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# Hierarchical Coordinated Voltage Control of Active Distribution Network and Microgrid Based on Multi-Agent Technology

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***ABSTRACT.*** *In the new era, consumers put forward higher requirements for the active distribution network. For safety reasons, it is also necessary to study the management technology of microgrid connected to the active distribution network. Based on this, this paper proposes a multi-agent based hierarchical coordinated voltage control technology for active distribution network Agent microgrid. Considering the characteristics of various distributed power sources, a multi-agent model of distributed power sources is established. Using multi-agent system to realize the coordinated control of distributed generation and traditional transformer regulation simplifies the calculation complexity on the basis of ensuring the accuracy of traditional power flow calculation, and has strong application value. Voltage and reactive power control based on multi-agent technology has better flexibility, intelligence and openness, and has achieved a leap forward compared with conventional power electronics technology.*

***KEYWORDS:*** *Multi-Agent, Distributed power supply, Microgrid, Voltage and reactive power control, Active distribution network*

## 1. Introduction

With the increasing pressure of global resources and environment, the social demands for environmental protection, energy conservation and emission reduction and sustainable development are increasing day by day. The mature development of micro-grid technology is an effective means to implement active management and control for local load balance of distribution network, improvement of power supply reliability and improvement of renewable energy utilization rate [1]. Due to the

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distributed characteristics, massive control data and flexible control methods of microgrid, traditional unified scheduling and centralized control methods are difficult to effectively solve these problems. Distributed control is to achieve energy management objectives through self-management and cooperative operation of local equipment [2], which can be well adapted to the characteristics of decentralized and changeable power supply and flexible grid structure in active distribution network. The application of microgrid technology to energy conservation and emission reduction and to improve the safety of power supply structure has laid a stable foundation for the intelligent and green development of power distribution network [3]. Microgrid technology solves the problem of new energy sources well, effectively controls the power distribution network's ability to absorb renewable energy and reliable power supply, and improves energy efficiency and power service quality. On the basis of referring to some related researches on voltage and reactive power control, this paper proposes a three-level distributed voltage and reactive power control system for microgrid based on multi-Agent, and focuses on the two-level voltage control of the system, and establishes the mathematical model of voltage control.

## 2. Multi-Agent Active Distribution Network and Microgrid Voltage and Reactive Power Control System

### *2.1 The structure design of voltage and reactive power control system for active distribution network and Microgrid based on multi-agent*

Active power distribution network includes various types of distributed power sources and load integration, where photovoltaic power generation represents renewable clean energy power generation and micro gas turbine represents small distributed thermal power generation. Through reactive power regulation by voltage and reactive power control equipment in each region, the characteristic that reactive power cannot be transmitted for a long distance is well solved, and reactive power local balance is realized [4]. When the microgrid operates alone, it can profit by transferring peak load based on the peak-valley electricity price mechanism, thus reducing its equivalent operation and maintenance costs. After the full-network voltage sensing is realized, the active distribution network can ensure that the full-network voltage is within the limit value requirements by adjusting the output power on the basis of the existing data information. Under normal circumstances, the microgrid is connected to the main distribution network, and when receiving an off-grid operation instruction or a fault occurs, the microgrid is disconnected from the main distribution network; The smaller the loss of power load, the smaller the loss to the power supply side and the user side, i.e. the greater the benefit [5]. When the microgrid is in the grid-connected operation mode, the microgrid can not only receive power from other grids, but also output power to other grids.

Figure 1 below shows the technical framework of distributed autonomous

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operation proposed in this paper, which is divided into two levels. The first level is the autonomous operation balance of power supply and load in each region. The second layer is the coordination and complementary balance between regions.

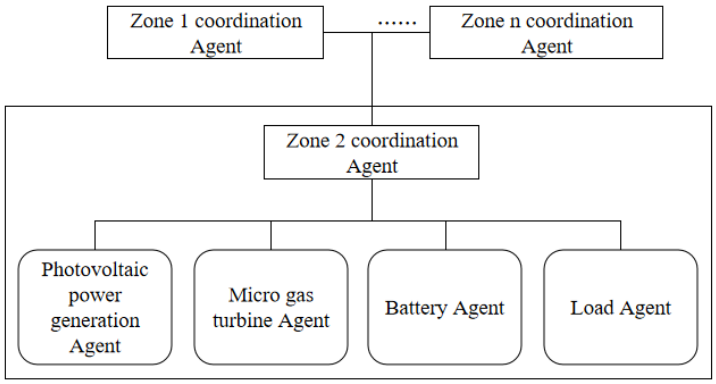


*Figure 1 Technical framework for autonomous operation*

Microgrid can scientifically and effectively control the power generation load in units, and can well integrate and efficiently utilize distributed power sources in microgrid. In the case of grid-connected operation, the main grid and the microgrid can provide a certain amount of electric energy to the load. Once a grid failure occurs, the microgrid will automatically disconnect. It can automatically obtain environmental information and make response, and can also carry out energy coordination interaction with other Agent in the system, send out information or obtain information, and make response according to the received information. The voltage and reactive power data of each microgrid level Agent are collected, the operation state of the whole grid is analyzed, and the state of the whole grid is evaluated. And with the increase of the number of pilot nodes, the computational complexity of region division will increase significantly. Agent can independently manage and control objects, store data and upload information to coordination agent in real time [6]. However, the active and reactive power generated will change at any time according to the power balance condition inside the system, which is similar to the balance node. This control method is mainly used in the main controller unit when the microgrid island is running. The obtained policies are fed back to the sub-agents, corrected, and after many iterations and satisfaction verification, the user-side policy set is stored in the knowledge base.

### *2.2 Mathematical algorithm of secondary voltage control*

Monitor and control the power level and start-stop status of photovoltaic power

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generation equipment to ensure reliable and safe operation of the equipment. That is, the voltage change trend within a certain range is estimated on the basis of known quantity measurement, and the voltage data of each node in the distribution network need not be known to ensure that the voltage of each node in the sensing area is within the limit range. Communicating with the upper-level main distribution network, on the one hand, receiving the instructions from the main distribution network to disconnect from the network; On the other hand, it monitors the operation status of the main distribution network, and can coordinate with the main distribution network in time in case of failure, disconnect the connection with the main distribution network and implement off-grid operation [7]. It provides a new solution for fault recovery. At the same time, there are both interest correlation and interest conflict between the power grid side and the user side.

In this paper, it is assumed that the microgrid group consists of three microgrid, Agent the model based on multi-agent is [8]

$$[a_1, a_2, a_3, \Omega_1, \Omega_2, \Omega_3, T, S, O, R] \quad (1)$$

Where: $a_1, a_2, a_3$ is the limited action set of each microgrid; $\Omega_1, \Omega_2, \Omega_3$ is the limited observation set of each microgrid; $T$ is the state transition function, and $t(s, a, s^{'})$ is the transition probability distribution from state $s$ taking action $a$ to state $s^{'}$; $S$ is a finite state set of microgrid groups; $O(d, a, s^{'}, o)$ is the probability of observing $o$ when moving to state $s^{'}$ after taking action a for state $s$; $R$ is the feedback equation.

If there are some fuzzy management orders at the highest level and the central controller of the microgrid has no right to reject them, it will cause harm to the normal operation of the microgrid. Active application of microgrid technology to achieve effective integration of distributed power sources and users, and access of microgrid technology to large power grids in the form of intelligent units. Distributed generation has strong volatility and instability, which has a great impact on the quality of voltage. In order to meet the demand for electricity and reduce the cost of electricity, monitoring and controlling the load on and off, power changes, management of load priority, etc.

## 3. Multi-Agent Hierarchical Coordinated Voltage Control Strategy

The coordination Agent makes the optimal control action command to the execution Agent according to the feedback information of the control Agent and its own microgrid voltage and reactive power monitoring. Considering the characteristics of different types of distributed power sources, an Agent model is built to carry out agent autonomy for distributed power sources and loads in the network,

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and output coordination rules for complementary and coordinated operation of various types of distributed power sources are designed. Energy storage in microgrid shares its remaining capacity. The sensing of the node with the highest regional voltage level can be realized by measuring the voltages of relevant nodes in real time. When the Microgrid Agent detects that the local voltage and reactive power are abnormal, it calculates the voltage and reactive power deviation according to the above two-level voltage and reactive power control algorithm and makes the optimal operation action selection. The coordination agent first sends a signal to the control agent to switch from V/F control to pre-synchronization control. The grid-connected detection agent starts grid-connected detection of the microgrid voltage and sends the detection result to the coordination agent. Based on this voltage and the set reference value, the corresponding control rules are formulated. The voltage control effect is good, and the required reactive power is relatively small, which can effectively reduce the power grid loss [9].

Each power supply is prioritized according to the cleanliness, photovoltaic has the highest priority, storage battery takes second place, and micro gas turbine has the lowest priority. Economy:

$$C_{\min} = C_{power} + C_{loss} \quad (2)$$

Where: $C_{\min}$ is the electricity cost; $C_{power}$ is the electricity price cost of the corresponding power supply; $C_{loss}$ is the power transmission cost of the corresponding power supply.

Each load is prioritized according to its importance, with interruptible load having the lowest priority. Economy: that is, power supply has the highest income.

$$E_{\max} = E_{power} - E_{loss} \quad (3)$$

Where: $E_{\max}$ is the power supply income; $E_{power}$ is the electricity price income of the corresponding power supply; $E_{loss}$ is the power transmission cost of the corresponding power supply.

The test program was written by MATLAB, and a micro-grid and active distribution network system with 3 units was constructed, and connected to 2 typical European micro-grid structures [10]. The unit characteristic data of microgrid and active distribution system are shown in Table 1.

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*Table 1 Unit characteristic data*

| Unit serial number | Lower power limit/kW | Power limit/kW | Up-regulation rate / ( kW · min $^{-1}$ ) | $a_i$ / (Yuan· MW $^{-2}$ ) | $b_i$ / (Yuan· MW $^{-1}$ |
|---|---|---|---|---|---|
| 1 | 200 | 600 | 6 | 0.012 | 8.63 |
| 2 | 400 | 1200 | 15 | 0.032 | 5.52 |
| 3 | 100 | 500 | 15 | 0.044 | 6.77 |

Strategy is a complete description of how the participants play the game. It refers to the action plan that each participant can take in the game. Each participant has a variety of strategies to choose from. The fully distributed control method controls the power supply and load separately, reducing the calculation and communication volume of each central controller. However, the distributed control of power supply and load lacks data exchange between power supply and load. The system structure of the active power distribution network must be operated effectively, and the micro-grid, active power distribution and distributed power supply must be supervised and controlled, and the information and energy must be communicated in time, thus greatly improving the stability of power grid operation in our country. In the process of grid-connected operation of active distribution network and distributed power supply, the large power grid is mainly taken as the support, and a combined operation system is formed by means of active distribution network and a plurality of microgrid. Each microgrid achieves the goal of coordination and mutual aid through surplus capacity sharing, and the distributed power sources in the area are automatically absorbed, thus effectively reducing the exchange power between the microgrid area and the main network. Through multi-agent autonomy, it dynamically responds to the changes of distributed power output and load demand in the active distribution network, and realizes autonomous, balanced and efficient operation of the active distribution network after the distributed power is connected.

Considering the influence of randomness of distributed generation, the dynamic optimization submodel based on maximum dissatisfaction dynamically adjusts the distribution probability of each generation of evolutionary population, which can obtain the optimal coordinated scheduling decision of active distribution network and microgrid under the condition of further ensuring system stability. The active power distribution network, microgrid and the whole system are optimized respectively, and the results are shown in Table 2.

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*Table 2 Economic benefits under three optimization objectives*

| Optimization objective | Cost of active distribution network (Yuan) | Microgrid cost (Yuan) | Total system cost (Yuan) |
|---|---|---|---|
| Active distribution network | 15522.32 | 9528.71 | 25,051.03 |
| Overall | 11037.07 | 8723.74 | 19,760.81 |
| Microgrid | 14926.67 | 6942.04 | 21,868.71 |

Here, the system is divided into microgrid forms, and the interconnection between microgrid is required to be reduced as much as possible, showing weak coupling relationship, so as to ensure that the secondary voltage control in one microgrid will not lead to voltage instability of another microgrid. Fig. 2 shows the reactive power output of the generator after load disturbance. after multi-Agent voltage and reactive power control is applied, the reactive power output can be rapidly and effectively increased by adjusting the automatic voltage regulator of the generator to make up for the reactive power deficiency of the system.

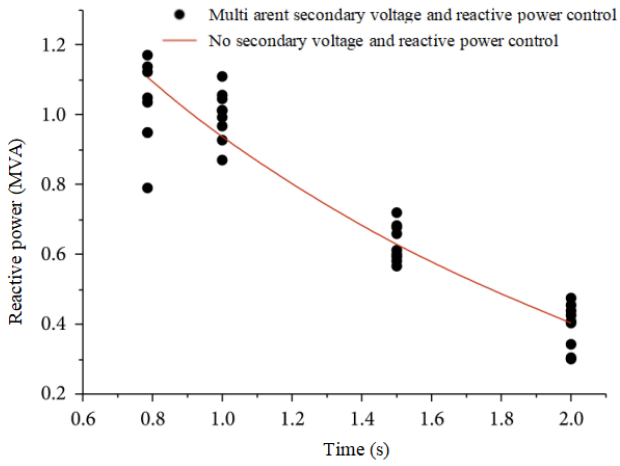


*Figure 2 No-power output curve of generator under load disturbance*

After the microgrid is connected to the active distribution network, a highly interactive network system is formed in time. At the same time, the diversity, multi-level, multi-constraint, multi-mode and other characteristics of voltage distribution become problems in the design optimization of nonlinear systems. However, the introduction of microgrid can effectively adjust the power size and flow direction of the active distribution network, thus improving the utilization efficiency of distributed power sources. Microgrid has relatively more spare parts for systems

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with poor reliability and relatively less spare parts for systems with higher reliability, which is in line with the actual situation. The basic idea is to divide the microgrid into individual unit microgrid according to the electrical distance between power generation equipment and load, while the microgrid composed of unit microgrid is called combined microgrid. Assuming that for a certain fault point, the power grid agent and the customer general agent respectively give two different strategies and can randomly form four recovery schemes. If this value is set to or slightly lower than the maximum power under the corresponding illumination temperature in each time period, the photovoltaic reactive power output capacity will be restricted. If the grid connection requirements are met, the islanding detection agent is controlled to close the switch at PCC, and the control agent is controlled to change the control method at the same time, the pre-synchronization control is switched to the P/Q control, and the microgrid is smoothly switched to the grid connection operation.

## 4. Summary

China has a large population in the world and is the country with the most serious phenomena of environmental pollution and energy depletion. However, the widespread application of microgrid technology effectively controls and manages this problem and has been listed as a key research object in China. The hybrid operation control method of microgrid based on multi-agent technology proposed in this paper has the characteristics of local autonomous operation Agent unified dispatching operation by the central controller of microgrid in the whole network, thus not only realizing the normal operation control of microgrid in function. The combination of microgrid and main distribution network has greatly improved the reliability of power supply, improved power quality and reduced power loss. Compared with traditional power flow calculation, the proposed sensing algorithm uses the data collected by remote terminal equipment and voltage sensing algorithm to realize voltage distribution sensing of the whole network, and its effectiveness is verified by an example. A plurality of microgrid can effectively improve the regional energy utilization efficiency, transfer the regional peak load and reduce the equivalent operation and maintenance cost by sharing the residual energy storage capacity of each microgrid.

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