Application of IEC61850 in Intelligent Distributed Network Automation

Lifang Wu1,*, Xiaoyong Yu1, Shaonan Chen1, Weixiang Huang1, Kai Tao2

1Electric Power Research Institute, Guangxi Power Grid Co.,Ltd, Nanning 530023, P. R. China
2Nanning Electric Power Supply Bureau, Guangxi Power Grid Company, Nanning 530031

*Corresponding author e-mail: wu_lf.sy@gx.csg.cn

Abstract. The safe and stable operation of the power grid system is conducive to ensuring the orderly development of China's economy. Therefore, we must firmly grasp the development trend of the power distribution automation power system, comprehensively grasp and understand its existing problems, and formulate targeted solutions. This paper mainly studies the application of IEC61850 in intelligent distributed network automation. The communication application IEC 61850 of the master station and the terminal in the distribution network automation is the current development direction. The use of object-oriented modeling technology and a unified configuration language can improve interoperability between devices, reduce communication configuration, and reduce the workload of installation and commissioning. The communication service mapping defined by IEC 61850 is completely suitable for distribution network automation communication. Adopt distribution Intelligent control technology and design based on the IEC61850 standard are the development trends of intelligent power distribution terminals. This paper gives the structure of a distributed intelligent distribution automation system. The control mode studied in this paper has an impact on the system's annual outage time indicators, and the indicator SAIDI is correspondingly increased, and the corresponding proportions are 52.1% and 43.2%. ENS and ASAI are proportional to the optimization level of this indicator, so it can be shown that the construction of distribution network automation can effectively reduce the power outage duration of the entire system, which has a significant effect on improving the reliability of distribution network power supply.

Keywords: Power Distribution Terminal, Distributed Intelligence, IEC61850, Distribution Network Automation
1. Introduction

As people's living conditions gradually improve, the reliability of power supply has become more and more important. The power industry is the pillar of urban development, so the backwardness of the power industry will seriously limit the overall progress of the city, and the construction of urban distribution networks is becoming increasingly important. The power grid is constantly expanding, but the problems of power quality and power supply reliability are becoming increasingly prominent, and even instantaneous power interruptions are intolerable. This puts higher demands on it. Therefore, it is urgent to improve the automation construction of urban distribution network. After increasing the level of urban distribution network automation, the time and actions that can be operated by operation and maintenance personnel will be greatly reduced, which can avoid the occurrence of misoperations. How to improve the reliability of power supply of weak links by improving the automation level of urban distribution networks and improving the reliability of weak links has attracted the attention of major power companies and enterprises.

Supported by various emerging technologies, it has promoted the upgrading of distribution network technology, which has continuously improved the distribution network automation, and has provided a huge guarantee for the reliability of power distribution networks [1-2]. As far as the overall construction effect of the distribution network is concerned, there are still some shortcomings in the development and construction of distribution network automation technology, which will have a partial impact on the quality of the power system's power distribution. Further research is needed on the existing basis to strive for It can fully realize the advantages of distribution network automation [3-4]. The power distribution terminal is the basic equipment of the feeder automation system [5]. Traditional feeder automation has two modes: local control mode based on feeder recloser and segmenter and centralized remote control based on power distribution terminal and communication network. Both of these methods can achieve minute-level feeder autonomy. More [6-7]. The self-healing speed is an important indicator of the self-healing characteristics of the intelligent distribution network. In order to further improve the self-healing speed of the distribution network, using distributed intelligent control technology to achieve self-healing of feeders in seconds is an urgent requirement for the construction of intelligent distribution networks.

The emergence and application of distribution network automation technology has promoted the transformation of the traditional power supply mode, which can realize the real-time monitoring of the power supply operating status of the distribution network. For the occurrence of power supply failures, it is possible to analyze and confirm the fault area in the shortest time and automatically complete the relevant Operation, to control the impact of faults to a minimum, and to ensure normal power supply in non-faulty areas, which has a critical impact on the reliability of power distribution networks [8-9]. Distribution network automation monitors the power supply system and makes corresponding actions through current and system changes to maintain the stability of system current and voltage and improve the efficiency of operation and maintenance. Compared with the traditional manual control mode, it can save more human resources, and is directly controlled by the computer system to ensure a good human-computer interaction effect. It also provides fault information for the staff and ensures that it can be resolved in the shortest time. Restore power [10-11]. In addition, during the automatic operation of the distribution network, it will automatically record the changes in the amount of power
supply, and provide data support for subsequent optimization management, which is of great significance to further improve the reliability of distribution network power supply.

2. Method

2.1. Basic working principle of distributed intelligent fdir
Logic feeder refers to a single feeder or a feeder part with a feeder switch as the starting point and a contact switch as the ending point under normal operating conditions. Because the division of logical feeders is a logical concept, changes in network topology do not affect the scope of logical feeders, and the state of switches does not affect the division of logical feeders. The static network topology of each logical feeder can be described using a standard IEC61850 configuration file. In this paper, the distributed intelligent feeder automation system is implemented by multiple logic devices. At the feeder layer, there is a one-to-one correspondence with the logical feeder objects, and a feeder layer logic device is deployed, which is hereinafter referred to as an FDIR logic device. The FDIR logic device, as the main body of the FDIR function logic judgment, needs to obtain the system information in this logic feeder domain. In the terminal layer, a terminal-level logic device is deployed at each switch, which is hereinafter referred to as a TMU logic device. The TMU logic device is responsible for collecting system information (such as switch position, current / voltage information, overcurrent / fault direction information, etc.) at the switch where it is located and sending it to the FDIR logic device at the feeder layer in real time [12]. Since the FDIR logic device also only obtains the local power distribution network information, it also needs to cooperate with other related FDIR logic devices to obtain the required corresponding information. FDIR logical devices use peer-to-peer communication structures to exchange information. The fault location and isolation functions can be implemented in a single FDIR logical device, and the fault recovery function requires the interaction of two or more FDIR logical devices.

2.2. Information exchange model
IEC 61850 defines relatively complete abstract service interfaces, including basic model specifications and information exchange service models. The information exchange service model includes a client / server model, a common substation event (CSE) model, and a sample value transmission model. By defining the abstract communication service interface method, IEC 61850 realizes the separation of abstract communication services from specific communication protocols, ensuring that EC61850 can use advanced communication technologies. The communication between the master and the terminal uses a client / server model. The data transmission adopts the EC61850 report model, so that both normal data transmission can be guaranteed and abnormal data can be quickly released. Use and general GSE model between terminal and terminal layer. GSE includes general-purpose-oriented substation events and general substation status events. The use of GSE should be limited to the feeder layer to avoid blocking the backbone network.

2.3. Simulation method
In the case of obtaining the reliability data of each component of the power distribution system, computer software is used to simulate the permitted state in each case, and the reliability index is
obtained from a large number of simulation scenarios. The number of simulations of the simulation method has nothing to do with the size of the entire system, and the convergence speed has nothing to do with the dimension of the problem. The simulation method program is relatively simple to implement and can obtain the relevant reliability index distribution. However, this method has a large amount of calculation and takes a long time. Under the same sample data, the higher the reliability level, the worse the accuracy. The simulation method can simulate the actual operation of the system. The scenarios are more realistic, the considerations are more comprehensive, and there are fewer assumptions. The logical composition of the analysis method generates a hybrid method. The basic idea is: use Monte Carlo simulation method to simulate The system runs the conversion process, and uses the analytical method to calculate the effective duration of each element in its state, and replaces the sampled value of the duration. The hybrid method increases the operating speed of the system and reduces the calculation variance. It is a research method commonly used in recent years to study the reliability of distribution networks.

3. Experiment

3.1. Reliability evaluation process

The simulation method is based on the failure rate and average repair time of the corresponding components in the distribution network, and continuously generates random analog numbers to simulate the corresponding changes in the status of each component. According to the sequence, the reliability parameters of the distribution network are analyzed and the relevant records are recorded. Indicators, such as the number of power outages and the total time and average time of power outages, have been described in detail in Chapter 3 for centralized reliability indicators. Through long-term simulation, various reliability indexes of the entire system can be obtained. After establishing a failure mode impact analysis table for a m-element distribution network, the specific steps of calculating the reliability index by using Monte Carlo simulation are:

1. Input simulation time N (unit: year)
2. Generate m random numbers R1 and obey [0,1] to find the trouble-free operating time of the component.
3. Find the fault-free running time min, then this component is defined as i, and this component fails first. Have a random number R2 that obeys [0,1] for this component and find TTR.
4. According to the failure mode impact analysis table, record various reliability indicators of the component failure.
5. Determine whether the time is over. If the end condition is reached, go to step 6. If not, go back to step 2 to continue the simulation.
6. At the end of the calculation, the statistics of the corresponding load point power outage frequency, power outage time, lack of power supply and other indicators within the simulation time are calculated, and then the reliability index of the entire distribution network is calculated.

4. Discuss

4.1. Example analysis
In the figure, the feeder outlet switch is a recloser and the other switches are segmenters. The action delay \( \Delta t \) of the adjacent segmenter is 7s, the Y time limit of the segmenter is 5s, and the XL time limit is 100s. Table 1 shows the reliability indicators of the distribution network in the following three modes.

**Table 1. Reliability indicators in each mode**

| Types of section                              | Fault isolation time FIT | Mean time to repair failure |
|-----------------------------------------------|--------------------------|-----------------------------|
| No distribution network automation            |                          |                             |
| Local control mode                            | 2h                       | 20min                       |
| Centralized control mode                      | 10s                      | 9s                          |

Algorithms are programmed on the OpenDSS platform. The simulation time is 5000 years, and the reliability indicators are calculated separately. 1 indicates that there is no distribution automation, 2 indicates local control mode, and 3 indicates centralized control mode. The corresponding results are shown in Figure 1.

![Figure 1. Reliability simulation results in control mode](image)

The corresponding indicator (ENS) of insufficient battery indicates insufficient battery caused by long-term and short-term power outages. As shown in Figure 1, the results of the calculation of the corresponding reliability indicators can be obtained:

1) The two control modes of distribution network automation have significantly affected the long-term power failure frequency indicator SAIFI, which has reduced the indicator, and both of them have similar improvements in SAIFI. For the entire system, the SAIFI indicator decreased by 61%.

2) From the table, we can see that the more the feeder segments are, the more significant the distribution automation is to reduce SAIFI.

3) It can be concluded from the current data that the CAIDI indicator is growing. The reason for this result is that the realization of distribution network automation will cover the time to repair the
fault, so the time will increase.

In the case of the centralized control mode, this indicator is reduced by half an hour compared to the case of the local control mode.

4) The short-term power failure frequency indicator MAIFI of the entire system has increased under the situation of distribution network automation. However, the centralized control mode is lower than the index in the local control mode, because the local control mode needs to automatically separate faults, and the recloser also needs to be reclosed multiple times, which takes a long time.

5) From the direction of the entire system, it can be seen that the above two different control modes have an impact on the system's annual outage time indicators, and both have correspondingly increased the indicator SAIDI, whose corresponding proportions are 52.1% and 43.2%. ENS and ASAI are proportional to the optimization level of this indicator, so it can be shown that the construction of distribution network automation can effectively reduce the power outage duration of the entire system, which has a significant effect on improving the reliability of distribution network power supply.

4.2. Distribution network automation strategy to improve power supply reliability

(1) Power control equipment update

In the process of distribution network automation construction, in order to improve the control effect of the power supply of the power grid, a variety of power control equipment is often installed and installed in the power distribution system, and the automatic control of the power supply of the grid is met through the effective integration of the equipment and the system. Among them, the transformer is the core equipment of the power distribution network, which needs to be selected and installed according to the actual situation to ensure that it can operate under normal loads. However, in actual installation, the factors such as insufficient estimated growth rate of electric density, irrational selection, and transformer consumption affect the equipment's overloaded working state after installation, which affects its functional performance. Through the selection and update of power control equipment, the actual power supply of the distribution network lines is dynamically monitored and controlled to better provide favorable conditions for the stable operation of transformers and other equipment, and to determine that they can meet the requirements of equipment operation for electrical loads, Reduce the power supply problems caused by such factors, and improve the power supply reliability and security of the distribution network system.

(2) Design of automatic monitoring system

To realize flexible adjustment of the power supply mode according to the line load of the power distribution system, it is necessary to grasp the actual operating status of the power distribution line in real time and support accurate load data to ensure the scientificity of the power supply mode. Design and apply the automatic monitoring system to the power distribution network, that is, transform and optimize the original monitoring system, further improve the accuracy of system monitoring, and obtain more accurate information and data. Among them, it is necessary to improve the integration effect of the automatic monitoring system and the entire distribution network, and obtain more accurate line load feedback values through the effective connection between the two to provide a basis for power control and mode adjustment. In addition, the installation of the automatic monitoring system requires that it can record the load of the power distribution system in different periods, and
then the power supply company can reasonably select the power equipment such as the transformer according to the recorded values to ensure that it can fully meet the system power supply requirements.

(3) Installation of fault location system

During the operation of the distribution network, failure problems will inevitably occur due to the influence of various factors, affecting the quality and reliability of power supply. Under normal circumstances, abnormal power supply to the distribution network requires professional maintenance personnel to troubleshoot and locate the fault area. The entire process takes a long time, and the troubleshooting process is more complicated, requiring more equipment and equipment to support it. And during the monitoring process, the related lines need to be powered off, which will cause large-scale power outages and affect the normal power consumption of users. For the purpose of improving the reliability of the power distribution network, the fault location system is applied to it, and effective integration with the power distribution system can accurately and quickly detect and locate the fault point, and then directly dispatch maintenance personnel to the site to solve it. It takes less time and has less impact on normal power supply areas, which can improve the quality of power supply services.

5. Conclusion

In the safe and stable operation of the power system, distribution automation plays an irreplaceable role. It is conducive to ensuring the orderly progress of social life and production and improving the core competitiveness of enterprises. The construction of distribution network automation is an inevitable trend of the times, especially with the support of various new technologies. In recent years, the automation level of the entire power grid system has been continuously improved. With the support of distribution network automation technology, dynamic monitoring and control of the entire power supply process can be realized. With continuous adjustment and optimization, the fault point can be located and resolved in the first time, and normal power supply can be restored with minimal cost. Makes the system power supply reliability continuously improved.

References

[1] ZENG Dehui, WANG Gang, GUO Jingmei. Adaptive Current Protection Scheme for Distribution Network with Inverter-interfaced Distributed Generators[J]. Automation of Electric Power Systems, 2017, 41(12):86-92.

[2] Azita Dabiri, Balázs Kulcsár. Distributed Ramp Metering—A Constrained Discharge Flow Maximization Approach[J]. IEEE Transactions on Intelligent Transportation Systems, 2017, 18(9):2525-2538.

[3] D. Wang, Y. Zheng, H. Zhou. Platform and Key Technology for Distributed Bus Protection Based on Multi-HSR Network[J]. Automation of Electric Power Systems, 2017, 41(16):27-34.

[4] Cristiano Cervellera, Danilo Macciò. Distribution-Preserving Stratified Sampling for Learning Problems[J]. IEEE Transactions on Neural Networks & Learning Systems, 2018, 29(7):2886-2895.

[5] Kui Zou, Xinsheng Ge. Neural-network-based fuzzy logic control of a 3D rigid pendulum[J].
International Journal of Control Automation & Systems, 2017, 15(2):1-11.

[6] Shengbo Eben Li, Yang Zheng, Keqiang Li. Dynamical Modeling and Distributed Control of Connected and Automated Vehicles: Challenges and Opportunities[J]. IEEE Intelligent Transportation Systems Magazine, 2017, 9(3):46-58.

[7] J. Shi, F. Wen, P. Cui. Intelligent Energy Management of Industrial Loads Considering Participation in Demand Response Program[J]. Dianli Xitong Zidonghua/automation of Electric Power Systems, 2017, 41(14):45-53.

[8] Jerker Delsing. Local Cloud Internet of Things Automation: Technology and Business Model Features of Distributed Internet of Things Automation Solutions[J]. IEEE Industrial Electronics Magazine, 2017, 11(4):8-21.

[9] L. Zhou, D. Zhang, C. Li. Access capacity analysis considering correlation of distributed photovoltaic power and load[J]. Dianli Xitong Zidonghua/automation of Electric Power Systems, 2017, 41(4):56-61.

[10] P. Liu, G. Lyu, X. Kang. Application of IEC 61968 based conformance test technology in distribution network information exchange[J]. Automation of Electric Power Systems, 2017, 41(6):142-146.

[11] Felipe Camara, Antonio C. S. Lima. A Multiple Time-Step Formulation of Frequency-Dependent Network Equivalents[J]. Journal of Control Automation & Electrical Systems, 2018, 29(2):230-237.

[12] J. Ma, Q. Jiang, Y. Zhao. Optimal power flow of low-voltage DC distribution network considering on-state voltage drop of DC solid-state breaker[J]. Automation of Electric Power Systems, 2017, 41(5):39-45.