Research summary of key technologies of smart grid based on active distribution network

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Abstract. Active distribution network is an important scheme to make the distribution network safer, more reliable and more economical in the environment of distributed power development. It is an important part of smart grid. Scholars at home and abroad have put forward many key technologies. This paper expounds the key technologies of active distribution network from four aspects of active distribution network planning access, active distribution network control, fault recovery and load control Research status, and then compared its advantages and disadvantages, finally introduced the application prospects.

1. Introduction
Smart grid is the intelligence of power grid, also known as smart power and "grid 2.0". It is built on the basis of integrated, high-speed two-way communication network, through the comprehensive application of advanced sensor measurement technology, advanced equipment technology, advanced control methods and advanced decision support system technology, to make the power market excellent.

Based on the advanced automatic control system, intelligent communication technology and big data processing technology [1].

Understanding the development trend of distribution network at home and abroad, the traditional distribution network technology is more difficult to adapt to the current changes. Therefore, summarizing the development trend of smart grid technology, using the three-way technical resources of source network and load to promote the coordinated optimization of modern renewable energy utilization and distributed generation and distribution is the hot trend of scientific research.

Based on the background of the development of active distribution network, this paper will comprehensively explore the smart grid technology, and comprehensively analyze the key technologies from the three aspects of source network load, and make a certain elaboration and Prospect on the existing problems and applications of active distribution network in the smart grid to be further explored.

2. Connotation of active distribution network
Distributed power supply and electric vehicle charging facilities are more and more involved in the operation of power grid. The traditional distribution system with single distribution energy is upgraded to a multi-functional distribution system with distribution, transmission and storage energy, which
challenges the design of traditional distribution network and affects the reliability, economy and power quality of distribution network operation. The main problems are as follows: the power grid has been operated before. There are uncertainties in the process, such as the power quality produced by new distributed generation is restricted by natural factors; the distribution network is complicated; two-way power flow occurs in the distribution network; the problem of increasing the load management of the distribution network; the problem of improving the utilization rate of distribution equipment, etc. these problems can be solved to a certain extent by the key technologies of the active distribution network.

3. research progress of key technologies of active distribution network

Compared with the traditional distribution network, the real-time communication of the source network load is one of the key characteristics of the new distribution network. A large number of distributed power sources, power grids and electric vehicle charging piles are coordinated with each other to optimize the operation of the whole network. The intelligent power network can only build an intelligent distribution network if it meets the needs of all aspects. Now this problem is used to Active distribution network is solved by optimizing the configuration of distributed power supply, optimizing the control of active distribution network, optimizing the recovery in case of failure and optimizing the management and control of load. Therefore, the key technologies of active distribution network are divided into four aspects: planning access, active distribution network control, fault recovery and load management and control. So that the active distribution network can meet the new application trend.

3.1. Key technologies of active distribution network access planning

The research on the optimal configuration of distributed generation mainly includes the location and capacity determination of distributed generation, and the optimal configuration of generation. The optimal configuration of distributed generation based on the traditional distribution network can not make full use of the new energy such as renewable distributed generation. The active management of active distribution network can make the power flow in the distribution network with distributed generation more effectively, to improve the utilization ratio of new energy resources [2]. In reference [3], a joint algorithm optimization model combining genetic algorithm and ant colony algorithm is proposed for the location and capacity determination of distributed power generation. The timing characteristics of different distributed power generation and load are considered to optimize the operation economy. Reference [4] is about the uncertain factors of investment and operation cost and load of distributed power generation this paper presents a distributed power optimization model considering the uncertainty of information. The model is solved by the improved calculation method and verified by the ieee33 node distribution network. However, more accurate model and optimization algorithm are needed to solve the problem of uncertainty factors.

3.1.1. Technologies considering distributed energy access. In view of the voltage and power problems that will affect the system when the distributed power is connected to the distribution network, the optimization methods of these uncertain problems can be divided into three categories, namely, random planning, fuzzy planning and robust optimization. The active distribution system and network architecture are a complex mixed integer nonlinear algorithm problem, including the safety constraint equations of circuit laying, distributed power coordinates and other parameters, and the two kinds of optimization methods are proposed The mixed integer linear programming (MILP) can be used to optimize the solution of large-scale mathematical model. In reference [5], based on robust optimization and MILP, a joint planning model of distribution system including location, capacity and grid planning of distributed generation is established, and the mature commercial software plex is used to finally, the software development of the GUI development environment based on MATLAB is carried out.

The objective function proposed in this paper is the minimum annual investment cost of the line and the annual network loss cost of the system. The function optimization model is as follows: $F(d,m)$ is the annual cash value coefficient, $d$ is the return rate of the line, $m$ is the life cycle of the
line, $C^k$ is the unit length price of the $k$, a $\theta^k_{ij}$ is the binary variable of the $k$ line installed on the $ij$ of the line corridor, when $k = 1$, $k = 0$ No installation; $l_{ij}$ refers to the length of corridor $ij$ of the line; $C^{loss}$ refers to the cost of unit power network loss; $P^{grid}$, $P^{DG}$ and $P^O$ respectively refer to the active power provided by the access point of the main network substation at node $i$, the active power injected by the distributed power supply and the active load of point $I$. According to a series of constraint function, the standard function can get the planning model of the whole system. Finally, through the transformation of MILP model, the linear model is obtained, and finally the optimization purpose is achieved.

$$Min = F(d,m) \cdot \sum_{i \in \Omega_L} \sum_{k \in \Omega_T} C^k \theta^k_{ij} l_{ij} + 8760 \cdot C^{loss} \sum_{i \in \Omega_N} \left( P^{grid}_i + y_i P^{DG}_i - P^O_i \right)$$  

(1)

3.1.2. Technology considering demand side response. In addition to the supply side power supply, a large number of distributed power supply installed on the demand side of electric energy has the ability of self-power supply. The participation and regulation of the demand side resources play a positive role in improving the utilization rate of renewable energy, the balance of supply and demand of source and load, as well as cutting peak and filling valley. If the active distribution network can make full use of and dispatch the demand side resources, it can make the response coordination between the supply side and the demand side A flexible active distribution network is built. The objective function is to maximize the utility value of electricity on the demand side. The Benders Decomposition method is used to calculate the model for integer planning. The residential electricity regulation model is established. The control method of electricity consumption mode is proposed for different demands of different electrical equipment on the demand side.

3.2. Key control technologies of active distribution network

The core technology of active distribution network is automatic intelligent control technology, which is mainly summarized from the core technology of communication monitoring control and collaborative control. In reference [6], aiming at the problem that the system loss caused by large-scale access of distributed power increases the node voltage limit, a direct AC / DC active distribution network optimization control strategy based on SOP is proposed, which is optimized by genetic optimization The algorithm improves the problem of power loss and regulating voltage out of limit, and validates the validity. In reference [7], for the current complex problem of active distribution network voltage regulation, the gray wolf algorithm is proposed to coordinate distributed voltage and traditional reactive power compensation device to get Pareto solution set, and the public area solution is selected as the voltage control strategy, and the wired low voltage is the optimal solution to achieve dynamic voltage coordination The application of these methods is not mature enough. They do not consider the characteristics of distributed power, flexible load and other sources, networks, loads and other aspects, and need to be further studied and applied.

3.2.1. Communication monitoring and control technology of active distribution network. The active distribution network needs the communication technology as the key support. The integrated and two-way communication network is composed of intelligent sensor measurement technology, optimized control decision system technology and advanced communication equipment. The operation and power supply of the active distribution network is more reliable, economic, efficient, safe and environmental protection with the cooperation of the distribution network. In order to achieve the above goals, reference [8] has designed In order to meet the actual demand of the active distribution network monitoring and control system, in addition to the installation of the traditional pull sensor, additional meteorological and temperature sensors are added. First, the sensor based on ZigBee
technology monitors the pull of the wire, the pull of the wire and the electrical equipment the system consists of sensor acquisition node, data processing virtual gateway and monitoring control terminal. By connecting the corresponding DIY integrated computer (PIO) chip, the sensor nodes can communicate with the distribution network wirelessly.

Figure 1 shows the topology of ZigBee technology in smart grid to establish acquisition and control network application. ZigBee is a low-power LAN protocol based on IEEE802.15.4 standard. It is a low-power, low-cost, low-speed, short distance, short delay, high-capacity, high security wireless communication technology. In practical application, various network topologies are transmitted through wireless communication, based on it is composed of many small nodes of signal acquisition and monitoring network. Through sensor channel scanning, a new ZigBee network is established to transmit wireless signal communication to ZigBee router and finally to ZigBee signal processing module. GPRS communication module adopts high-performance industrial wireless module and embedded processor, which is suitable for outdoor harsh environment. It supports transparent data transmission and domain name resolution it can develop software system by itself with configuration software and users. By analyzing and receiving data to GPRS signal processing module, the signal is transmitted to Internet network through GPRS network. The server obtains the final processing data of sensor from Internet network, and the staff of monitoring center operate the corresponding nodes through the received data information, so as to realize remote leaving and closing Function.

3.2.2 Cooperative control technology of active distribution network. There are three control modes in the active distribution network: centralized control, single-layer distributed control, centralized and partitioned control. In reference [9], the centralized control and installation of the active distribution management system (ADMS) is proposed. The system is controlled globally by the grid control center. According to the power supply situation, real-time operation information, load prediction and other information of the distribution network, the optimal operation method is calculated by the algorithm, and then the information is transmitted to the substation some controllable units can adjust and control in real time to make the distribution network run best in figure 2.
3.3. **Key technologies of active distribution network restoration**

At present, when distributed energy system is connected to the distribution network, it is easy to form an unconscious Island, which is necessary for the safe and reliable operation of the active distribution network. The fault recovery algorithm of the active distribution network includes three types: fault location, isolation and power recovery in the non-fault area. In reference [10], the uncertain bilevel programming theory is used to establish an active distribution network fault recovery model taking into account the uncertainty of new energy output. Based on the game theory method and chaos particle swarm optimization algorithm, the solution process of upper optimization and lower optimization is designed to obtain the fault location of active distribution network. A two-stage recovery strategy including load management and network reconfiguration is proposed in document. By using the optimal solution model of network reconfiguration based on efficient genetic algorithm, the optimal operation scheme of active distribution network in island state is realized, and the power quality and operation economy are guaranteed. However, the problem of monitoring and locating faults is not considered.

![Fig. 2 structure diagram of centralized and sub regional energy control](image)
WSNs is a wireless sensor network, which is composed of sensor nodes. It has the characteristics of accurate coordinate positioning, real-time data monitoring and transmission, and autonomy. In practical application, WSNs network data location data is located by calibrating some nodes or its own positioning algorithm, while unknown nodes are calculated by the reference of network nodes with known coordinates.

Reference [11] proposes that the traditional determination of the fault coordinates of the smart grid is to locate the fault points of the distribution network or electrical equipment and determine the existing inaccuracy and low efficiency. The determination of the fault location needs to go through a long test, and even requires manpower to go to remote sites for field inspection. The location monitoring diagram of WSNs in the smart grid is shown in Figure 3. In order to achieve Based on WSNs node fault location technology, the real-time data of distribution network, communication equipment and electrical equipment collected by WSNs network in the sensing layer is transmitted to the special wireless broadband network of electric power through the network layer information communication. The gateway platform of the application layer will target the fault information received, and then do it in time Processing.

The main localization algorithm of this technology is the clustering localization algorithm. An improved PDV hop clustering localization algorithm is proposed to save energy consumption for the whole system operation. The particle formula of updating speed is as follows:

\[
v_j(t+1) = \nu(t) + \sum_{j=1}^{n} h_1r_1 \left( P_j - x_j(t) \right) + h_2r_2 \left( G_j - x_j(t) \right)
\]  

(2)
The improved formula for updating displacement particles is as follows:

$$
x_{i+1} = \left( \frac{n \sum_{j=1}^{l} x_j y_j - \sum_{j=1}^{l} x_j \sum_{j=1}^{l} y_j}{n \sum_{j=1}^{l} x_j^2 - \left( \sum_{j=1}^{l} x_j \right)^2} \right)^{-1} \left( \frac{n \sum_{j=1}^{l} x_j y_j - \sum_{j=1}^{l} x_j \sum_{j=1}^{l} y_j}{n \sum_{j=1}^{l} x_j^2 - \left( \sum_{j=1}^{l} x_j \right)^2} \right) \cdot \bar{x}_i
$$

(3)

Among them, $l$ is the real distance between the known node and the unknown node, $h_1, h_2$ are acceleration factors, $r_1, r_2$ are random numbers, $P$ are individual extremum, $G$ are group extremum.

After the algorithm improves the accuracy of cluster points, the location of cluster classified nodes is reasonably located, the data transmission rate is improved and the energy consumption is optimized. The wireless sensor used in power grid fault detection is solved the battery limitation of network nodes makes the troubleshooting more comprehensive.

3.4. Key technologies of load control in active distribution network.

The development of communication technology and sensor technology measurement technology not only provides help for the above technologies, but also provides support for demand side load control and other related technologies. In the active power distribution network, the management department of power grid company can get real-time load data through advanced measurement and monitoring equipment, and can use intelligent demand side terminal for management or use intelligent socket for control It is of great significance to realize active load management and control, optimize the operation of distribution network, and stabilize the power fluctuation of distributed generation. It is pointed out in reference [12] that the popularity of electric vehicles increases the investment of energy storage equipment. Therefore, as a scheduling resource, the existing flexible load is added to the coordination and balance link of power network, and the technology of distributed generation and energy storage equipment is strengthened, which can be effectively handled The problems of power fluctuation and balance of energy supply and demand.

Dynamic electricity price is also a technology worthy of research and development. Reference [13] proposes to use block chain technology to support the development of dynamic electricity price. The dynamic electricity price system of distribution network based on block chain can meet the decentralized way to realize power point-to-point transaction. It can realize smart power transaction of micro grid load side, grid side, power side and storage side Based on the block chain system, smart contract is adopted to purchase electric energy in real time; digitalize energy and facilitate the management of energy assets; at the same time, the distribution network model is also digitalized and can be controlled accurately; the data security traceability on the block chain ensures the historical preservation of electric energy purchase data, and each end can not only secure electric energy transaction, but also reduce investment cost and increase performance This system directly provides a safe and reliable electric energy trading platform for the distribution network of distributed power generation. This technology is in line with the Internet innovation, and it is a low investment and high return electric energy trading system for the electric energy industry and related industries. It has realized a win-win value system for the supply and demand ends.

3.5. Comparison of advantages and disadvantages of four key technologies

The key technologies of active distribution network have been implemented a series of typical demonstration projects at home and abroad, which test the theory with practice and application. Planning access, control technology, monitoring technology, fault recovery technology and load control technology have developed to different degrees, but they all have their advantages and disadvantages.
The communication monitoring and control technology can safely and reliably advance the monitoring and management technology, obtain the data information of electrical equipment and meteorological changes in real time and accurately. The advantage of this technology lies in the low investment cost, easy installation and strong expansibility. The wireless transmission method solves the medium difficult problem of wired transmission, such as space occupation.

The wireless communication technology has been paid more and more attention by scientific research, and the new advanced measuring and control equipment emerge in endlessly, which makes GPRS technology and ZigBee technology play an important role in the active distribution network. But at the same time, the technology has not comprehensively considered the characteristics of reactive power compensation and fault monitoring in the distributed network, such as source, network, load, etc., which needs to be further studied and expanded Use.

To some extent, the above technologies make the source network load more coordinated and flexible. See Table 1 for the comparative analysis of the current development of these technologies.

| Technical name                        | Technological contribution                                                                 | Insufficient technology                                                                 |
|---------------------------------------|-------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Distributed energy access technology  | Using MILP and mathematical algorithm to optimize the model, good expansibility can be obtained by piecewise linearization, and the solution obtained can guarantee the optimality | It is difficult to solve the model convergence when the variables are too large          |
| Demand side response technology       | Reduce the uncertainty of source load and balance the benefits of equipment input and maintenance | Blockchain technology is immature and algorithm is huge and complex                        |
| Communication monitoring and control technology | Simple design and expansion, easy installation and low cost, and can obtain the operation state of electrical equipment and changes of surrounding environment | The characteristics of reactive power compensation and fault monitoring in the distributed network are not considered comprehensively |
| Cooperative control technology       | Global optimal control and flexible activation of distributed generation                   | The control area is difficult to maintain stability and high cost due to its flexibility |
| Node fault location technology based on WSNs | Fast location, short time-consuming, low energy consumption and remote control to isolate faults | The equipment limit is large and the cost is high                                        |
| Load management and control technology based on dynamic electricity price | Considering the interests of users and effectively controlling the load                   | Blockchain technology is immature and algorithm is huge and complex                      |

4. application prospect of key technologies of active distribution network

The optimal power flow is of great significance in the control field. In the key control technology of active distribution network, the source load is coordinated by the optimal power flow control of both sides of the source load, so that the distribution network can operate reliably and efficiently. The optimal power flow application is satisfied.

Finally, because a large number of distributed power access, affecting the utilization rate of power grid equipment. First, through the monitoring control technology and self-healing technology, the safety and reliability of the equipment are guaranteed. After that, through the key technology of load management and control and the key technology of active distribution network planning access, the
electric vehicle and energy storage equipment such as the power side participate in the operation of
distribution network, and distributed power supply At the same time, the load equipment is used to cut
the peak and fill the valley.

The requirements that each technology can meet are shown in Table 2.

Table 2 Application of key technologies of active distribution network

| Technical name                                      | Application of demand side response interaction | Application of power quality control | Application of renewable resources consumption | Application of most power flow control | Application of equipment utilization improvement |
|----------------------------------------------------|------------------------------------------------|--------------------------------------|-----------------------------------------------|---------------------------------------|--------------------------------------------------|
| Distributed energy access technology               | ☑                                               | ☑                                   |                                               | ☑                                    | ☑                                               |
| Demand side response technology                     | ☑                                               |                                      |                                               |                                      |                                                  |
| Communication monitoring and control technology     | ☑                                               | ☑                                   | ☑                                            | ☑                                    |                                                  |
| Cooperative control technology                      | ☑                                               | ☑                                   | ☑                                            | ☑                                    | ☑                                               |
| Node fault location technology based on WSNs        |                                               |                                      |                                               |                                      | ☑                                               |
| Load management and control technology based on dynamic electricity price | ☑                                               | ☑                                   | ☑                                            | ☑                                    | ☑                                               |

5.  Conclusion

With the improvement of power grid construction level in China, a large number of flexible loads participate in power grid operation. The operation of power grid needs more advanced technologies to optimize processing, such as distributed power, new energy vehicles, etc. the reliability, flexibility and economy of active distribution network make the development prospect of distribution network show more possibilities. Under the smart grid technology, from the source network load the purpose of this paper is to summarize and analyze the key technologies and the prospect of these technologies. This paper comprehensively analyzes the technical support needed by active distribution network in order to achieve multi-party coordination and flexible and reliable operation. Finally, it compares the development trend of distribution network in the future with the shortcomings to be studied. With the development of new renewable energy utilization and intelligence With the development of electricity consumption, the distribution network will be more complex and flexible, and advanced technology and scientific research equipment will provide more powerful support.

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