Communication System for Distribution Automation Using EPON

Zhong-wei Sun, Qingrui Guo, Yanin Ma, Fengjie Sun
School of Electrical & Electronic Engineering
North China Electric Power University
Beijing, China

Abstract—**In electrical power industry, the distribution network is an important part of the total electrical supply system as it provides the final link between the bulk transmission system and the customers. And a reliable communication network constitutes the core of the distribution automation system (DAS). Although a number of communication technologies have been applied to meet the utility's operational and planning purposes, there is no one-communication technology that is right for every situation. This paper proposes a novel communication method for distribution automation using Ethernet Passive Optical Networks (EPON). Based on centralized control scheme, a three-layer communication structure for DA is designed, which provides a good communication alternative for the DAS.**

Keywords-Ethernet Passive Optical Networks (EPON); distribution automation system (DAS); communication; centralized control scheme

I. INTRODUCTION

An electric power system consists of three principal divisions: generation, transmission, and distribution systems. The generation plants produce electricity using fossil fuels, nuclear fuels, natural gas, water falls, oil, and so on. Transmission lines transfer electricity to substations near customers. Distribution systems directly supply electricity to customers. In power systems, one of the most exciting and potentially profitable recent developments is the increasing use of automation techniques in monitoring, control, and assessment [1].

Distribution Automation Systems (DAS) has been defined by the IEEE as systems that enable an electric utility to monitor, coordinate, and operate distribution network components in real-time mode from remote control centers [2]. Traditional distribution systems were designed to perform one function—distribute electrical energy to end-users. The distribution system of the future is a concept for a fully controllable and flexible distribution system that will facilitate the exchange of electrical energy and information between participants and system components and benefit from the application of new technology for power generation and control. The distribution system of the future will use advanced distribution automation and new technologies [3].

Passive optical networks (PON), especially Ethernet PON (EPON) is a promising solution for access network because it provides low protocol overhead, higher bandwidth, lower costs, broader service capabilities, and easy integration of Local Area Networks (LANs) into future Ethernet-based optical networks [4,5]. In this paper, we propose a novel communication method for distribution automation using EPON. The rest of the paper is organized as follows: the next section gives a description of distribution automation system. The proposed communication system for distribution automation using EPON is given in section 3. The conclusion is given in section 5.

II. DISTRIBUTION AUTOMATION SYSTEM

A. *Architecture of the distribution automation*

The distribution automation system provides capabilities for a central server to collect operation data such as voltage and current, to monitor and control Remote Terminal Units (RTUs) which are dispersed in the remote areas, and to detect and restore faults automatically [6]. Generally, the operation and management mode of the DAS usually adopts hierarchical structure, namely, master station layer, sub-station layer and terminal layer, as shown as fig. 1.

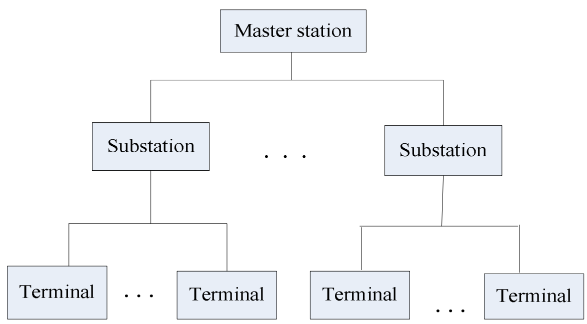

Figure 1. Hierarchical structure DAS.

- Master station layer: The master station implements the overall integration of distribution automation applied functions, which involves Super Control and Data Acquire (SCADA), Feeder Automation (FA) function, and Geographic Information System (GIS) function etc.
- Substation layer: The substation layer is in charge of collecting data from terminal layer and transmits data to master station layer, and at the same time, transmits

the command sent by master station layer to terminal layer.

- Terminal layer: The terminal layer of distribution automation has many kinds of equipment including Feeder Terminate Unit (FTU), Transformer Terminate Unit (TTU) and Distribution Terminate Unit (DTU) etc, which implements the functions of acquiring tele-metering, tele-command and tele-adjusting data of distribution primary equipments, controlling the equipments, catching and processing the fault message.

B. Communication system for automation system

A DAS involves the integrated technologies of computer, communication, and electric devices. As information exchange between the DAS server and field equipments becomes more critical for the system operation, communication technology plays an integral part of the distribution system. Distribution Automation communication requirements are driven by business functional requirements which may include, but are not limited to, the following [7]:

- Feeder status monitoring
- Feeder voltage quality monitoring
- Reactive power monitoring (capacitor bank monitoring)
- Managing reactive compensation (capacitor bank switching)
- Feeder switch control
- Feeder sectionalizer and recloser control
- Supervisory control of feeder fault isolation schemes
- Provide communication channels for fault isolation schemes
- Monitor customer power quality
- Read customer meters for total usage
- Read customer time-of-use usage
- Control end-use loads according to predetermined schedules
- Control end-use loads according to system conditions, such as peak load periods.

The history of distribution automation has a close relationship with communication media. For the application of DAS, several communication options have been considered including (1) Power line communication, (2) Microwave radio communication, (3) Satellite communication, (4) Optical fiber communication, and (5) Wireless communication. Each possible communication technology for distribution automation introduces its own advantages and disadvantages [8,9].

- Power line communications is a popular choice for distribution automation because it provides communications wherever the power lines are located. Disadvantages include the fact that communication will be disrupted by disturbances in the distribution line, and switching of the distribution line will cause communication routing to change.
- Microwave radio systems have been traditionally applied only in point-to-point station or substation communications with wide bandwidths. But emerging commercial products may make them useful in smaller applications in the distribution environment. Microwave is useful for general communications for all types of applications.
- Satellite systems likewise are effective for reaching difficult to access locations, but are not good where the long delay is a problem. They also tend to be costly.
- Fiber-optic cable is a very technically attractive solution, offering relatively unlimited bandwidth. Its dielectric and EMI/RFI noise immunity characteristics make it an ideal fit in the high-voltage operating environment. While fiber optic solutions are expensive, they offer two large benefits: first it allows utilities to bring back large amount of data on a frequent basis. Second, it can provide true, real-time communications. These benefits make fiber optic communications an attractive alternative if getting large amounts of data on a real time basis is critical and the location is not extremely remote.
- Wireless solutions have shown the potential for automating distribution networks because they communicate virtually anywhere at a very low cost. Several wireless communication technologies currently exist for electric system automation [10]. However, these communication technologies are suited to the applications that send a small amount of data and thus, they can not provide the strict Quality of Service (QoS) requirements that real time substation monitoring applications demand..

Many researchers and several international organizations are currently developing the required communication technologies and the international communication standard for electric system automation. It is agreed that there is no one-communication technology that is right for every situation. Utilities must weigh the advantages and disadvantages of each to determine the right technology for their application. Hybrids of two or more of the above technologies can provide optimal service for selected DA functions.

Two trends have been driving increased interest in distribution automation: 1) New intelligent electronic devices increase the available data at every distribution point, and 2) Development of new technology have decreased the costs of communicating with distribution equipment.

III. Proposed DAS Based on EPON

A. EPON

The EPON is a PON in combination with Ethernet. The EPON consists of one Optical Line Termination (OLT), multiple Optical Network Units (ONUs), and an Optical

Distribution Network (ODN) with passive optical components. All transmission in the EPON are performed between an OLT and all ONUs connected with the OLT, as shown in Fig. 2. In the downstream direction, the EPON is a point-to-multipoint network, and an OLT broadcasts the information to all ONUs. In the upstream direction, the EPON is multipoint-to-point network, the whole available upstream channel bandwidth is divided into transmission units (typically termed slots) using the Time Division Multiplexing (TDM) technique, which can be assigned to the active ONUs.

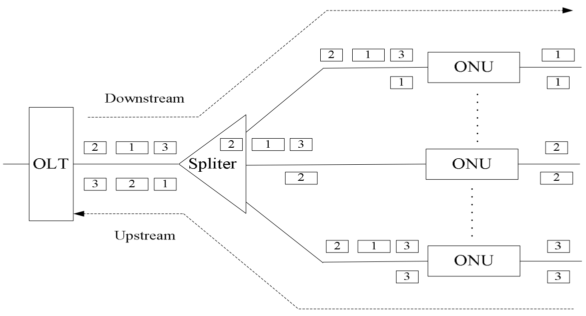

Figure 2. The principle of EPON.

Though the EPON mainly takes a tree topology structure, it can also take a ring topology structure, a bus topology structure and a hybrid topology structure when needed, as shown in fig.3

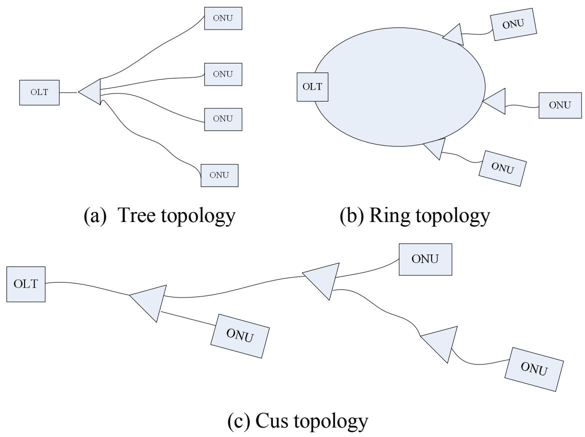

Figure 3. Typical EPON topology structure.

B. *Communication system using EPON*

The functions included in the distribution automation system are for both operational and planning purposes. These functions can be classified as FA functions, distribution analysis functions, and customer management functions etc. Current distribution network automation systems are usually implemented in two control mode: The local control mode and the central control mode. The system with local control mode is appropriate for areas where the requirement for communication can not be met. However, the continuing power system automation increases the use of intelligent electronic devices with communication capabilities for efficient distribution system protection, control and monitoring operations. Nowadays, the utilization of the systems with central control mode is becoming the mainstream for advanced DAS. And the main function of advanced DAS will be the remote control of switches to locate, isolate the fault and restore the service, when a fault occurs in the power distribution line. In this way, computer can monitor the physically based distribution system model in real time and change the on/off status of switches in the remote control mode. Operators can easily change the on/off status of switches through simple mouse operations on the single line diagram. Upon occurrence of a fault in the distribution line, a change of status is picked up by a fault indicator inside of the automatic switches and an event signal is sent to the central station computer. As a result of this performance, information about the faulted spot is displayed on the schematic diagram. Therefore, operators can directly observe alarm/event message by the audible and visible display.

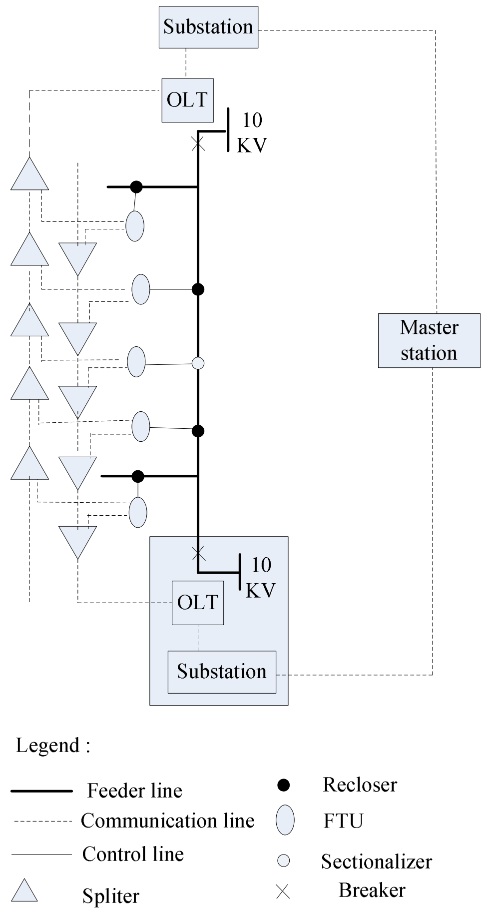

Figure 4. Configuration of EPON system for distribution automation.

Fig. 4 shows the configuration of EPON communication system for distribution automation, where the centralized control scheme is adopted. As shown in Fig.4, a redundant EPON communication structure is employed, due to the high reliability requirement of DAS. When the working EPON communication link breaks down, the backup EPON communication link will be activated and the backup EPON communication link will be used. Hardware elements needed for the implementation for this mode include intelligent reclosers and sectional switches, and feeder terminal units (FTU) that have communication functions. Here the ONU is integrated in the FTU and acts as a module of the FTU. And Software elements include a feeder automation (FA) program running in the control center, which is in charge of fault location, fault isolation and fault recovery. On the occurring of a fault, fault signals are transmitted from these FTUs and received by the control center, and taking these fault signals as inputs, fault location can be accomplished by FA software. Then tripping commands are generated by the software according to a predefined order and sent to these FTUs. After the hipping operations of these switches, fault isolation is done. Finally, reclosing strategies are formed by the software utilizing a certain fault recovery algorithm and after executing these reclosing commands, the blackout is cleared.

IV. CONCLUSION

The operational and commercial demands of electric utilities require a high-performance data communication network that supports both existing functionalities and future operational requirements. Based on the EPON, this paper proposes a novel communication system for distribution automation, and a three-layer communication architecture with centralized control mode is also described. The proposed communication method provides a communication alternative for the DAS.

ACKNOWLEDGMENT

The authors would like to thank the members who had participated in State Grid ICT EPON research project for their support and advice.

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