Application Research of EPON in Distribution Automation System

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Abstract

This paper introduces the basic principle of EPON and discusses the feasibility of EPON applied in distribution automation system from the aspects of transmission ability, reliability, security, expandability and economical efficiency. Based on analysis of the structures commonly applied in distribution network, a constructing scheme is designed to solve the communication access problems in distribution automation system.

Keywords: EPON; distribution automation; communication system; constructing scheme

1. Introduction

Distribution automation system can achieve more intelligent power distribution, and optimize the allocation of power resources. It is one of the most important foundations for achieving smart grid [1]. Distribution automation system need effective communication methods to transmit control commands from the master station system to many remote distribution terminals and transfer different kinds of real-time information acquired by distribution terminals to the master station system in the opposite direction. There are a large number of distribution terminals in distribution network. They are distributed in large area and running in harsh environment, so how to construct communication system reasonably is the key factor to influence the performance of distribution automation system.

Distribution automation system can be divided into three layers: distribution master station layer, distribution substation layer and distribution terminal layer. Correspondingly, communication system of distribution network can be divided into two layers: backbone transmission layer from distribution master station to distribution substation and access layer from distribution substation to distribution terminals [2]. All fiber coverage has been achieved from distribution master station to distribution substation and distribution substations between, so backbone transmission layer choose SDH to build communication system. But access layer is lack of good communication method, so it is a major concern in constructing distribution automation system.

2. The Feasibility of EPON Applied in Distribution Automation System

2.1. The Basic Principle of EPON

EPON is a single fiber bi-directional optic access technology with point-to-multipoint structure. The EPON system is composed of OLT (Optical Line Terminal), ONU (Optical Network Unit) and

ODN (Optical Distribution Network) [3]. The reference architecture is shown in Fig. 1.

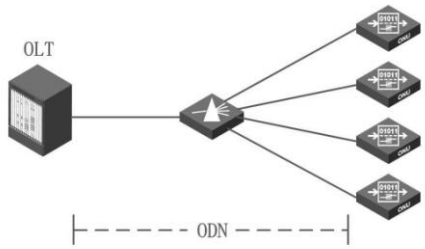

Fig. 1: The reference architecture of EPON

OLT provides the interface between network side and service nodes and communicates with ONUs through single or multiple ODNs. ODN is a distribution network composed of optical cable and passive optical components. ONU provides user side interfaces, completes photoelectric conversion and realizes access of different kinds of service.

In the downstream direction, OLT broadcasts Ethernet packets with specific identifier to ONUs. Each ONU receives its own downstream packets according to the corresponding identifier and discards others. In the upstream direction, all ONUs are synchronized to a common time reference, and each ONU is allocated a timeslot which is capable of carrying several Ethernet packets. An ONU should buffer frames received form a subscriber until its timeslot arrives. When the timeslot arrives, the ONU bursts all stored frames at full channel speed.

2.2. Feasibility Analysis

Compared with traditional communication schemes such as distribution line carrier, wireless private network and wireless public network, the access scheme based on EPON has obvious advantage. The following discusses the feasibility of EPON applied in distribution automation system from the aspects of transmission ability, reliability, security, expandability and economical efficiency.

Transmission Ability: EPON system has very high bandwidth. It can support maximal symmetrical speed of 1.25Gbps both in upstream and downstream. With the development of technology, this value can be increased to 10Gbps. The transmission ability can fully meet the requirements for different kinds of service in distribution network such as state variables, analog quantity and fault information. Moreover, there is a wide margin to satisfy development requirements in the future.

Reliability: EPON is a pure media network, of which ODN is composed entirely of passive components. Therefore it can avoid electromagnetic interference and lightning influence on communication equipments; The optical cable has strong anti-corrosion capacity; ONUs in EPON are connected in parallel mode, so if some branch fiber breaks, some EPON port damages or some ONU halts, other ONUs can still work normally; EPON system has perfect protection mechanism, double laser planes can be adopted to provide 1+1 channel protection and 1+1 line protection [4].

Security: Although ONUs in EPON system share single transmission channel, they only send data in their own timeslot, thus avoiding data collision and realizing logic insulate of different channels. Meanwhile EPON system can adopt two encryption algorithms: triple-churning and AES-128 to prevent illegal ONUs from acquiring data. So security requirements of data communication can be satisfied in distribution automation system.

Expandability: EPON system adopts point-to-multipoint structure, so it has excellent expandability. When adding terminals, it only needs to change optical splitter to increase optical direction. If optical splitter with large splitting ratio is

reserved, expansion can even be achieved without service interruption.

Economical Efficiency: There is no power supply and electronic component during transmission, so construction and maintenance cost can be reduced. Meanwhile EPON system doesn't need service cost as in wireless public network, so it can save long-term operation and management cost.

3. Design of EPON Constructing Scheme

In distribution automation system, the optical cable is laid along power cable direction, so the structure of communication network should coincide with the structure of distribution network. Based on analysis of the structures commonly applied in distribution network, the structures of EPON system are designed in the following sections.

3.1. Single Power Source Radial Structure

Single power source radial structure is a structure with clear connection mode, convenient operation and less construction investment. The topology is shown in Fig. 2. The main line in this structure is often separated to three or four sections. Power supply radius is about 3~5km [5].

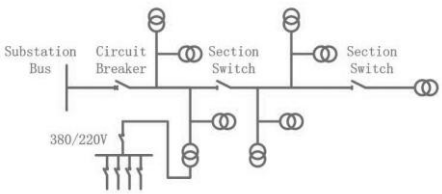

Fig. 2: Single power source radial structure

Chain-like structure can be adopted in EPON system to coincide with single power source radial distribution network. OLT is laid in distribution substation. Multilevel optical splitters laid beside each section switch are connected under one EPON port. ONUs are laid in the FTU box. The topology is shown in Fig. 3. Communication distance of OLT is about 20km, so it can satisfy the requirement of power supply radius.

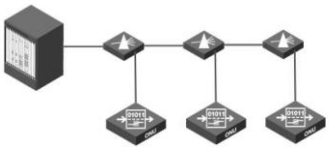

Fig. 3: The topology of EPON system: chain-like structure

3.2. Single Power Source Loop Structure

In single power source loop network, two cable lines from single substation bus are extracted to form a circuit loop. If a fault occurs in one of the lines, all loads in the loop can be supplied by the other line. So the reliability is higher than that of radial structure. The topology is shown in Fig. 4.

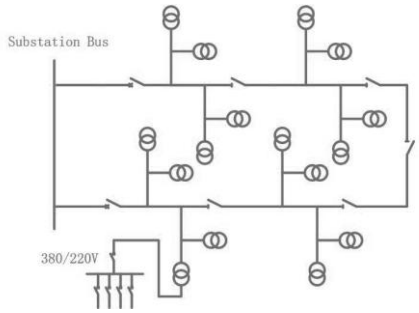

Fig. 4: Single power source loop structure

Loop structure can be adopted in EPON system to coincide with single power source loop distribution network. The topology is shown in Fig. 5. Multilevel optical splitters are connected under two different EPON ports of OLT. So the

EPON ports of ONU are in different laser planes. This structure can provide 1+1 line protection and increase communication reliability.

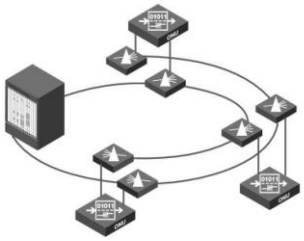

Fig. 5: The topology of EPON system: loop structure

3.3. Double Power Sources Hand-in-Hand Structure

Double power sources hand-in-hand structure is commonly adopted in town distribution networks. The ends of main lines from two power source are connected to realize open loop operation [6]. The topology is shown in Fig. 6. If a fault occurs in one of the lines or power sources, power supply of non-fault area can be resumed quickly by switching operation.

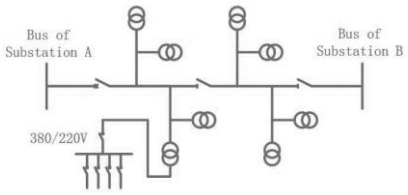

Fig. 6: Double power sources hand-in-hand structure

Hand-in-hand structure can be adopted in EPON system to coincide with double power sources hand-in-hand distribution network. The topology is shown in Fig. 7. Two OLTs are laid in different distribution substations. Multilevel optical splitters are connected to the OLTs in two directions. This structure can provide full optical path protection, if a fault occurs in one of the OLTs, optical splitters or ONUs, the communication channel won't interrupt.

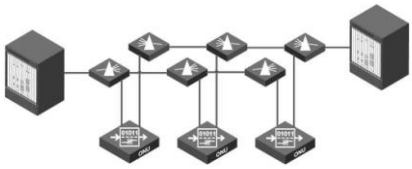

Fig. 7: The topology of EPON system: hand-in-hand structure

3.4. Double Power Sources Double "T" Structure

Double power sources double "T" structure not only takes full advantages of "T" connection mode such as cable economization, simple installation and flexible operation, but also provides reserve power transformer and low voltage distribution system to increase power supply reliability [7]. The topology is shown in Fig. 8.

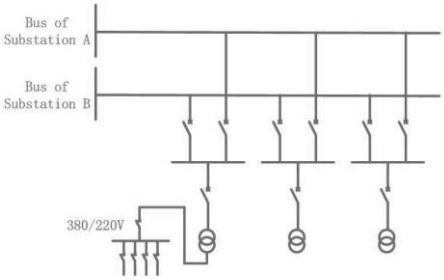

Fig. 8: Double power sources double "T" structure

Double "T" structure can be adopted in EPON system to coincide with double power sources double "T" distribution network. The topology is shown in Fig. 9. Like the hand-in-hand structure, two OLTs are laid in different distribution substations and multilevel optical splitters

are connected to the different OLTs, but the optical direction is almost the same. This structure can also provide full optical path protection and high communication reliability.

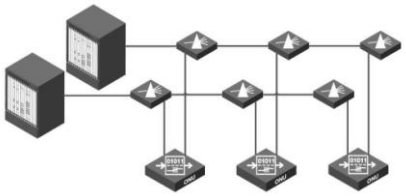

Fig. 9: The topology of EPON system: double "T" structure

4. Conclusions

In the process of building a unified, strong and smart grid, distribution automation technology is of great significance to improve the power supply reliability, increase the capacity, lower line losses and reduce labor intensity. As an important part of distribution automation, the stability and reliability of communication system is directly related to the normal operation of distribution automation system. The access scheme based on EPON can well satisfy the requirements of distribution automation on reliability, transmission ability, security and economical efficiency. It also has very good adaptability to future distribution services. With the technology development of optoelectronic devices and price descending, advantages of EPON will gradually appear. It will certainly get extensive application in distribution automation communication system.

5. Acknowledgment

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6. References

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