New Communication Mode for Distribution Substation Monitoring

Jing ZHOU
HuNan Power Supply Branch, SMEPC Shanghai
zhoujing@hn.sq.smepc.com

Ming ZHANG
Urban Power Supply Company, SMEPC Shanghai
zhangming@sq.smepc.com

Lin-Feng GU
HuNan Power Supply Branch, SMEPC Shanghai
gulf@hn.sq.smepc.com

ABSTRACT

This paper discussed the existing techniques in power system communication. The transmission characteristics of the optical-fiber and the carrier-wave based communication of shielded electric power cables in substations were presented. The four schemes of information transmission in substation are discussed: remote-terminal unit (RTU) transmits, modem based method, remote-terminal server based method and low bit-rate asynchronous data interface approach. Finally, based on the available communication resources, a simple, reliable and cost-effective solution for information transmission in substation is proposed.

0. Introduction

Electrical power systems in Shanghai has various voltage levels, such as 380V, 10kV, 35kV, 110kV, 220kV and 500kV, the electrical networks below 220kV have received more and more attention since Shanghai is the regional dispatching center. The power supply companies and their subsidiary companies have built supervisory control and data acquisition (SCADA) systems, and automatic remote terminals have been equipped in the 220kV~35kV substations. The information of the substations can be acquired instantaneously and transmitted to the dispatching center, therefore the dispatchers can be acquainted with the information of the substations in real time, whenever there's an accident in the networks or substations, the information can be available in the dispatching center, thus control measures can be taken through SCADA system and safety of the equipments in substations can be insured. With the operation experience of a few decades, we have realized that the SCADA system is an indispensable tool for the supervisory and control of substations. In the SCADA based dispatching system, communication technology is extremely important, serving as a bridge connecting the data acquisition devices and the remote receiving devices. This paper briefly reviews the techniques existing in power system communication applications.

1. Transmission properties of optical-fiber cable

Audio-frequency electric cables were used for information transmission in the past; however, the slow bit-rate and poor reliability greatly hindered their application. Nowadays, the fast development of optical-fiber technology tremendously promotes the update of the communication mediums in substations. In comparison to the conventional electric-cable based communication, the optical-fiber cables have great advantages, such as wide bandwidth, higher communication capacity due to increase of transmission frequency up to 100,000 times compared with microwave communication, thus the bandwidth and capacity can also be enhanced to 100,000 times.

Due to the limitation of the technology, the bandwidth and communication capacity of optical-electronic devices can not meet the theoretical values; however, the optical-fiber based technology has many superior characteristics. For instance, the loss due to the decaying of information is less; the distance for retransmission is longer (due to short wave), therefore, the initial construction investment and maintenance can be reduced thus increasing the reliability. The optical-fiber has cladding and sandwich layer, the optical signals only transmit through sandwich layer, and good characteristics for anti-interference can be realized since the frequencies of outside electromagnetic interference

(EMI) signals are far less than the frequency of optical signals inside the sandwich layer. Due to severe EMI in the electrical transmission systems, the conventional medium of information transmission suffers from inaccuracy, less reliability. The optical-fiber materials have good insulation capabilities, thus secure communication can be guaranteed even when the system is suffered from strong EMI environment. Furthermore, the optical-fiber technologies have various applications in power system, such as audio information transmission, remote signals transmission, serial-port communication and Ethernet communication.

With the rapid development of the optical-fiber technology, most of the special communication networks in electric power systems have undergone the transition of updating the existing networks. Recently, a new type of optical-fiber cable has been invented, based on optic-electronic compound structure which can be fixed directly on the electrical towers. This optical-fiber cable has perfect reliability and more robust to external forces. It's evident to say that the optical-fiber communication has become an indispensable part in the electrical power industry which guarantees the safety and stable operation of the power system.

2. Power-line carrier communication

The electrical networks have become more complicated due to the rapid increasing demand of electricity. For instance, the HuNan Power Supply Branch, Shanghai Municipal Electrical Power Company (SMEPC) has equipped more than 600 units of 10kV substations, and this number is updated with an increase rate of dozens of new substations each year.

These substations provide abundant of information, and all the datum would be transmitted to the dispatching center so the dispatchers can have a general understanding of the situation in substations, including the power flow, thus the structure of the electrical network can be adjusted accordingly. And also the information about system faults can be recorded so that immediate counter-measures can be taken, therefore working efficiency can be greatly improved. The operators can also benefit from the information provided from the system faults, inspection time can also be shortened and efficiency for fault clearing can be improved thus the customers can get benefit ultimately. Whereas, the substations cover a wide area with a tremendous amount of information, causing great burden to the popularization of the automation of distribution substations.

The key factor affecting this problem is due to the communication issues. As it's known to all, the construction investment and laid-down cost for communication networks constitute a large amount in the total investment in substation automation projects, especially when the optical-fiber cables are constructed. The overhead lines in big cities are tend to be buried underground, the underground passages suffer from inadequacy since it's comparatively difficult to excavate the pavement and also due to lack of conduit pipes, the communication problem has become an urgent technological difficulty, that's to say how to solve the widespread "the last one kilometer" problems.

Carrier-wave communication provides one of the best solutions for information transmission in distribution networks, which is a unique communication scheme in electrical power system. Electrical power line carrier-wave communication utilizes the existing electrical power lines, and the analog or digital signals are modulated with the fundamental waveforms of electric voltages thus high speed communication can be realized. The salient feature of this communication method is that it doesn't need to lay down new cables, once there are electrical lines, there would be data transmissions. Nowadays, the shielding layer based carrier-wave communication utilizes the shielding layer as transmission medium, it's an cost-effective solution without extra investment, and it has a lot of advantages such as economical, stable, reliable and not easy to be damaged, small investment and convenient

to construct. This method only needs to add carrier-wave generator and coupler at the both sides (transmitting and receiving terminals); DPSK (the phase difference of the adjacent code carrier-wave signals) based modulation techniques can be utilized for information transmitting on the existing electrical cables. Therefore, this technology is suitable for the dispersed substations which have small amount of information for each substation, such as the 10kV and lower voltage-level substations.

3. Implementation schemes

Due to the special structure of electrical power networks, the shield layer based carrier-wave technique can only send the information to the upper-level power sources, how to send this information to the dispatching terminals? Here a few methods are presented and discussed.

3.1 RTU based retransmission

Fig.1 illustrates the remote terminal unit (RTU) based retransmission method, this method utilizes the shield layer power cable to transmit the signals obtained from distribution substation to the transformer substation. In this scheme, the master/slave carrier-wave device (CWD) architecture is adopted as shown in Fig.1.

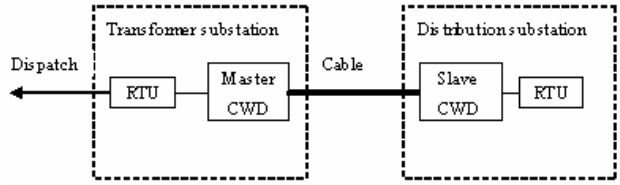

Fig.1 RTU based retransmission

The advantage of this scheme is that it doesn't need to add extra devices except some carrier-wave devices. However, the disadvantages are as follows: (i).Protocol test is needed in the transmission channel, and the database at the dispatching terminal needs to be modified in order to enhance the information handling capability; (ii).Since there are a large number of distribution substations affiliated to the transformer substation, the working efficiency of the RTU at transformer substation side would be affected, thus might lead to system collapse; (iii).The information of the transformer substation and the distribution substations utilize the same remote terminal unit, hence it's less flexible when the SCADA system is adopted in the application.

3.2 Modem based approach

As shown in Fig.2, this approach utilizes modem instead of RTU at the transformer substation to receive the information obtained from the distribution substations, and then send to the dispatching center through audio frequency (AF) power cable.

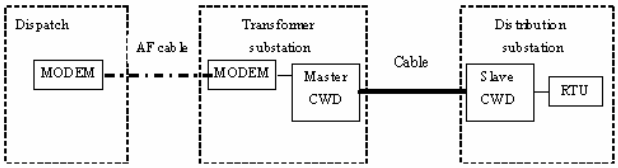

Fig.2 Modem based approach

The advantage of this method is that the information transmit doesn't rely on the RTU of the transformer substation, hence the burden of RTU can be reduced; the flexible data acquisition system can be connected in the dispatching terminal, such as SCADA system, distribution system management system and production management system. However, the disadvantages still exist, for instance, the audio-frequency channel would be occupied, and also the modem devices must be installed at two terminals with slow data transition speed. And more modem devices are needed if there are several master carrier-wave devices in the transformer substation.

3.3 Remote-terminal server based approach

As depicted in Fig.3, this scheme utilizes a terminal server with multi-channel serial ports which is installed in the transformer substation, the information of the master carrier-wave devices (CWD) are send to the server through the multi-channel serial ports, and then the server is connected to the optical-fiber transmitter, the information are decoded at the dispatching terminal using optical receiver.

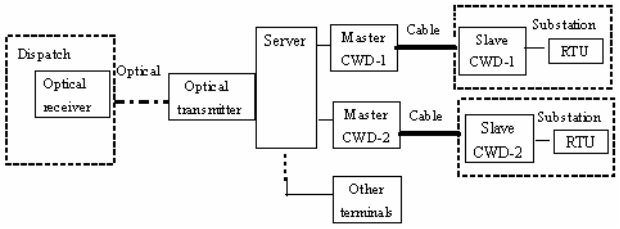

Fig.3 Remote-terminal server based approach

The advantages of this approach are: (i).Optical-fiber network is sufficiently utilized and fast data transition speed is obtained; (b). Multi-channel serial-port server is used, thus abundant information can be processed; (c).This approach doesn't rely on the information of substation RTU and the dispatching terminal can get access to other systems flexibly. Disadvantage is that all the data are transmitted using the same server, thus the same data acquisition system must be used in the receiving terminal at the dispatching center.

3.4 Low bit-rate asynchronous data interface

Fig.4 illustrates the schematic of low bit-rate asynchronous data communication. The output of master carrier-wave devices (CWD) are sent to low speed asynchronous data interface of PCM, and then sent to the dispatch terminal through optical-fiber cable. The carrier-wave information at the dispatch terminal can be accessed to SCADA system or distribution system, or sent to respective sub network after accessing to the terminal server.

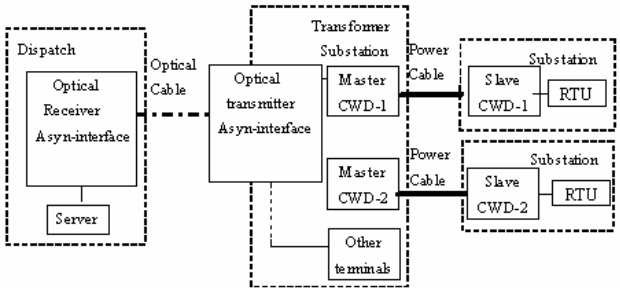

Fig.4 Low bit-rate asynchronous data interface

This approach combines the advantages of the previous three methods mentioned in section 3.1 to 3.3. And the information can be utilized in the different data acquisition systems. However, this method also has some difficulty in application, since the optical transmitter or receiver at the substation normally has a low speed data interface disk (V.24) and 4 serial ports. If there are more master carrier-wave devices (CWD) in the substation, extra data interface disks must be equipped both at the transformer substations and the dispatching terminals. This solution should be the best for information transmission in distribution substation.

4. Conclusion

The combined application of shield layer carrier-wave communication and the optical-fiber cables has been applied in the 10kV substations by the HuNan Power Supply Branch, Shanghai Municipal Electrical Power Company (SMEPC), the information obtained in the substations are send to the dispatching terminal to fully explore the remote terminal units (RTU). Up to Now. 303 cables have been equipped with shielded layer carrier-wave communication devices, and 80% of these cables used the fourth solution, low bit-rate asynchronous data interface approach, then the information of distribution substation can be utilized by the dispatching terminal; therefore, the 70 units of 10kV substations can be monitored instantaneously.

To conclude, with the development of technology and maturity of communication mediums, more approaches can be applied in the substation communication. We should fully utilize the available resources and try to find a most economical, reliable and simplest scheme for information transmission in the electrical power supply systems.