The Communication Network Scheme Based on EPON and Industrial Ethernet Technology for Smart Distribution Network

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Abstract. In order to meet the demand of security zone and reliable transmission for the business in smart distribution network, this paper proposes a communication network scheme based on EPON and industrial Ethernet technology on the basis of analysis for business requirements. The scheme using the advantage of EPON and industrial Ethernet technology, transmits different partitions business on distribution network. The analysis shows that the scheme can improve the reliability of transmission while guaranteeing the business security. It has reference value for the planning construction of smart distribution network.

1. Introduction

With the continuous improvement of the intelligent level of the power grid, as the key link of the power grid facing users, the distribution network is also evolving to the distribution automation structure. Distribution and communication network which is the carrier of communication between power grid and users, plays an important role. The design of network structure scheme should not only meet the requirements of different security levels for service, but also ensure the security and reliability of service transmission, which makes the important effect of communication network in the safe and reliable operation for distribution network more prominent [1].

The traditional communication network of the distribution network is mainly composed of power communication private network and wireless communication public network. The power communication private network mainly includes optical fiber communication network and medium voltage carrier network. However, the current communication modes cannot fully meet the requirements of security protection level and information security and reliability [2]. This paper, which is based on the in-depth analysis of business requirements for intelligent distribution network, puts forward a neoteric kind of communication network scheme for power distribution network based on the technology of EPON and the industrial Ethernet. The scheme considers the security demand level of different business, forms the dispatching electricity data network and using electricity data network, and protects business transmission security and reliability. It has certain reference significance to the intelligent distribution and communication network construction.

2. Demand analysis of smart distribution network business

2.1 Smart distribution network business requirements

2.1.1 Communication requirements for Distribution automation. Mainly to meet the monitoring
information, acquisition and control of fault location information for distribution network terminal equipment, such as switch station, column switch, ring network unit, etc.), with the characteristics of high real-time and high reliability [3].

2.1.2 Communication requirements for longitudinal network protection. Using the communication channel of power distribution network to realized longitudinal network protection. The operation time of distribution network line protection is about 500-700ms, and the delay of communication channel is 1s.

2.1.3 The business requirements of distributed power source and energy storage. The interactive communication delay between power distribution dispatching and state detection, control, management information is second level, with communication bandwidth of 64kbps-1mbps. The interactive communication delay between SCADA, AGC and AGV control information of distributed energy stations and the dispatching is second level, with communication bandwidth of 30kbps.

2.1.4 Communication requirements of load demand management. According to the special requirements of large load users, demand side of load management needs to be carried out, including load prediction, power quality monitoring, distribution of load control parameters and other functions. The communication delay is minute and the communication bandwidth is 5kbps.

2.1.5 Communication requirements of smart electricity meters. Collecting electricity information of users real-time, uploading information to power distribution dispatching such as electricity status, and transmit electricity charges, intelligent home appliance control and other information to users real-time. The data volume and real-time performance of the long-distance two-way communication of the intelligent electricity meters are moderate, and the communication bandwidth is 4-30bps.

2.2 Communication network requirements of smart distribution
In addition to meeting all kinds of service channel requirements, smart distribution network construction also needs to meet the following requirements.

2.2.1 Safety. According to the requirements of ‘the overall safety protection scheme of power monitoring system’ and ‘the safety protection scheme of power distribution monitoring system’, the safety protection work of power monitoring system should adhere to the principles of ‘safety partition, network exclusive, horizontal isolation, vertical certification’. The security partition of distribution network service system is shown in table 1. Services in different regions should be carried by private network.

| Numerical order | Service function                 | Control area | Manage information area |
|-----------------|---------------------------------|--------------|-------------------------|
| 1               | Distribution network dispatching automation | √            |                         |
| 2               | Distribution production rush repair command |              | √                       |
| 3               | Power load control management    | √            |                         |
| 4               | Electrical energy collection     | √            |                         |
| 5               | Low frequency and low voltage load reduction |              | √                       |
| 6               | Grid geographic information      | Dispatch geographic information | Managing geographic information |
| 7               | Electric Power Marketing         |              | √                       |
2.2.2 Reliability. The communication equipment of the distribution network has been used in the external environment for a long time and are in bad condition. The equipment performance should be fully considered to meet the requirements of industrial level. At the same time, the capability of distribution communication network channel to be standby and self-healing quickly should be considered to provide guarantee for reliable operation [4].

2.2.3 Expandability. The large number and wide distribution of terminal equipment in distribution network increase the network scale and network complexity of communication system. On the premise of meeting reliability and security, the easy expansibility of equipment should be considered and the communication mode that is easy to realize network node expansion should be reasonably selected [5].

3. EPON and industrial Ethernet working principle

3.1 EPON working principle

EPON is a PON network based on Ethernet protocol. It is a single-fiber bidirectional optical access technology with point-to-multipoint structure. It consists of the Optical Line Terminal (OLT), the Optical Network Unit (ONU) and the Optical Distribution Network (ODN). The principle is shown in figure 1.

OLT is a multi-service platform that as a local device, usually located in a central switching bureau. OLT uplink oriented data transmission network can provide power and optical port, and interface rate can reach 10 megapixels, while downlink oriented optical distribution network can provide fiber PON interface, whose function is to provide optical communication between business network and ODN. ODN consists of optical fiber and passive spectrometer, all of which are passive devices. It can distribute downlink data and gather uplink data, and complete optical signal power distribution, wavelength reuse and other functions. ONU is mainly used for the interface between ODN and user-side devices, providing the interface between user and ODN, usually placed on the user terminal side. ONU uplink interface is PON port, connecting to passive optical network, and downlink supports multiple types of interfaces (electrical port, RS232/RS485, PSTN, etc.), which can be configured according to user-side devices [6].

EPON adopts wavelength division multiplexing technology to carry out two-way communication of service signals at the same time. TDMA technology is used for uplink data transmission and broadcasting is used for uplink data transmission.
EPON network is flexible, with multiple cascade modes and hand-in-hand optical protection modes. In the optical fiber protection mode of hand-in-hand ring network, OLT is placed at both ends of hand-in-hand line, and two optical fibers are used to realize the protection of station information communication in the way of channel redundancy. The access mode of optical fiber protection of hand-in-hand ring network is shown in figure 2.

![Figure 2. Access Mode of fiber protection on hand-in-hand ring network](image)

3.2 Industrial Ethernet working principle

Industrial Ethernet is an industrial communication network based on Ethernet and TCP/IP technology. In the aspect of real time, the real time response speed of the network is improved by reducing Ethernet load, increasing network speed, switching Ethernet and full duplex communication, flow control and virtual LAN, etc. In terms of reliability, Ethernet can form a ring topology, and Ethernet automatic protection switching (EAPS) technology reduces the self-healing time to 50 ms [7]. Ethernet switch networking mode is shown in figure 3.

![Figure 3. Networking mode of industrial Ethernet switch](image)

Both EPON and industrial Ethernet technologies can meet the requirements of distribution network business in terms of real-time performance, reliability and security, and their performance characteristics are shown in table 2.

Table 2. Characteristics for EPON and industrial Ethernet

| Performance             | EPON                  | Industrial Ethernet              |
|-------------------------|-----------------------|----------------------------------|
| business support        | voice/data/video      | voice/data/video                  |
| maximum transmission distance | 20km                | 80km                             |
| transmission speed      | 1.25Gb/s              | 100Mb/s, 1000Mb/s                |
| self-healing ability    | better                | better                           |
| reliability             | About good            | good                             |
| cost of investment      | ordinary              | higher                           |
| Can satisfy distribution network business | Electricity information collection | Distribution automation, load control management |
4. Communication networking scheme of distribution network based on EPON and industrial Ethernet technology

4.1 networking scheme

In order to meet communication network security, reliability and economy of the smart distribution network, this paper puts forward a kind of intelligent power distribution network based on the technology of EPON and the industrial Ethernet communication network scheme. The scheme using high reliability of the optical fiber communication network can realize safe partition and network respectively for production control type of business and management information, and form the dispatching electricity data network and using electricity data network. The dispatching electricity data network and using electricity data network carry services respectively, as shown in table 3.

| Numerical order | Type of network                | Classification of service          | Service name                              |
|-----------------|--------------------------------|-----------------------------------|-------------------------------------------|
| 1               | dispatching electricity data network | Production control class          | DSCADA                                    |
|                 |                                |                                   | Load control management                   |
|                 |                                |                                   | Electrical energy collection              |
|                 |                                |                                   | Electric Power Marketing Management       |
| 2               | using electricity data network  | Management information class      | Electricity information collection        |
|                 |                                |                                   | Electric vehicle charging                |

In the dispatching center, the master station which of dispatching is built, and the router of dispatching electricity data network is configured to serve as the center of production control data processing in the distribution network. The access network of dispatching electricity data network adopts industrial Ethernet technology with high equipment reliability, and adopts ring topology structure to carry distribution automation business, load control and other production control business. The convergence layer is networked by routers and placed in 220kV and 110kV substations. Two sets of industrial Ethernet three-layer switches are configured at the 220kV and 110kV substations to access the router of data distribution network. The upper connection channel is carried by SDH transmission network and uploaded to the distribution dispatching center through the dual-plane main and spare channels. The terminal is configured to access the switch.

In the marketing center, the master station of the distribution using electricity data network is built, and the router of the distribution data network is configured as the center of the distribution network management information data processing. The access layer of the allocated electric data network adopts EPON technology and forms the network hand in hand to carry electricity information collection, electric vehicle charging pile and other management information businesses. The convergence layer is networked by routers and placed in 220kV and 110kV substations. The 220kV and 110kV substation are equipped with dual OLT, which are connected to the router of the distribution using electricity data network. The upper connection channel is carried by SDH transmission network, and uploaded to the marketing center via dual plane main and secondary channels. ONU is configured at the side of the 10kV terminal.
The principle of scheme networking is shown in figure 4.

4.2 Scheme performance analysis

4.2.1 Service secure transmission
In this scheme, the services of different distribution network zones are transmitted through different communication network channels, and the sub-network transmission of distribution network services is realized from the physical layer. In the context of the continuous improvement of the attention paid to the safety of the current power network operation, the safety protection requirements are truly implemented and hidden dangers are eliminated.

4.2.2 Strong self-healing
EPON and industrial Ethernet equipment all adopt industrial-grade standards, and the hardware has the advantages of high temperature resistance, corrosion resistance, well electromagnetic compatibility, and strong adaptability to harsh environment. "Hand in hand" ring network of EPON solves the impact on the whole network when a single node fails. Industrial Ethernet has good network self-healing ability, and the coexistence of two networks greatly improves the reliability of distribution network information transmission.

4.2.3 Network scalability
EPON network adopts non-uniform passive spectrometer on the main optical fiber. On the premise of reserving optical fiber resources and optical power, it can ensure that the main optical power is reserved for lower-level capacity expansion node equipment. For newly added nodes, only the spectrometer and ONU need to be added, so as to realize network capacity expansion.

5. Conclusion
Based on the existing communication network technology of the distribution network, this paper puts forward a smart distribution network networking scheme based on EPON and industrial Ethernet technology. After analysis, this scheme realizes the security of intelligent distribution network services in terms of security protection and guarantees the reliability of different service transmission in terms
of network self-healing. It has reference significance to the construction and implementation of smart distribution network.

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