Research on Improving the Success Rate of Electricity Information Acquisition System by Using Medium Voltage Power Line Carrier Communication Technology

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Abstract. This paper studies the application of medium voltage power line carrier in Electricity Information Acquisition System, discusses the main application scenarios of medium voltage power line carrier, compares three upstream communication modes of medium voltage power line carrier, optical fiber and wireless public network, and summarizes the investment cost, construction and maintenance of medium voltage power line carrier. The field operation proves that the medium voltage carrier communication technology can improve the success rate of Electricity Information Acquisition System.

1. Introduction

Electricity Information Acquisition System (hereinafter referred to as acquisition system) is an important part of the national smart and strong power grid. It is one of the effective technical means to support the implementation of the national energy transformation strategy. It is also the equipment and data base of the widely popularized electric power in the Internet of Things. Since 2010, State Grid Corporation has been promoting the construction of acquisition system in an all-round way. After nine years of construction and development, it has built an automation system covering the whole power network. Various communication technologies have been widely developed and applied in the acquisition system. In the early stage of project construction, 230M communication mode is used in the upstream channel of acquisition system. In the middle and later stage, because of the maturity of public network communication technology and low maintenance cost, GPRS, CDMA and other communication modes are widely used in southern cities. A few developed cities also use optical fiber channel to collect power data. At present, the average daily communication success rate of acquisition system is over 98.5%. However, with the increasing demand for data application within power
enterprises and the vast number of power users, higher requirements are put forward for the success rate of communication with acquisition system. For some special scenarios, medium voltage power line carrier is an effective upstream communication solution.

2. Application of Power Line Carrier Communication Technology

2.1 Power Line Carrier Classification
Power line carrier is the unique communication mode of power system. For electric power enterprises, the established power line network can be used to transmit data and information while transmitting power. It can save the cost to the greatest extent and has a good input-output ratio. It is undoubtedly the preferred communication scheme for acquisition system. According to the level of power transmission voltage, power line carrier communication is also divided into high voltage (10kV and above), medium voltage (10kV), low voltage (380/220V) power line carrier communication.

2.2 Application Scope of Power Line Carrier in Acquisition system
The acquisition system mainly realizes the data acquisition on the power user side, and the power dispatching department is responsible for the automatic acquisition of power plant, gateway and other users. Therefore, the high-voltage power line carrier has no application in the acquisition system; the low-voltage power line carrier technology is mature, and has been widely used in downlink data acquisition of the acquisition system. Medium Voltage Power Line Carrier refers to the carrier communication whose transmission line voltage level is 10 kV. It can be used in the upstream data acquisition of acquisition system.

3. Application of Medium Voltage Power Line Carrier in Acquisition system

3.1 Medium Voltage Power Line Carrier Application Scenario
At present, in the acquisition system, the communication between the main station and the acquisition terminal mainly uses GPRS, CDMA and other wireless public network communications. while some remote areas, mountainous areas, or island areas have weak or no public network signals, which largely restricts the improvement of the success rate of acquisition system communication. Medium voltage carrier communication technology can effectively solve this problem.

There are two application scenarios of medium voltage carrier in in-service telecommunication information acquisition system:

3.1.1 Uplink Communication Scheme in Single and No Signal Station Area.

![System architecture of Single and No Signal Station Area.](image-url)
3.1.2 Uplink Communication Scheme in Multi-Signalless Station Area. When there are many Unsignalized stations in the whole power line, the main carrier machine can be installed at the outlet of the substation, and a slave carrier machine can be installed at each Unsignalized station area. The main carrier machine collects all the data of the stations, and then uploads the data through the wireless public network or by borrowing the backbone communication network of the substation.

![System architecture of Multi-Signalless Station Area](image)

3.2 Technical scheme and Application

The devices needed at the main node include coupler, main carrier and carrier communication manager. The devices required at slave nodes include couplers, slave carriers and slave terminals. The carrier machine is connected with the terminal or the manager. When the terminal or the manager needs to send data outward, the carrier machine first receives the digital signal from the digital signal interface of the terminal or the manager, then processes the digital signal into the carrier signal, and then transmits the carrier signal to the distribution line through the coupling device. When the carrier signal arrives on the distribution line, the carrier machine first acquires the carrier signal from the distribution line through the coupling device, then processes the carrier signal into a digital signal, and transmits it to the terminal or the manager through the digital signal interface. The data transmission between the terminal and the manager can be realized by acquiring and transmitting the digital signal by the carrier machine, as well as transmitting and receiving the carrier signal.

The medium-voltage carrier communication coupler constructs the carrier communication channel between medium-voltage carrier communication machine and 10 kV distribution line. The medium-voltage carrier communication machine obtains information from the concentrator in the low-voltage side distribution box of transformer. After modulation, it is coupled to 10 kV line by 10 kV coupler. The medium-voltage carrier communication host receives load from 10 kV line by 10 kV coupler. Wave signal is demodulated and sent to the main station of power acquisition by GPRS. Medium-voltage carrier communication support master-slave scheme. Take a 10 kV line as an example. Before installation on site, we should use signal survey equipment to measure the intensity of communication signal. Then we select the strong signal area as the main signal area, the weak
signal area as the slave area, and the slave area can be set up according to the actual measurement value.

The installation schematic diagram of medium voltage carrier equipment is as follows:

![Figure 3. Medium Voltage Carrier Equipment Installation Diagram.](image)

The carrier communication manager is mainly responsible for communicating with the main carrier machine and the main station of power information collection. Through data forwarding of the carrier communication manager, the communication between the slave terminal and the main station is established. The main function is to set up and manage the downlink slave terminal and the slave carrier machine. At the same time, it receives the communication messages sent by the main station and forwards them to the corresponding slave terminal. Extract data of downlink subordinate equipment.

Master and slave couplers: There are two kinds of couplers: integrated capacitor coupler and clamped inductor coupler. The integrated capacitor coupler is suitable for overhead lines to realize carrier signal transmission and power frequency current isolation. Its 10kV terminal (top) is connected to the 10kV line, and the signal line (bottom connector) is connected to the carrier signal line. The clamped inductor coupler is suitable for power cable lines. It can be directly clamped outside the power cable. Based on the principle of electromagnetic induction, the carrier signal is coupled to the shielding layer and three-phase core of the power cable.

Master and slave communication machine: Power line carrier digital communication machine is the key equipment to realize medium voltage power line carrier communication. It has digital signal interface and carrier signal interface. RS232 interface of main carrier machine is connected with routing serial port conversion module of management machine through serial port connection line and RS232 interface of slave carrier machine is connected through serial port. The line is connected with the GPRS serial port conversion module of the slave terminal.

Jianchang County, Liaoning Province, is located in a mountainous area, where mountains overlap and winding. This geographical location makes the mobile signal blocked by peaks. Some remote mountainous areas are covered by blind areas, and some mountainous areas are unstable. In addition, the relatively poor consumption capacity in such mountainous areas is not an important customer group of telecommunication operators, and their willingness to increase investment in this area is relatively low. There are often no signals and off-line problems in the acquisition system. According to the statistics of staff on-site inspection, there are 57 stations in Jianchang County which have no signal and often drop lines, including 51 public transformer stations and 6 special transformer stations, 21 non-signal stations and 36 frequently drop lines. 57 transformers in the region are equipped with equipment, and the medium voltage power line carrier technology is applied. After three months of debugging, the system is currently running stably, and various data acquisition indicators are
effectively improved. Among them, the success rate of special transformer acquisition increased by 0.1%, and that of common transformer acquisition increased by 0.35%, and the success rate of low-voltage acquisition increased by 0.12%.

3.3 Programme Characteristics

3.3.1 Comparison of various scheme. There are many kinds of communication modes in acquisition system. When choosing the schemes, we will compare the various schemes and make a comprehensive decision on the selected schemes. This paper compares three schemes: optical fiber, medium voltage carrier and wireless public network.

Table 1: Comparisons of communication schemes

| Performance                | Optical Fiber | Medium Voltage Carrier | Wireless Public Network |
|----------------------------|---------------|------------------------|-------------------------|
| Communication Rate         | High          | medium                 | low                     |
| Reliability                | High          | High                   | low                     |
| Accuracy                   | High          | High                   | High                    |
| Functional Completeness    | medium        | High                   | low                     |
| Information Security       | High          | High                   | low                     |
| Construction Cost          | High          | low                    | low                     |
| Usage Cost                 | High          | low                    | medium                  |

In terms of communication rate, the optical fiber communication rate is the highest, the medium-voltage carrier communication rate is moderate, and the wireless public network communication rate is low. The medium-voltage carrier communication rate of 100 Kbps can meet the data transmission requirements of the acquisition system. In terms of reliability, the wireless public network communication is vulnerable to interference from external environmental noise. The congestion problem during the peak period of voice communication, and natural disasters, military exercises will have a great impact on wireless public networks, even local communication paralysis. Optical fibers and medium voltage carriers belong to wired private network communications, which are less affected by external interference, and there is no congestion problem. In terms of accuracy, wireless public networks, medium voltage carriers and optical fibers can be used. In order to meet the application requirements of mining function, in terms of functional completeness, there are blind areas in wireless public network and some areas of optical fiber can not be laid, which leads to the defects of the two communication modes in the completeness scheme, and there is no such problem in medium voltage carrier. In terms of information security, medium voltage carrier and optical fiber belong to electricity. Special power communication network has controllable security risks and high security; the security of wireless public network is prominent and vulnerable to external attacks, which brings hidden dangers to the safe operation of the network; in terms of construction cost, optical communication equipment needs to be installed and optical cables laid in the construction of optical communication, which costs a lot, and medium-voltage carrier equipment costs and optical communication. The telecommunication equipment is comparable, but it does not need to lay lines, which greatly reduces the cost. The wireless communication equipment has low cost, no wiring and low construction cost. In terms of usage cost, wireless public network needs to pay the flow fee continuously in the course of operation, and the equipment upgrade and replacement cost brought by the rapid development of wireless technology is extremely high. Optical fiber communication needs to organize human resources to ensure its normal operation, and the maintenance workload of optical cable is large, such as the damage of optical cable, route adjustment and so on. Voltage carrier communication uses the power line of the power department as the transmission channel, without paying the fee, and ensures the smooth transmission channel of the carrier signal while ensuring the normal transmission of the power. The cost is low.

In summary, medium voltage carrier communication has the advantages of less investment, simple equipment, easy construction, convenient maintenance and management, because it uses existing and perfect distribution lines as transmission channels and does not require line investment.
Medium-voltage carrier equipment does solve the problem of information acquisition in no-signal station area. The acquisition stability is relatively reliable and the data is accurate, but there are still some shortcomings. First, the installation needs power outage, and the marketing personnel can not install independently. It needs the cooperation of distribution profession. At present, the installation equipment only applies with individual signals and can not cover the area. The cost of single point installation is high. Secondly, slave can only realize the function of data reading and transmission, and can not execute other commands such as parameter sending and remote control to the acquisition terminal; thirdly, because of the difficulty of fault handling of coupling equipment on high-voltage lines, blackouts need to be recorded in the blackout operation system in advance, and the elimination period is longer; fourthly, after upgrading the concentrator, Medium-voltage carrier equipment internal settings need to be modified, and equipment maintenance personnel should be in place in time.

Medium-voltage carrier equipment really solves the problem of information acquisition in no-signal station area, and the acquisition stability is relatively reliable and the data is accurate. Using medium voltage carrier wave to realize data transmission of distribution automation and power automation is an effective supplementary means to improve the success rate of acquisition system. Especially in rural network and urban network which is not easy to lay optical cable, medium voltage carrier is the best communication scheme.

4. Application Prospect

The practical application proves that the medium voltage carrier can provide a stable and reliable upstream communication channel for the acquisition terminal and ensure the realization of the full collection of power information. Distribution lines are widely distributed, so it is not necessary to re-lay communication lines and save a lot of manpower, material and financial resources. Distribution lines are maintained by special personnel without relying on third parties or other maintenance teams, which reduces operation and maintenance costs. Distribution lines belong to power companies and can be completely maintained. It is controlled by the power company, so that it is easy to manage and communicate with any station concerned. It is more reliable and safe. Signals are transmitted in the distribution line, not affected by the geographical environment. Where the distribution line is set up, the communication can extend to where. Medium-voltage carrier communication takes 10 kV distribution line as transmission channel, which makes full use of existing distribution lines and has incomparable advantages compared with other communication modes. It is of great significance to promote the development of new technology of power information acquisition system, and lays a solid foundation for the realization of a unified and strong smart grid. It has broad application prospects.

5. Concluding Remarks

Medium-voltage carrier equipment is directly connected to the power line, which can further study and deepen the application to achieve the maximum return on investment. For example, medium-voltage carrier is used to identify the ownership relationship between transformer and 10KV line, to provide basis for line loss in the same period, and medium-voltage carrier can also be used to realize condition monitoring of 10KV line, to realize fault warning and fault location, and to improve power supply reliability.

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