REACTIVE POWER AND VOLTAGE PARAMETERS CONTROL IN NETWORK SYSTEM

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Abstract: *Energy supply systems on the modern aspect of the development of engineering and technology are considered as the Internet, an infrastructure designed to support energy, information, economic and financial relationships between all entities involved in the production, transportation, and consumption of all types of energy. The thesis aims to a reactive power and voltage control management control strategy based on virtual-reactance. Furthermore, this thesis's goal at the higher reactive power management control complexity caused by the access of distributed power systems, and the problem such as large data exchange capacity, low accuracy of reactive power distribution, a slow convergence rate, and so on, may appear when the controlled objects are large. Simultaneously, big amounts of data are treated to parallel processing by using the parallel distributed processing, realize the uncertainty transformation between qualitative concept and quantitative value. In the thesis, technologies, and devices of the reactive power and voltage control smart grid system studied in this work serve as basic scientific materials for increasing the efficiency of energy use.*

Key words: *reactive power control, voltage control, distributed generator in network system.*

INTRODUCTION

Nowadays, the quick evolution of a smart network plays a major role in optimizing resource assignment, defensive capability, efficiency, compatibility operation, management and control, and facilitating power system transactions [1,2]. A Distributed Generator (DG) plays an active role in increasing demand side management, grid flexibility, distribution network reconstruction, and solving environmental problems [3]. Nevertheless, with the gradual expansion of the power grid, the power storage and the grid connection of frequency conversion equipment, PV panels, and wind power systems make the network topography of the electrical power system more and more complex [4]. Several factors of the power system, such as different load modes, line reactance mismatch, cyclic reactive current, and distributed power system overload, can influence the distribution of reactive power [5,6,7], which all raise higher requirements for the voltage reactive power control strategy and the global optimal allocation of the reactive power grid.

VOLTAGE REACTIVE POWER MANAGEMENT CONTROL

P_i and Q_i are the active and reactive power transmitted by the inverter, U_i is the voltage amplitude of the inverter power output node i, δ_i is the voltage phase angle of the inverter power output node i, and U_j is the node j voltage amplitude, the impedance between node i and node j is $Z_i = R_i + j\ X_i$, then the apparent power generated by each DG is

$$S_i = U_i I_i^* = U_i \delta_i \left(\frac{U_i \delta_i - U_j}{R_i + jX_i}\right)^* \qquad (1)$$

Separating present and imaginary parts of (1) yields:

$$P_i = \frac{U_i}{R_i^2 + X_i^2}\left[R_i\left(U_i - U_j \cos\delta_i\right) + U_j X_i \sin\delta_i\right], \qquad (2)$$

$$Q_i = \frac{U_i}{R_i^2 + X_i^2}\left[X_i\left(U_i - U_j \cos\delta_i\right) - U_j R_i \sin\delta_i\right]. \qquad (3)$$

The change in DG angular frequency has a regulating effect on the active power of the system. By changing the output voltage of a DG, the reactive power of the system can be adjusted, the adjustment of the angular power and output voltage of each DG to the system power are shown in the following equation (4) and (5)

$$\omega_i = \omega_i^{exp} - \nabla_{P_i} P_i^{exp}, \qquad (4)$$

$$U_i = U_i^{exp} - \nabla_{Q_i} Q_i^{exp}. \qquad (5)$$

where: ω_i is the angular frequency of the i-th DG, U_i is the voltage amplitude of the output of the i-th DG, ω_i^{exp} and U_i^{exp} are the expected value of the angular frequency and the expected value of the voltage amplitude in the DG grid-connected mode, respectively, P_i^{exp} and Q_i^{exp} are the expected value of the active power and the expected value of the reactive power of the i-th DG, respectively, ∇_{P_i} is the proportional control coefficient of the virtual gradient of angular frequency, and ∇_{Q_i} is the proportional control coefficient of the virtual gradient of voltage amplitude. The value range of both ∇_{P_i} and ∇_{Q_i} is without the measurement unit, which can be calculated according to following equ; (6) and (7):

$$\nabla_{P_i} = \frac{\omega_{e*}\left(\omega_i^{max} - \omega_i^{min}\right)}{P_i^{max}} \qquad (6)$$

$$\nabla_{Q_i} = \frac{\left(U_i^{exp} - U_i^{min}\right)}{Q_i^{max}} \qquad (7)$$

where: P_i^{max} and Q_i^{max} are the output maximum active and reactive power of the i-th DG, respectively, ωe is the system rated angular frequency, ω_i^{min} and U_i^{min} are the angular frequency that allows the lower limit value and the voltage amplitude allows a lower limit of the i-th DG, respectively, ω_i^{max} is the allowable upper limit of the angular frequency of node i, U_i^{exp} is the expected value of node i voltage amplitude in grid connection mode.

REACTIVE POWER MANAGEMENT CONTROL METHODS OF DG

The virtual-reactance technology is based on the physical relationship between voltage current and reactance. It has the property of reshaping the output reactance of the inverter without additional losses, and can fully solve the coupling effect of inverter output power. By adjusting the export voltage of the inverter, it can reasonably distribute the total reactive power of the inverter. This thesis will introduce virtual reactance technology into a power distribution grid with a DG, when controlling the equivalent output reactance of the DG grid connection inverter, adding an adjustment component, thereby adjusting the virtual reactance value in real time to change the R/X ratio of the DG. This can fully prevent the distribution grid voltage from exceeding the limit, adjust the power factor, improve system transient response characteristics and control voltage and frequency within a reasonable range, and simultaneously coordinate the output reactance between multiple DGs. In addition, this can also reduce the bad effect of voltage reactive power coordination control between DGs, adjust the power factor, improve the transient response characteristics of the system, the voltage and frequency manage in a reasonable scope, and mutually coordinate the output reactance between multiple DGs, to minimize the negative effect of voltage reactive power coordinated control between the DGs. Eventually, the precise distribution of reactive power is achieved, and the system voltage is minimized by adjusting the virtual reactance to adapt the system voltage.

As a means to construct an adaptive virtual reactance that changes a DG in real time over time and realize reactive voltage management, we assumed that the integrated reactance value of the line, load and reactive power compensation equipment of the DG is X_L, then the equivalent reactance value X_{equ} of the circuit where the DG is located can be calculated according to following equation (8):

$$X_{equ} = X_L + X_{vir}, \qquad (8)$$

where, X_{vir} is the virtual-reactance for the real-time control of voltage and adjustment of reactive power distribution. For example, following two DG parallel running simple systems that simultaneously supply the same load as shown in Figure-1.

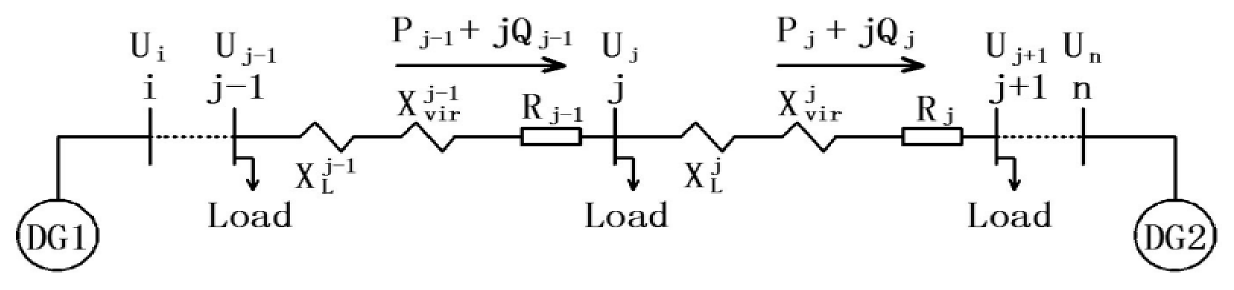

Figure-1. Elementary node system with two distributed generator.

At the coupling unit between active and reactive power, the *i*-th DG is selected as the reference point, and the voltage reference value of the DG is assumed to be U_{is}, i.e:

$$U_i = U_{is}. \tag{9}$$

The virtual-reactance meaning of the DG can be calculated according to equation (10).

$$X_{vir} = X * \frac{U_{ref}^{un} - U_j}{U_j^{un} - U_j} * \frac{\nabla_{Q_j}}{\nabla_{Q_{ref}}}, \tag{10}$$

where: X is the adaptive reactance meaning for present time control of the DG equivalent output reactance, U_{ref}^{un} is the reference unit of the no-load output voltage of the reference DG, U_j^{un} is the no-load voltage output value of the *j*-th DG, U_j is the voltage amplitude output by the *j*-th DG, and ∇_{Q_j} is the virtual voltage amplitude of the *j*-th DG, $\nabla_{Q_{ref}}$ is the virtual gradient of the reference DG voltage amplitude.

CONCLUSIONS

The voltage and reactive power management control strategy researched in this thesis is based on an accurate reactive power distribution grid. The virtual-reactance is capable of doing adaptive adjustment in real-time. The result describes that it can change the resistance-inductance ratio of a DG, and hence the output reactance between multiple DGs can be coordinated, thereby forming an accurate reactive power distribution grid between the load and the power supply. In order to avoid the centralized processing of massive data in the control center and save computing time, this thesis used parallelly process massive data, so as to achieve the management of the system voltage and reactive power. It provides a reference for the research of grid-connected and voltage reactive power management control strategies for distributed power in smart grid systems.

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