the nonlinear dynamic droop control strategy is feasible and superior.

ISSN 2706-655X Vol.3, Issue 3: 44-49, DOI: 10.25236/IJFET.2021.030308

2. Traditional droop control principle

In power system, there is a corresponding relationship between the output active power and system frequency, reactive power and terminal voltage of generator. When the generator increases the output active power, the system frequency will decrease, and when the generator increases the output reactive power, the end voltage will decrease. Droop control strategy is a control method to adjust the voltage and frequency of micro-grid by simulating the operation characteristics of traditional synchronous generator.

The work flow of droop control in micro-grid is as follows: when the micro-grid is in grid connected state, the capacity of large grid is far greater than that of micro-grid. At this time, the frequency and voltage of micro-grid are provided by the large grid. Distributed power supply adjusts its static curve by adjusting the frequency and voltage of the connection point to send out corresponding active and reactive power commands. When the micro-grid is in the isolated state, the load of the micro-grid determines the output power of the distributed power supply. At this time, each distributed power supply shares the load of the micro-grid to ensure the power balance of the system, and adjusts the voltage amplitude and system frequency according to the droop characteristic curve. When the system load changes, the above-mentioned adjustment process will be repeated until the system reaches a new balance. Therefore, the droop control process sacrifices the voltage amplitude and frequency of the micro-grid[4]. Figure 1 shows the droop control model when two distributed power supplies are running in parallel.

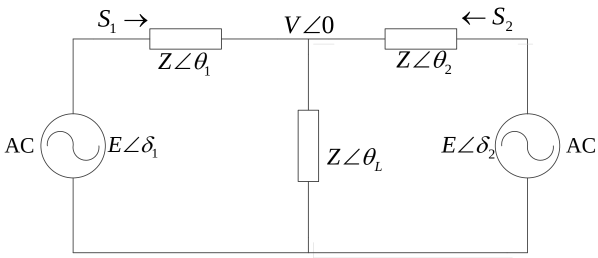


Figure 1 Droop control model for two distributed power supply in parallel

Power expression provided when distributed generation supply to load Z:

$$\begin{cases} P_i = \dfrac{E_i V}{Z_i}\cos(\theta_i - \delta_i) - \dfrac{V^2}{Z_i}\cos\theta_i \quad (i=1,2) \\ Q_i = \dfrac{E_i V}{Z_i}\sin(\theta_i - \delta_i) - \dfrac{V^2}{Z_i}\sin\theta_i \quad (i=1,2) \end{cases} \tag{1}$$

In expression (1), the active and reactive power output for distributed power supply, and the impedance and impedance angle of the line, and the voltage and phase angle are the voltage at the bus side. When the impedance of the line is sensitive, expression (1) can be changed to expression (2):

$$\begin{cases} P_i = \dfrac{E_i V}{Z_i}\delta_i (i=1,2) \\ Q_i = \dfrac{E_i V\text{-}V^2}{Z_i}\ (i=1,2) \end{cases} \tag{2}$$

Expression (2) shows that the active power of micro-grid is output by adjusting its phase angle, and reactive power is realized by adjusting its voltage amplitude, and finally realize decoupling control of active and reactive power of micro source. However, there is differential relationship between phase and frequency, that is expression (3):

$$f_i = \frac{\omega_i}{2\pi} = \frac{1}{2\pi}\cdot\frac{d\delta_i}{dt} \tag{3}$$

The characteristic curves of frequency and active power, voltage amplitude and reactive power [5]can be obtained as shown in Figure 2.

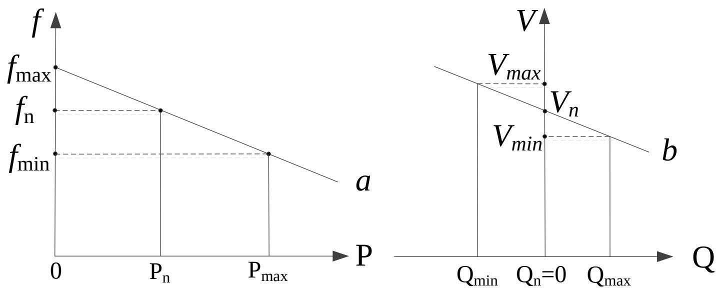


Figure 2 Schematic diagram of traditional droop control

where f_{max} and f_{min} represent the maximum and minimum frequency of the system output, f_n and P_n represent the reference frequency and the corresponding active power of the system, V_n and Q_n represent the reference voltage amplitude and corresponding reactive power of the system, m and n represent the droop characteristic curve coefficient, V_{max} and V_{min} represent the maximum and minimum voltage output of the system.

Then the droop characteristic curve expression[5] in the traditional droop control strategy is expression (4).

$$\begin{cases} f = f_n - a(P - P_n) & (0 \le P \le P_{\max}) \\ V = V_n - bQ & (Q_{\min} \le Q \le Q_{\max}) \end{cases} \tag{4}$$

3. Improved droop control strategy

In order to overcome the shortcomings of traditional droop control strategy, a nonlinear dynamic droop control strategy is proposed. Its schematic diagram is shown in Figure 3. According to the characteristics of hyperbolic tangent function, the function has the most value in its definition domain, and the difference between the maximum values is set as the offset of frequency and voltage, so as to ensure that the output frequency and voltage of micro-grid will not be offset too much, By the regulation of nonlinear dynamic droop control, the fixed droop coefficient used in traditional droop control strategy presents nonlinear characteristics with the function change, and has the fastest dynamic response speed and regulation ability at the maximum slope. With the droop regulation, the slope of droop curve of nonlinear dynamic droop control is gradually reduced, and the regulation ability is gradually reduced, so as to prevent over adjustment and ensure the stability of the system.

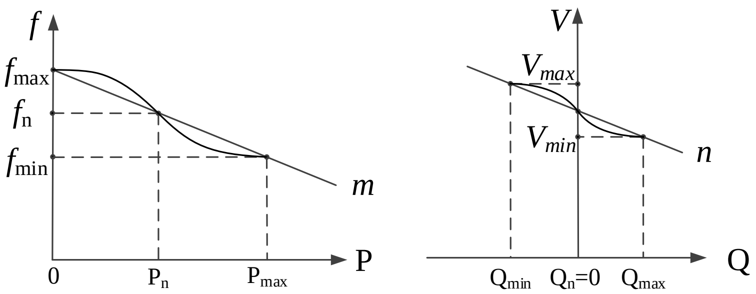


Figure 3 Schematic diagram of nonlinear dynamic droop control

The expression of droop curve of nonlinear dynamic droop control strategy is as follows:

$$\begin{cases} f = f_n - \Delta f \tanh \dfrac{3\left(P - P_n\right)}{P_n} \\ V = V_n - \Delta V \tanh\left(\dfrac{3Q}{Q_{\max}}\right) \end{cases} \tag{5}$$

where Δf and ΔV represent the maximum offset of frequency and voltage, which can make the output voltage and frequency of micro-grid system stable within the set range; Other parameters mean

ISSN 2706-655X Vol.3, Issue 3: 44-49, DOI: 10.25236/IJFET.2021.030308

that the traditional droop curve expression is consistent.

3.1 Simulation modeling and switch setting

The micro-grid system is constructed as shown in Figure 4: the distributed power supply in the figure adopts traditional droop control and nonlinear dynamic droop control respectively. There are three loads load1, load2, laod3 and three switches K1, K2 and K3 in the micro-grid. The micro-grid is connected to the main grid through the common end, and the connection with the main grid and the load switching are adjusted by the on-off control of the switch. The frequency and voltage stability of micro-grid are analyzed by the connection between micro-grid adjustment and main grid and load change. The output waveform of two droop control strategies is compared by simulation.

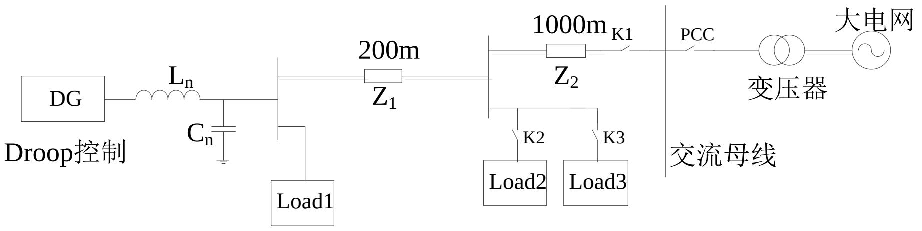


Figure 4 Simulation structure of micro-grid with droop control strategy

The main parameters of the simulation model are shown in Table 1:

Table 1 Main parameters of simulation model

category	parameter setting
distributed power supply	U_{DC}=0.8kV,L_n=0.6×10^{-3}H,C_n=1.5×10^{-3}F,R_n=10×10^{-3}Ω, U_O=380V
droop control parameter	droop control coefficient: a=2×10^{-5},b=4×10^{-4} PI:k_{up}=10,k_{ui}=100 P:k=5
reference value	f_n=50Hz,U_n=311
frequency fluctuation range	Δf= ±0.2Hz
voltage fluctuation range	ΔU= ±10V
load	*Load1*:25×10^{3}W+j5×10^{3}var,*Load2*:25×10^{3}W+j5×10^3, *Load3*:5×10^{3}W+j30×10^{3}var

Set the switch on / off of simulation model, as shown in Table 2.

Table 2 Switch action settings of simulation model

time	action	status
0-0.4s		Load1 running, island running status
0.4s	K2 off	transition state
0.4-0.6s		Load1 and load2 running, island running status
0.6s	K3 on	transition state
0.6-0.8s		Load1, load2 and load3 running, island running status
0.8s	K2,K3 off	transition state
0.8-1.0s		Load1 running, island running status
1.0s	K3 on	transition state
1.0-1.2s		Load1 and load3 running, island running status
1.2s	K2 on, K3 off	transition state
1.2-1.6s		Load1 and load2 running, island running status
1.6s	K2 off	transition state
1.6-1.8s		Load1 running, island running status
1.8s	K1 on	transition state
1.8-2.2		Load1 running, grid-connected status
2.2s	K1 off	transition state
2.2-3		Load1 running, island running status

ISSN 2706-655X Vol.3, Issue 3: 44-49, DOI: 10.25236/IJFET.2021.030308

3.2 Analysis of simulation results

The frequency change of traditional droop control strategy and nonlinear dynamic control strategy is shown in Figure 5. During the switching on and off process, the load changes with the change of active power, and also causes frequency fluctuation. The output frequency fluctuation range of micro-grid with traditional droop control strategy is 49.7-50.6 Hz, and the frequency fluctuation range is 0.9 Hz. There is a large deviation from the set value of 50Hz. The output frequency fluctuation range of micro-grid with nonlinear dynamic droop control strategy is 49.97-50.1hz and the frequency fluctuation range is 0.13 Hz. Compared with the two, the output frequency of the micro-grid with nonlinear dynamic droop control strategy is more stable and the stability of the system is higher.

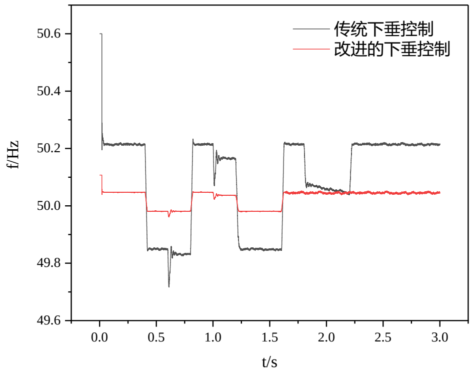
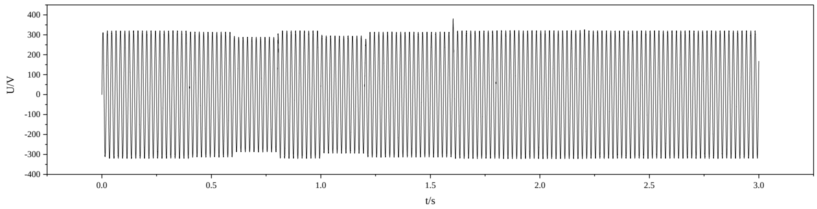
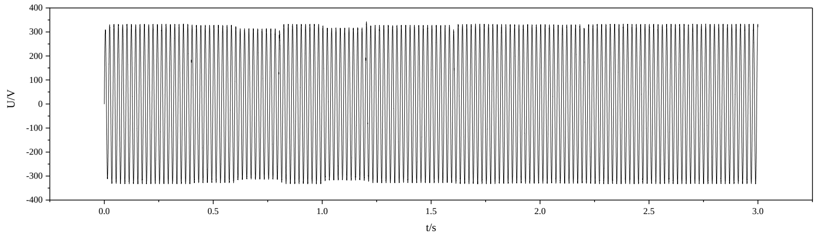


Figure 5 Comparison of frequency output of two droop control strategies

The output voltage waveform of micro-grid is shown in Figure 6, which adopts the traditional droop control strategy model and the improved droop control strategy model. It can be seen that the increase or decrease of reactive power of the system causes voltage offset in the process of switching on and off and load change. As shown in Figure 6 (a), the system is closed in sequence at the time of K2 of 0.4s and K3 of 0.6s. The voltage variation and offset of micro-grid system with traditional droop control strategy is large, and the output voltage waveform is lower than 300V. At the moment of 0.8s for K2 and K3, K2 and K3 are disconnected at the same time, and the system voltage is restored to about 311V. In the process of load switching, the voltage fluctuation of the system is large and will far exceed the set value, which has a great influence on the sensitive load in the power grid. As a comparison, as shown in Figure 6 (b), the output voltage waveform of model using nonlinear dynamic droop control strategy is always higher than 300V, whether it is closed at K2 and K3 (K2 closed point is 0.4s, 1.2s, K3 closing point is 0.6s, 1.0s) or at the break time (K2 breaking point is 0.8s, 1.6s, K3 disconnection point is 0.8s and 1.2s). The comparison of the results in Figure 6 shows that the output voltage of the micro-grid with improved droop control strategy is more stable.



(a) Voltage output diagram of traditional droop control strategy



(b) Voltage output diagram of nonlinear dynamic droop control strategy

Figure 6 Comparison of voltage output of two droop control

ISSN 2706-655X Vol.3, Issue 3: 44-49, DOI: 10.25236/IJFET.2021.030308

4. Conclusion

This paper studies and analyzes the droop control strategy of the micro-grid interface inverter. Aiming at the shortcomings of the traditional droop control strategy, a nonlinear dynamic droop control strategy is studied. The simulation results are compared with the traditional droop control strategy, When the internal load of the micro-grid is changed by the improved droop control strategy, the frequency and output voltage of the system are more stable, which ensures the stability of the micro-grid operation.

References

[1] Reginaldo V. Ferreira,Sidelmo M. Silva,Hélio M. A(2019). Antunes,Giri Venkataramanan. Dynamic Analysis of Grid-Connected Droop-Controlled Converters and Synchronverters[J]. Journal of Control, Automation and Electrical Systems,vol.30,no.5.

[2] Ko BS, Lee GY, Kim SI, et al(2018). A positioning method of distributed power system by considering characteristics of droop control in a dc microgrid[J]. Journal of Electrical Engineering & Technology, vol.13,no.2,pp.620-630.

[3] Xueshen Zhao,Ke Peng,Qing Wan,Xi Yan,Cong Zhang,Yuehao Zhao(2018). Research on Droop Control Strategy of Multi-terminal AC/DC Hybrid Distribution System[J]. Energy Procedia,145.

[4] Sahoo S, Mishra S, Padhy NP. A decentralized adaptive droop based power management cheme in autonomous DC microgrid[C]. Power & Energy Engineering Conference. New York: IEEE, 2016: 1018-1022.

[5] Manasa Mythri Kodali,K. S. Srikanth(2016). Power Management Strategy for Hybrid Microgrid System under Islanded Condition using Adaptive Droop Control[J]. Indian Journal of Science and Technology, vol.9, no.28.