CONVERTER MAGAZINE
Volume 2021, No. 8

Research on Voltage Control of Active Distribution Network With Micro Grid Based on Multi-Agent Technology

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Abstract

In fact, due to the relative backwardness of distribution network management and the complexity of network structure, not all nodes are equipped with load real-time measuring equipment, and because of the huge number of distribution network nodes, it is not advisable to carry out accurate power flow calculation to obtain the voltage distribution of the whole distribution network from both economic and technical aspects. In this paper, a double-layer cooperative MAS(multi-agent systems) control framework is established, and intelligent agents are set in feeder layer and node area layer respectively. Functions that need quick response and can be judged and decided only based on local information are independently performed by the lower-level regional agents. Using the information of voltage perception, the reactive output of distributed power supply can be regulated by voltage estimation algorithm, so that distributed power supply can participate in voltage regulation, and multi-agent technology can be used to make the reactive power of distributed power supply cooperate with on-load transformer to realize comprehensive voltage control of active distribution network. The reactive power generated by various DG(distributed generations) in microgrid is brought into the optimized control variables, and combined with the traditional control strategy, various reactive power sources at microgrid level are coordinated to control the voltage of each contact point.

***Keywords**: Mas, Microgrid, Active distribution network, Voltage control*

Ⅰ. Introduction

With the increasing awareness of fossil energy shortage and environmental protection, it has become a development trend that DG(distributed generations) is connected to make the distribution network active [1-3]. Micro-power grid is a system composed of micro-power supply and load, which is a single controlled unit. Micro-power supply can take many forms, including photovoltaic power generation, wind power generation, cogeneration of heat, electricity and cooling, and various energy storage devices such as storage battery, super capacitor and superconducting electromagnetic energy storage system. However, the access of DG will lead to the complexity and diversity of the original single power flow of distribution network, which makes the traditional means of voltage regulation and control of distribution network face serious challenges [4-5].

With the rapid development of artificial intelligence, MAS (Multi-Agent Systems) has been widely used. MAS is a system that can intelligently and flexibly respond to the changes of working conditions and the demands of surrounding processes. From the presentation of Agent to the present, the presentation of distributed problems and their solutions have greatly promoted the development of Agent technology. At this stage, the main purpose of the research is no longer to deal with all kinds of questions by agents independently, but to pay more attention to how to put several agents together to form a MAS [6-7]. Literature [8] considers that when the traditional voltage control methods are ineffective, the method of reducing DG active output can restore the out-of-limit node voltage to normal. Reference [9] directly controls the active and reactive power of DG to meet the limitations of access point voltage and line heat capacity. Literature [10] puts forward six initiatives of active distribution network, which are “active planning, active management, active control and active service, active response of users and active participation of DG”. Based on this, the planning technology of active distribution network, operation control technology of DG and

ISSN: 0010-8189

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demand side response technology are discussed. Literature [11] expounds the origin and differences of active distribution network, microgrid and active distribution network, and highlights the necessity of developing active distribution network through comparison.

This paper mainly studies the control strategy of the active distribution network with microgrid, using multi-agent technology to control the active distribution network with microgrid, and using hybrid control strategy. Compared with centralized and decentralized control methods, the multi-agent technology of hybrid control is not only convenient for the instruction transmission between the upper and lower levels, but also more convenient for the information among the lower agents at the same level, that is, it combines the advantages of centralized and decentralized control methods of multi-agent technology.

Ⅱ. The Basic Theory of Mas

MAS provides an effective framework and implementation mechanism for realizing distributed and coordinated control for complex interconnected systems. The observation of the physical environment by Agent is usually measured by sensors. The observation of computing environment is obtained through system calling, program calling, information exchange and so on. Agent's response to environment can also be divided into two categories: physical and computational. For the distribution network control agent, its response to the physical environment is to change the grid and operation mode and adjust the load through the opening and closing of the control switch. The response to the computing environment includes storing decision results, sending messages, adjusting policies and so on.

The most outstanding advantages of MAS are autonomy, flexibility, cooperation and scalability. Autonomy means that agent can make their own response and behavior planning based on the observation of external environment and built-in knowledge or rules. Flexibility is mainly for system configuration.

In MAS, Agents can communicate and cooperate with each other to jointly solve complex problems that cannot be solved by a single agent [12]. MAS can simulate the organizations and groups of human society, and use its ways of thinking and means of dealing with problems to accomplish tasks together. An important feature of MAS is that Agent can communicate with each other. Agents can obtain information, negotiate with other agents and even change the goals and beliefs of other agents through communication.

Taking the distribution control MAS as an example, flexibility means that the controller can be deployed to any feeder line, and then automatically change its protection and control settings according to the sensed operation status of distributed power supply. Cooperation means that agents can interact with other agents through negotiation and interaction, thus forming mutual cooperation. Scalability means that the system can easily add new functions without affecting the existing function settings.

Ⅲ. Voltage Control of Active Distribution Network with Microgrid

A. Distributed Hierarchical Mas

For the actual distribution network, each agent in MAS is attached to the intelligent equipment of the distribution network in the form of software. For example, the distributed power agent is installed in the distributed power control device, the switch agent will be installed on the corresponding switch equipment, the microgrid agent will be installed in the microgrid control center and the feeder agent will be installed in the substation. Various communication networks can be used for communication between agents.

This paper only studies the function and cooperation mechanism of the agent, not the hardware equipment, and also does not consider the failure of the communication network. The MAS structure established in this paper is shown in Figure 1.

ISSN: 0010-8189

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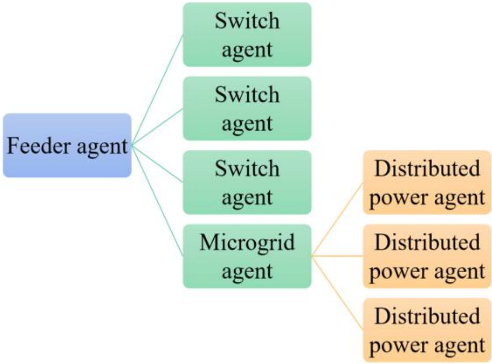

Fig.1 Mas of Distributed Control Structure

The whole system is divided into three layers according to the actual situation of distribution network:

(1) The first layer only contains feeder agents, and information can be exchanged between feeder agents;

(2) The second layer includes switch agent, microgrid agent, switch agent and microgrid agent, which can interact with the feeder agent of the first layer. In the physical structure of the power grid, these switches and microgrid belong to the feeder where the feeder agent is located.

(3)The third layer contains distributed power agents, which only interact with microgrid agents for information. In the physical structure of the power grid, these distributed power agents belong to the microgrid managed by microgrid agents.

The microgrid agent belongs to the second layer in the hierarchical structure, which has communication links with the distributed power agent at the bottom layer and with the feeder agent at the top layer. The microgrid agent has three functions:

(1)When the microgrid is established, the microgrid will send information to the feeder agent of the feeder where it is located, including the communication address of the microgrid;

(2)When a distributed power supply is newly added in the microgrid, the information of the distributed power supply agent is received and forwarded to the feeder agent;

(3)Receive the command from the feeder agent, which includes asking its internal distributed power supply to be full and stopping full.

The feeder agent is located at the top layer of the whole hierarchical structure and has the function of updating network data. When a microgrid or distributed power supply is added, the data can be updated in time by interacting with the microgrid agent information. And send the updated data to the feeder agent connected with it to complete the data update of the whole network. After receiving the fault information sent by the switch agent, send the information to all microgrid agents, and order their internal distributed power supply to be fully developed. Then, according to the hours of fault repair, order the switch agent on the feeder to optimize the grid structure in different periods, and accept its calculation structure. Then, all the calculated grid structures are composed into candidate grid sets.

Fig. 2 shows the information interaction structure of RTE(Remote terminal equipment). It can be seen that the information interaction structure is tree-like from the main transformer, in which each line is a branch of the tree, and each RTE is each node on the branch. According to the scope of information interaction, it can be defined as three levels: local level, line level and distribution network level.

ISSN: 0010-8189

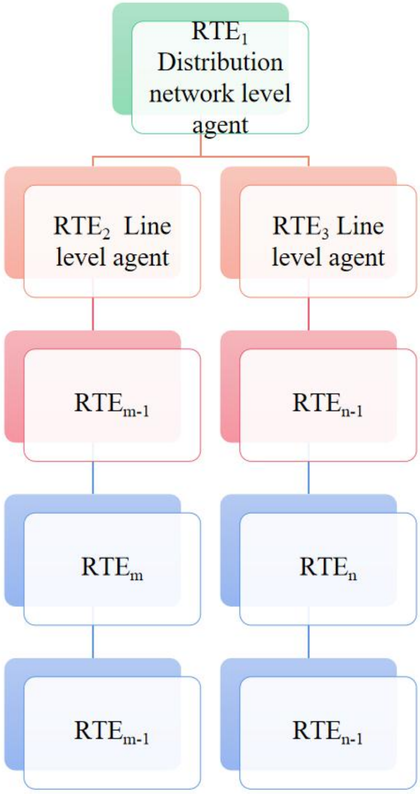

Fig.2 Rte Information Interaction Structure

As can be seen from Figure 2, firstly, the voltage sensing of distribution network is divided into multiple local voltage sensing, then the sensing algorithm is used to perform local sensing from the bottom RTE, and finally the voltage sensing of the whole network is realized by processing and interacting the information layer by layer. Then, the calculation results and self-perceived data are transmitted to the upstream RTE, and the above process is repeated to obtain the voltage distribution of the whole line. Each branch transmits the self-perceived voltage distribution to the distribution network agent, and finally obtains the voltage distribution of the whole network.

B. Control Algorithm of Active Distribution Power with Microgrid

The original intention of MAS is to make the control mode operate according to the thinking mode of human mind. Compared with the traditional control mode, the multi-agent control system is a distributed intelligent model with more flexible autonomy and cooperation, and stronger ability to respond to emergencies.

In this paper, the droop control is considered to control the active distribution power with microgrid, that is, the droop characteristic curve similar to the primary frequency of generator is used to control the voltage, so that the curve of system operation is constantly adjusted to approach the droop characteristic curve set by the system.

ISSN: 0010-8189

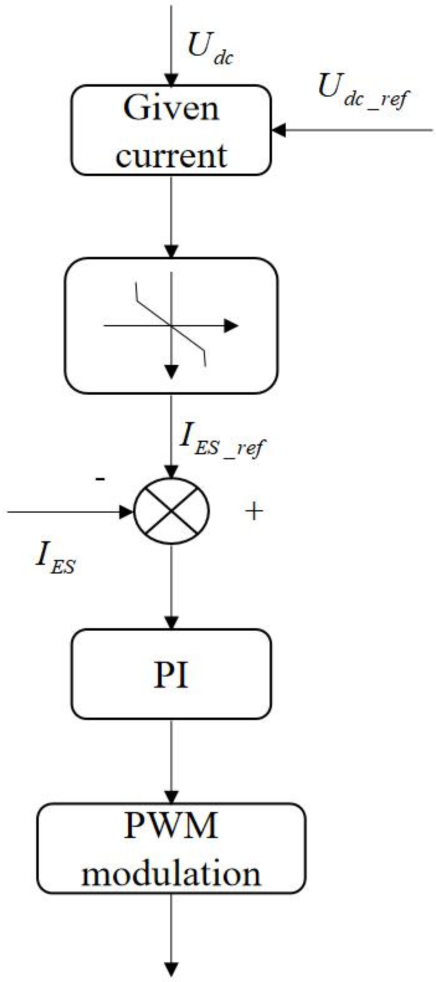

Fig.3 Dc Voltage Stabilizing Control Block Diagram

As shown in Figure 3, the microgrid is controlled by droop control, and the given I_{ES} can be expressed by the following formula:

$$I_{ES} = \frac{U_{dc\_ref} - U_{dc}}{\beta U_{dc}} \approx \frac{U_{dc\_ref} - U_{dc}}{\beta U_{dc\_ref}} = k\left(U_{dc\_ref} - U_{dc}\right) \quad (1)$$

In the formula, k is the droop control coefficient, and its value depends on the size of the energy storage battery pack. In the process of controlling the microgrid by droop control, the value of k is the most important factor for the safe and stable operation of the whole system.

However, using droop control to control the microgrid, there are many uncertain factors in the operation of active distribution power with microgrid containing various renewable energy sources, which will cause the microgrid control to be constantly adjusted, so this method may pose some potential threats to the microgrid.

C. Multi-Distributed Power Coordinated Optimal Control Model for Voltage of Each Contact Point of Microgrid

There are various forms of energy input and output in microgrid, including wind, light and other energy inputs, electricity, heat and other energy outputs, and various energy conversion devices, and these factors make the operation characteristics of microgrid more complex than that of a single DG.

If centralized and unified decision-making is implemented, the communication requirements are higher, so the microgrid hierarchical control mode came into being. Generally, there is a central controller in the hierarchical control mode, which is used to control the output power of each DG and realize the start-stop operation of each DG, so as to maintain the stability of system voltage and frequency. At the distribution network level, the equivalent generator reactive power output is included in the control variables, and the optimal power flow is calculated according to the distribution network optimization model, so that the voltage reference values at each contact point of the microgrid can be obtained.

This paper establishes the following optimization model:

Distribution network optimization model:

$$\begin{cases} \min f^D\left(x^D, u_d^D, u_c^D, Q_B\right) = P_{loss}^D \\ g^D\left(x^D, u_d^D, u_c^D, Q_B\right) = 0 \\ h^D\left(x^D, u_d^D, u_c^D, Q_B\right) \le 0 \end{cases} \quad (2)$$

Microgrid optimization model:

$$\begin{cases} \min f^M\left(x^M, u_d^M, u_c^M\right) = \left(V_{PCC} - V_{ref}\right)^2 \\ g^M\left(x^M, u_d^M, u_c^M\right) = 0 \\ h^M\left(x^M, u_d^M, u_c^M\right) \le 0 \end{cases} \quad (3)$$

Equation, f --The objective function of distribution network and microgrid optimization calculation, in which the distribution network f is the smallest P_{loss} (active power loss), and the objective function of microgrid optimization model is the smallest square of the difference between the voltage reference value and the actual value of each contact point;

x --State variable set, including node voltage parameters of distribution microgrid system;

u_d, u_c --And discrete control variables, including reactive power generated by various reactive power sources and gear position of on-load voltage regulating transformer, etc.

D, M --Active distribution network and microgrid;

V_{ref} --Voltage reference value of each contact point given after optimization of distribution network;

Q_B --The reactive power generated by equivalent generators at each contact point of microgrid is used as the continuous control variable in the distribution network optimization model.

g, h --Represents equality and inequality constraints respectively.

The research goal of this paper is multi-DG coordinated optimal control of the voltage of each contact point of microgrid. According to the optimization control method and model mentioned above, the distribution network and microgrid optimization model are solved respectively based on the interior point method. The specific solution process is shown in Figure 4 below:

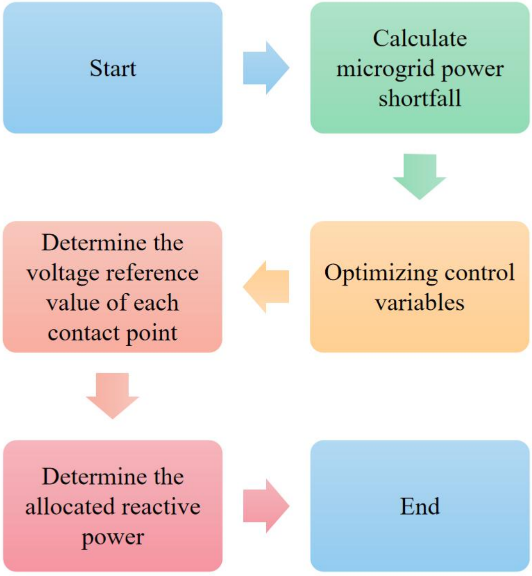

Fig.4 Optimization Calculation Flow Chart

Ignore the power loss at the microgrid level, calculate the internal power gap of microgrid, and equate each microgrid with a generator at each corresponding contact point at the distribution network level. The reactive power output of this equivalent generator is taken as the control variable, which is incorporated into the distribution network optimization model. Based on the interior point method, the optimal power flow of distribution network is calculated, and the voltage values of each contact point in the optimization result are transmitted to the corresponding microgrid. This voltage value is taken as the optimization objective function of each microgrid, and the reactive power output of each DG in the microgrid is taken as the control variable. At the same time, considering the related operation state and constraints in the microgrid, the reactive power distribution of each DG is determined through optimization calculation.

Ⅳ. Example Verification

To verify the correctness of the estimation algorithm, this paper uses the voltage estimation algorithm to get the voltage distribution of each node of the system when all DG's full power factor is 1 and the system parameters are unchanged, and when the reactive output of DG1 is changed to 1,0.5,0.0,0.5 and 1 Mvar respectively. Figure 5 compares the voltage distribution of the whole network when only DG3 reactive power capacity participates in voltage regulation and after the transformer participates in regulation.

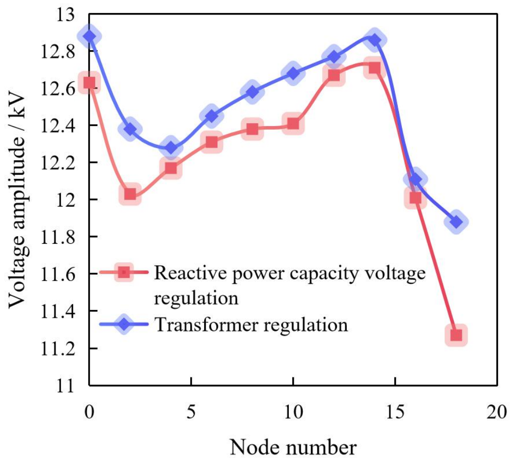

Fig.5 System Voltage Distribution

Ⅴ. Conclusion

In this paper, a voltage control strategy of active distribution network with microgrid based on multi-agent technology is proposed, which can effectively meet the supply of load and the requirement of stabilizing the bus voltage of DC microgrid described above in a system of mutual coordination and cooperation among Agent. The system adopts a distributed structure, which improves the reliability and security of the system. There are many different types of loads and distributed power sources in the system. When it is perceived that the distribution network voltage is out of limit, MAS is used to realize the coordinated control of DG and traditional transformer regulation, which simplifies the calculation complexity on the basis of ensuring the accuracy of traditional power flow calculation. The microgrid is equivalent to a generator at each contact point of the distribution network level, and its reactive power output is used as the distribution network optimization control variable. According to its own optimization results, the distribution network gives the voltage reference value of each contact point and transmits it to the microgrid as the optimization target at the microgrid level. The microgrid determines the reactive power distribution of each DG through optimization calculation, and transmits the optimization results to each DG through the communication system.

Ⅵ. Acknowledgment

Fund Items:Natural Science Key Research Project of Universities in Anhui Province: KJ2019A0860

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