Application of Distribution Automation Feeder Terminal in System Information Acquisition Technology and Communication Protocol

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Abstract. The use of advanced technology to realize automatic power distribution is an important technical tool to improve power supply reliability. Feeder automation is the key content of the realization of distribution automation, and it is also the most important link to solve the power quality and reliability of the distribution network. This article mainly studies the information acquisition technology and communication protocol based on the feeder terminal of distribution automation. In order to solve the problems of low data transmission efficiency, single function and improper technological progress in the early power distribution system, the operation requirements of the power distribution system were analyzed, and a new type of feeder automatic power distribution system was proposed. Aiming at the contradiction of the existing system communication protocol and the incompatibility of various manufacturers' products, this article proposes an efficient, reliable, and universal communication protocol, which is formulated on the basis of IEC60870-5-104 and is suitable for use in the main data transmission between stations and terminals. This article develops a local communication protocol for error correction, and conducts various tests in the information collection terminal. The test research results show that the basic errors of current, active power and reactive power are all in the range of [-0.2%, 0.2%], and the variation of voltage, current and active power are all in the range of [-1%, 1%], it shows that the distribution automation feeder terminal meets the system's technical requirements for the accuracy and speed of the terminal's data collection and has strong anti-interference ability.

Keywords: Distribution Automation, Feeder Terminal, Information Collection Technology, Communication Protocol.

1. Introduction

Power supply reliability is one of the important technical indicators to measure the power supply quality of power enterprises [1]. In the process of reform and opening up, my country has invested a lot of money in large-scale transformation of urban and rural power grids, and the conditions of power
Supply companies and low- and medium-voltage distribution networks have been greatly improved [2-3]. However, from the perspective of the reliability of energy supply and energy quality, there is still a big gap compared with the world average. Research on the distribution automation feeder terminal helps to improve the reliability of power supply [4-5]. Feeder automation is the core of the realization of distribution automation, and the entry point and main direction of the implementation of distribution automation [6]. Research on the information acquisition technology and communication protocol based on the distribution automation feeder terminal is conducive to constructing the distribution automation system based on the feeder terminal equipment [7].

Many scholars’ research on feeder terminals and distribution automation has played a guiding role in the writing of this article. In order to realize the interoperability between intelligent terminals of distributed feeder automation and ensure the communication security of the terminals, Sun Lingyan and Chen Yu proposed the use of built-in security Scalable Message and Online Presentation Protocol (XMPP) and User Datagram Protocol (UDP). The general object-oriented substation event (GOOSE) combined with the IEC 61850 communication mapping scheme, which uses a security protection scheme based on hash acquisition random subset (HORS) one-time signature to ensure the communication security of GOOSE messages [8]. Wen Yanjun believes that under normal circumstances, the safe and reliable operation of the distribution network is closely related to the flexibility and reliability of the distribution network structure, and feeder automation can greatly improve the reliability and safety of the distribution network [9].

The distribution automation system is an integrated system for real-time monitoring, coordination and control of equipment in the distribution network. The automation of the feeder system is an important link in our realization of the automation of the distribution system, and it is also an important link that directly affects the quality of the power supply system and the reliability of the distribution network. From the analysis of the normal operation results of the system, the system mainly has the following characteristics: automatic fault detection, automatic fault resolution isolation, reduced power outage impact range, rapid restoration of power supply in a defect-free area, and reduction of direct losses caused by losses; reduce and shorten the time and scope of equipment maintenance and downtime.

2. Research on Information Acquisition Technology and Communication Protocol Based on Distribution Automation Feeder Terminal

2.1. Distribution Automation System

(1) Distribution automation system structure

Because network equipment is widely distributed and widely distributed, and the amount of information is very large, the structure of the urban or regional distribution system is divided into three layers [10]. The main layer of the facility is the foundation of the entire distribution management and control system, which is responsible for collecting real-time information from various power distribution centers to ensure that the entire distribution system is in good condition [11]. The distribution network substation is the middle layer of the distribution network automation system, which performs the distribution function of SCADA and DA distribution network within its jurisdiction [12]. The terminal equipment layer is the main array of the distribution system, which completes the collection, processing and monitoring of a wide range of functions.

(2) Distribution automation system based on feeder terminal equipment

1) Automatic hierarchical processing of feeders

The feeder automation hierarchical processing strategy is related to the hierarchical structure of the distribution automation system, and it is usually processed in three different levels. Power distribution terminal layer: fault detection and identification; power distribution station layer: complete regional feeder automation processing and control centered on the power distribution station; power distribution master station layer: high-level global feeder automation solution, integrated with each sub-station Information, to solve the problem that each sub-station cannot handle separately.
2) Distribution terminal feeder automation
The automation communication network of the power distribution system supplier should be network communication, Ethernet optical fiber, LONWORKS network or CAN network. The feeder terminal has an appropriate network interface and network communication software. The feeder automation processing software is located at the feeder terminal. It is based on optical fiber Ethernet communication technology, which provides conditions for realizing mutual communication between supplier terminals or monitoring the transmission of information between adjacent power terminals and power distribution stations. The feeder terminal receives the current fault status information at the adjacent terminal, identifies the fault point in place, and completes the fault isolation on the spot.

3) Protection mode feeder automation
The circuit breakers of the primary equipment components or the inlet and outlet switches of the ring network cabinet are all selected circuit breakers, which have the ability to cut off the fault current. The circuit breaker must be configured with differential protection in a fault state. There is a dedicated communication channel for differential protection between adjacent switches. The feeder terminal of the power distribution has a differential protection function in the event of a fault, and is equipped with feeder automation processing software. Differential protection of the fault state, when a fault occurs at any point of the distribution network loop, the current fault state of the local edge is compared with the edge of the peer through the point-to-point communication between adjacent switches. The conditions at both ends are different, that is, the differential protection is activated and jumps. Turn on the switches on both sides of the fault point to complete the automatic fault isolation process.

2.2. The Content of Information Collection of Distribution Automation Feeder Terminal
(1) The amount of fault information
The distribution automation power station should be able to collect and process defect-related data and information in time, which is an important function different from traditional RTU distribution automation. Current or electrical data is used to identify faults in the power distribution system, generate information about the faults in the power distribution system, and the startup process, as well as the content of separation points and violation points. The actual data error is used as the data recorded in the event sequence and used for the events of the compiled script.

(2) Remote information
In the distribution network, in addition to collecting some equipment operating status information that is basically the same as the information automatically collected by the transmission network, it is also necessary to collect some special remote signaling information, including the record of signs and operation information. The terminal of the distribution automation status information provider and the position of the remote/local control switch.

(3) Pulse accumulation information
Pulse information includes two types of pulse input signals and statistical signals. Since power distribution network equipment usually operates in an unattended environment, monitoring the operating status of the equipment is essential. Therefore, the statistical indication of the operation of the main equipment is information about equipment maintenance provided for the automatic management of the power distribution network. In addition, statistical information about the operation of the distribution network should also be provided.

(4) Remote control and remote adjustment information
The trigger signal is a control signal that directly executes equipment tripping and shutdown operations. These control signals can be local operation commands or control commands issued by a remote control base station. The trigger signal is a control signal that directly executes equipment tripping and shutdown operations. These control signals can be local operation commands or control commands issued by a remote control base station.
2.3. IEC60870-5-104 Communication Protocol

(1) Communication process

The communication process of IEC60870-5-104 protocol includes two parts: link process and application process. The binding process includes functions to prevent message loss and message redundancy. The test process controls the data transmission process. The normal progress of the binding process is controlled and guaranteed by the APCI message. The application software is very complex and contains many types of application functions, including typical operations such as public telephone, time cycle data transmission, remote control/setting, substation activity upload, clock synchronization, event collection, parameter loading and test process transmission Files, etc. The test process supplements the application functions required by the protocol by sending different types of ASDUs.

3. Research Experiment on Information Acquisition Technology and Communication Protocol Based on Distribution Automation Feeder Terminal

3.1. Information Collection Test Based on Feeder Terminal of Distribution Automation

(1) Test environment

Temperature 20°C, relative humidity 55%.

(2) Test items

1) Basic error test

In the information collection test based on the distribution automation feeder terminal, the basic error test is carried out to test the basic error of the current, the basic error of the active power and the basic error of the reactive power. The test conditions for the basic current error are: power supply 220V, input current frequency f = 50Hz; the power for the basic power error test is the total power of the three-phase total, and the test conditions are: power supply 220V, input $U_a = U_b = U_c = 220V, f = 50Hz, \cos \varphi = 1. \sin \varphi = 1$.

2) Change the amount

In the information collection test based on the distribution automation feeder terminal, a change amount test is performed to test the variation of voltage, current, and active power. The test conditions are: power supply 220V, input $U_a = U_b = U_c = 220V, I_a = I_b = I_c = 5A, f = 50Hz, \cos \varphi = 1$ (P); then add each harmonic voltage and current so that the harmonic component accounts for 15% of the fundamental wave component, and the phase angle between the harmonic and the fundamental wave is 45°.

3.2. Power Parameter Calculation

Assuming that the sampled analog signal is a periodic time function, in addition to the fundamental wave, it also contains non-attenuated DC components and various harmonics. Then the voltage sequence $u(t)$ can be decomposed into the fundamental wave and each harmonic component in the form of:

$$
\begin{align*}
\rho_{kn} &= \frac{2}{\pi} \int_0^\pi u(t) \cos k\omega t dt \\
b_{kn} &= \frac{2}{\pi} \int_0^\pi u(t) \sin k\omega t dt
\end{align*}
$$

(1)

After calculation, the amplitude, phase angle and effective value of the k-th harmonic voltage are obtained:
4. Experimental Analysis of Information Acquisition Technology and Communication Protocol Research Based on Distribution Automation Feeder Terminal

4.1. Basic Error Test

In the information collection test based on the distribution automation feeder terminal, the technical requirements for the basic error of the test current, active power and reactive power are: the error is in the range of \([-0.2\%, 0.2\%]\). Table 1 shows the measurement results:

| Input current (A) | 1     | 2     | 3     | 4     | 5     |
|-------------------|-------|-------|-------|-------|-------|
| Current           | 0.017%| 0.004%| -0.019%| -0.012%| 0.102%|
| Active Power      | 0.034%| 0.056%| -0.031%| 0.143%| -0.130%|
| Reactive Power    | 0.046%| -0.012%| 0.118%| -0.044%| -0.104%|

Figure 1. Measurement Result

It can be seen from Figure 1 that in the information collection test based on the distribution automation feeder terminal, the basic errors of current, active power and reactive power are all in the range of \([-0.2\%, 0.2\%]\), which meets the requirements of the distribution automation feeder terminal information collection within the error, it shows that the distribution automation feeder terminal meets the system's technical requirements for the accuracy and speed of the terminal's data collection and has
a strong anti-interference ability.

4.2. Change Amount
In the information collection test based on the distribution automation feeder terminal, the technical requirements for the variation of the test voltage, current and active power are: the variation is in the range of [-1%, 1%]. Table 2 shows the results of the change:

| Harmonic (sub) | 3    | 5    | 7    | 9    | 11   | 13   |
|----------------|------|------|------|------|------|------|
| Voltage        | -0.025% | 0.051% | 0.003% | -0.004% | -0.056% | 0.031% |
| Current        | 0.034% | -0.016% | 0.022% | 0.004% | 0.047% | -0.026% |
| Active Power   | 0.004% | -0.042% | -0.057% | 0.013% | -0.061% | -0.109% |

![Figure 2. Change the Amount Result](image)

It can be seen from Figure 2 that in the information collection test based on the distribution automation feeder terminal, the variation of voltage, current and active power are all in the range of [-1%, 1%], which meets the requirements of the distribution automation feeder terminal information collection error, which shows that the distribution automation feeder terminal meets the system's technical requirements for the accuracy and speed of the collected data, and has a strong anti-interference ability.

5. Conclusion
In the early 1990s, the load management system used in many regions of our country had a single function and had poor technical transparency. With the development of time and the relaxation of power supply, the functional requirements of the system are getting higher and higher. The expansion of functions has led to an increase in parameter collection and monitoring, as well as higher requirements for data collection accuracy, communication speed and reliability. In response to these technical requirements, this article has conducted a lot of research on the speed and accuracy of terminal data collection of distribution automation providers and the improvement of system communication speed and reliability. The new data collection terminal can collect customer power
consumption data in real time, understand load changes in time, and rely on the master station system database to store load data so that the master station system can perform offline mining and data recovery.

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