Design and Implementation of the Wireless Data Acquisition System for Substation Based on IEC61850 and WIA-PA

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Abstract—**This paper presents a wireless data acquisition system for substation based on IEC61850 and WIA-PA, which can standardize the monitoring data transmission in a wireless way. First, the system structure is introduced; Second, the intelligent gateway and wireless adapter of system are designed; Finally, the validity of the system has been verified according to the practical application in the intelligent substation.**

Keywords-substation data acquisition; IEC61850; WIA-PA; wireless communication

I. INTRODUCTION

With the development of intelligent substation，the automation degree of substation improves gradually，the distributed on-line monitoring system which monitors all electrical equipments and operating environment has become the research hotspot[1]. But the main difficulties for the construction of distributed on-line monitoring system are the selection of communication mode and the problem about data standardization access [2].

At present, most substation monitoring data are transmitted by the wired way, and it is limited by an increasing number of monitoring quantities with routing, high cost, limited flexibility and scalability. At the aspect of data standardization access, IEC61850 is the main standard for smart substation[3]. However, the application of the online monitoring system based on IEC61850 standard in smart substation is still in the primary stage. Although many manufacturers are actively developing monitoring devices comply with IEC61850 standard, but the practical applications are few. In the existing smart substation, the online monitoring devices are almost not supported IEC61850 protocol, and the communication of online monitoring system that is fully realized in IEC61850 standard is also very few in new smart substation. So there must be a transition period to make the transition from the primary stage to the full realization of IEC61850 communication[4].

The proposed system in this paper can transmit different kinds of monitoring data in a wireless way, and the gateway supports IEC61850, so that it can realize the standardization access of monitoring data but also avoid the disadvantages of wire communication mode.

II. SYSTEM COMMUNICATION ARCHITECTURE

According to IEC61850 standard ， the substation communication system is divided into three levels, including the process level, the bay level and the substation level[5].The communication architecture of the wireless data acquisition system in this paper is established on the basis of this hierarchical structure, as shown in figure 1.
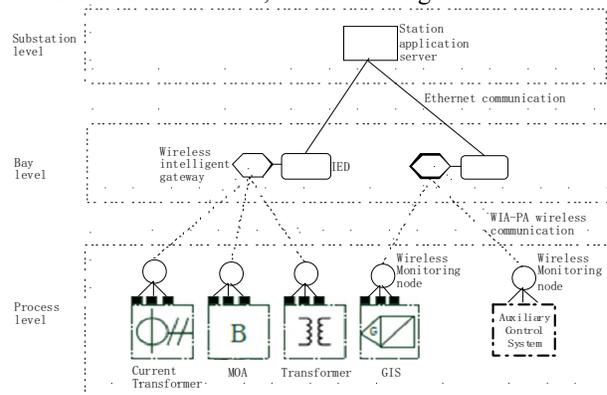

Figure 1.   system communication architecture

In the process level, there are many substation equipments for being monitored, such as current transformer, MOA(Metal Oxide Arrester), transformer, GIS(Gas Insulated Switchgear), and so on, and the equipment operating environment monitoring is also needed[6]. The wireless adapters are integrated into these monitoring devices, so that they can transmit various monitoring data to the wireless intelligent gateway through WIA-PA(Wireless networks for Industrial Automation-Process Automation) wireless network.

The bay level includes wireless intelligent gateway and IED(Intelligent Electronic Device), the wireless gateway device is responsible for communicating with the wireless adapter, and is connected with IED through an interface module, which can convert the data into IEC61850 standard from WIA-PA network protocol to communicate with IED using IEC61850. IED equipment is mainly used to upload the data receiving from wireless gateway to the station application server, and receive the control instructions and configuration information from the station application server.

Substation level as the monitoring and management center of the whole station is mainly responsible for analyzing the data uploaded from IED and sending down the control instructions. Ethernet is used for communication between the bay level and the substation level.

In this system, the communication in process level using the WIA-PA technology, it is an ultra-low-power intelligent multi-hop wireless sensor network technology which is more suitable for high reliability industrial application. It has adaptive frequency hopping, multi-path routing, and other characteristics, especially in substation complex electromagnetic environment[7][8].

III. SYSTEM DESIGN AND IMPLEMENTATION

The proposed substation wireless data acquisition system is realized by wireless adapter and wireless intelligent gateway.

A. The design of wireless adapter

Wireless adapter that connects with various monitoring devices, and the wireless intelligent gateway form the WIA-PA network, which enables wireless data transmission. Wireless adapter has two forms, one is embedded wireless communication module, which is mainly composed of antenna connector, matched filtering circuit, RF signal conditioning circuit, RF signal transceiver circuit, MCU and interface circuit, the composition block diagram is shown in figure 2.
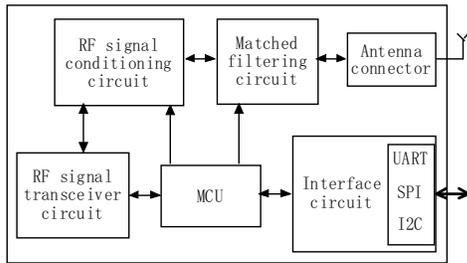

Figure 2.   The composition block diagram of wireless adapter

The MCU running WIA-PA protocol stack realizes the wireless data transmission by controlling the RF signal transceiver circuit and its external matching circuit. And the wireless adapter provides rich communication interfaces for easy integration with other devices. The factual picture of wireless adapter is shown in figure 3.

Figure 3.   The picture of wireless adapter

The integrated mode of this form of the wireless adapter and the monitoring device is internal integration, that the WIA-PA wireless module is integrated directly into the main circuit board of monitoring device through UART, SPI, I^{2}C

interface, as shown in figure 4. This integrated mode has the advantages of small volume, low cost, good sealing, high security, and so on. The MOA insulation monitoring device and core grounding current monitoring device use this integrated mode.   The factual picture of wireless MOA insulation monitoring node is shown in figure 5.
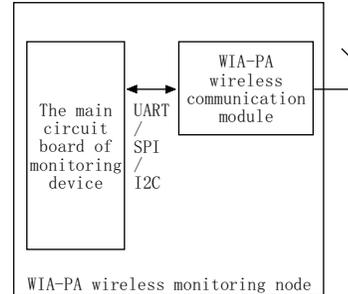

Figure 4.   The diagram of internal integration

Figure 5.   The picture of wireless MOA insulation monitoring node

Another form of wireless adapter is WIA-PA wireless transparent transmission module based on wireless communication module combining with peripheral circuits including power supply circuit and communication interfaces. The factual picture of WIA-PA wireless transparent transmission module is shown in figure 6.

Figure 6.   The factual picture of WIA-PA wireless transparent transmission module

This form of wireless adapter is integrated with the monitoring device using external interfaces such as RS232，RS485 or Ethernet, as shown in figure 7. This approach is mainly used in the case of inconvenient to achieve integration, such as SF6 gas monitoring device and waterlogging monitoring device. The factual picture of wireless waterlogging monitoring node is shown in figure 8.
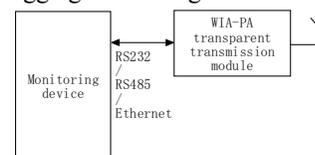

Figure 7.   The diagram of external integration

Figure 8.   The picture of wireless waterlogging monitoring node

B.   The design of wireless intelligent gateway

The wireless intelligent gateway communicates with each wireless adapter through WIA-PA network, and it includes IEC61850 protocol conversion module so that is able to communicate with IED in IEC61850 standard.

1)   Hardware Design

The hardware of wireless intelligent gateway is composed of RF communication module, MCU, memory unit, power management module, wired communication interface circuit, as shown in figure 9.
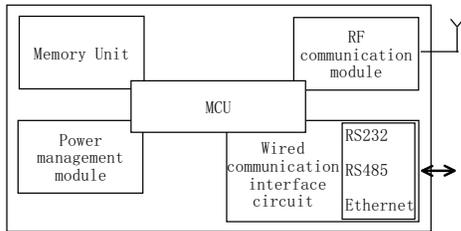

Figure 9.   The hardware composition of wireless intelligent gateway

The MCU running WIA-PA network management software and IEC61850 protocol conversion module, that is able to realize the network management and protocol conversion function by controlling the peripheral circuit units, and to communicate with the IED by wired interface such as RS232，RS485 or Ethernet, the factual picture of gateway is shown in figure 10.

Figure 10.   The picture of wireless intelligent gateway

2)   Design of protocol conversion between WIA-PA and IEC61850

IEC61850 defines 14 kinds of abstract class interface ACSI (Abstract Communication Service Interface) in the network layer and encapsulates the appropriate properties and services[9].Each IED contains one or more services, each service contains one or more logical devices, the logical device contains the logical nodes, and the logical node also contains data objects[10]. In the communication protocol conversion process, the communication port maps the data packets based on the MMS (manufacturing message specification) into the IEC61850 standard communication

data packets through 14 kinds of ACSI[11]. In this paper, the protocol conversion is the process which making the WIA-PA network data to application layer data through SCSM mapping.
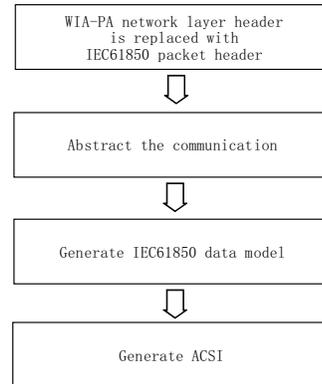

Figure 11. IEC61850 data model building steps

As shown above in figure 11, the process for building IEC61850 data model is divided into four steps. The first step is replacing the WIA-PA network layer header with IEC61850 protocol address and abstracting the communication function, then the data model is generated by inheriting and citing the IEC61850 standard model appropriately, at last, the ACSI of external access to these data model is defined.

IV.   APPLICATION OF THE WIRELESS DATA ACQUISITION SYSTEM IN THE PILOT SUBSTATION

The proposed substation wireless data acquisition system in this paper has been carried out the practical application testing in a pilot substation in Liaoning Province, and has been running for a few months. The validity of the system has been verified.

In the pilot substation, the monitoring devices which integrate the WIA-PA wireless adapter including MOA insulation monitoring device, core grounding current monitoring device, SF6 moisture and density monitoring device, waterlogging monitoring device and equipment temperature monitoring device. Details of monitoring items, integrated mode and number are listed in table 1:

Table 1. Monitoring nodes using WIA-PA wireless adapter

Monitoring items	Integrated mode	Number
Insulation of MOA	Internal integration	11
Core grounding current	Internal integration	4
Moisture and density of SF6	External integration	49
Waterlogging	External integration	22
Equipment temperature	Internal integration	63

The physical structure of the system is shown in figure 12. The wireless monitoring nodes which integrate the WIA-PA wireless adapter in process level transmit the monitoring information data to wireless gateway which in bay level via

the WIA-PA wireless network. The wireless gateway is connected to IED by serial interface and converts the WIA-PA network data to IEC61850 protocol standard data. IED is connected to the application server which in substation level via Ethernet, and uploads data and receives instructions.
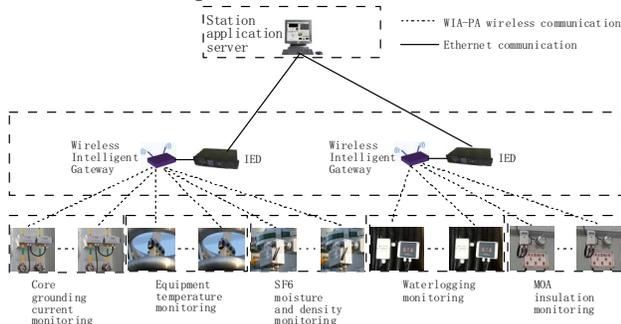

Figure 12. The physical structure of wireless data acquisition system

Figure 13-14 are the pictures of wireless intelligent gateway and wireless monitoring nodes installed in the substation.

Figure 13. The scene photo of wireless intelligent gateway

Figure 14. The scene photo of wireless monitoring nodes

V. CONCLUSIONS

This paper presents a substation wireless data acquisition system based on IEC61850 and WIA-PA, which can realize the standardized access of substation monitoring data in the present stage, but also can provide an idea for substation communication which in wireless way. The system has been applied in pilot substation in practice, which verifies its excellent communication performance, and there is a good prospect for the substation application. However, there are still many issues including integrated optimization and communication stability need to study. We will carry out further research on these issues.

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