The Application of the Distributed Measurement and Recording System Based on Wireless Technology for Start Debugging Process of EHV/UHV Transformer Substation

Peng JIANG\textsuperscript{1}, Jia-en SUN\textsuperscript{2} and Zhi-guo ZHOU\textsuperscript{2,*}

\textsuperscript{1}State Grid Zhejiang Electric Power Research Institution, China
\textsuperscript{2}School of Information and Electronics, Beijing Institute of Technology, China
*Corresponding author

Keywords: Start debugging process, Wireless technology, Transient state waveform recording.

Abstract. Due to the low efficiency of preparation, long-distance electrical wiring easily causing safety accidents and other problems during the start debugging process of EHV/UHV transformer substation. A distributed measurement and recording system for start debugging process based on wireless technology is developed. The current and voltage signal of the substation is collected through each node, and then the collected signal is uploaded to the upper computer by the wireless local area network, so as to realize the transient state waveform recording and other functions. The test shows that the system can obtain the transient waveform and equipment state of each node not only in real time but intuitively. The working frequency is 5.8GHZ or 2.4GHZ, which can be covered about 2km.

Introduction

In recent years, with the rapid economic development, the construction of power transmission and transformation projects has been accelerated, and the original substation has been expanded basically. In order to ensure the stable and reliable operation of the transmission and transformation project, the new launched substations need to conduct start debugging process, with the purpose of measuring the transient current and voltage during the switching process of the line switch, so as to analyze and test the system's overvoltage and overcurrent level, switch performance and reliability, etc. The traditional start debugging process adopts long-distance artificial line setting, which is inefficient in preparation and easy to cause certain safety problems. In addition, in the traditional way, the data read by the recorder should be analyzed and processed manually, which also caused some inconvenience for start debugging process.

For this reason, a wireless measurement and control system for start debugging process is developed. Combining wireless communication technology, high-precision sensor technology and embedded technology, it provides a safe and efficient wireless measurement and control solution for start debugging process. Through distributed measurement and control of all nodes, the system conducts distributed wireless acquisition and transmission of voltage and current electromagnetic transient signals, saving a lot of preparatory work at the early stage. Compared with the traditional start debugging process, the preparation time at the early stage and disassembly time at the later stage are only 25\% of the original, improving the efficiency a lot. In this system, the GPS/BD synchronous timing scheme is adopted to realize the clock synchronization of multi-node distributed measuring equipment \cite{1-4}, so as to ensure the data of each node is related \cite{5}. In addition, the system uses WLAN to ensures the data communication between each node and the central master station. This system also has professional software which is more concise, intelligent and efficient than the traditional recorder.

The Solution of the Distributed Measurement and Recording System

Overview

The main components of the distributed measurement and recording system for start debugging
process include the distributed current acquisition node, the distributed voltage acquisition node, the central master station, and the professional software for upper computer, etc.

As experiments go, the distributed voltage node collects signal from the generator step-up transformer, and the distributed current acquisition node collects signal from the measured lines. Then the signal of each node is synchronized by GPS/BD, and the signal collected by nodes is transmitted to the central master station through the wireless local area network. The central master station is connected to PC through the network cable, and the staff can view and analyze relevant data on the professional software of the upper computer. The system’s architecture is shown in Fig.1.

![Diagram](image-url)

**Figure 1. The system’s architecture.**

### The Distributed Voltage Acquisition Node

The working process of distributed voltage collection node is signal collection, ground line isolation, signal transformation, ADC sampling, GPS time synchronization, signal processing, data packaging and data communication. At present, the method adopted is to directly collect the voltage through the wire from the generator step-up transformer, which first passes through the ground isolation module (Separate the ground wire of the power supply from the ground wire of the input, preventing the power grid from generating large current to burn out the equipment at the moment of starting up). The voltage is then converted into a signal which is suitable for processing by the signal conversion module.

The main internal structure adopts the architecture of ARM+FPGA+ADC to realize high-speed data collection. ADC adopts industrial grade AD device of 6-channel and 200kSPS, which is controlled by FPGA to collect and read data. Besides controlling ADC collection, FPGA also has the function of clock synchronization, reading time and 1pps signal from GPS/BD module, marking the collected data with an accurate timestamp and then sending it to ARM [5].

ARM adopts high-performance processor based on industrial CortexA8 architecture, and communicates with FPGA through GPMC interface to achieve functions such as high-speed reading of collected data, receiving upper computer’s control instruction, calculating trigger state, saving key data and data packaging. The device is also equipped with a network bridge and antenna, which is responsible for the wireless transmission of signal communication. The node has a battery inside which is expected to be available for at least 23 hours. In addition, there is an external power supply port in case of emergency. The node can simultaneously input the ABC three-phase voltage from generator step-up transformer for measurement and control. The voltage input range is ±10mv ~ ±400, and the voltage frequency range is 10Hz ~ 50KHz. The hardware structure of distributed voltage acquisition node is showed in Fig.2.

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The Distributed Current Acquisition Node

The design scheme and working principle of the distributed current acquisition node is basically similar to the distributed voltage acquisition node, and the collected signal is transmitted wirelessly to the central master station through the network bridge and antenna. The acquisition principle is showed in Fig.3.

A little difference is it first collects and processes the voltage signal on current probe, and then the target current signal is obtained by dividing the resistance of the current probe. This kind of probe is very small and light, when measure the secondary circuit of current transformer substation, the current acquisition node is supposed to placed next to substation relay room and then insert the current probe into the measured line carefully. This node can simultaneously input ABC three-phase voltage for measurement and control. The current input range is 10mA~6A, and the current frequency range is 10-50kHz.

The Central Master Station

The center master station contains a wireless transmission module, which adopts an industrial-grade high-speed wireless network bridge. The wireless network bridge is connected with each node through Ethernet cable, and the nodes are connected to the central master station according to WLAN provided by the central master station. In this way, the wireless transmission of data within the station is realized. The wireless transmission module realizes the wireless data communication through antennas.

The central main station is the center and access point of the entire WLAN. The signal of the voltage and current collected by nodes is sent to the central master station through the wireless network antenna. The working frequency is 5.8GHz or 2.4GHz, which can be covered about 2km.

The central master station is placed close to the substation relay room and has convenient power supply, so the network line is used for power supply.
In addition, the central main station is also integrated with radio frequency communication module, which can communicate with smart battery remotely through the communication module, in order to acquire battery power information, temperature information and other state quantities remotely. What’s more, it also can control the power supply of the acquisition nodes.

The Professional Software

The upper computer software includes three functions: real-time receiving and displaying the working status and data waveform of the acquisition node; To analyze and process the collected and displayed waveform; File storage and import.

The three functions can be divided into basic service layer, protocol layer, object model layer and GUI layer. When the upper computer works normally, there is a thread in the background, which will send the operation status information of the acquisition nodes at regular intervals, facilitating the central master station to monitor the power supply and communication status of each acquisition node. Realizing the function of checking the data waveform of the collected voltage and current signals, processing the data intelligently and the monitoring each node. The relevant analysis interface is shown in Fig. 4.

Field Experiment

From 2014 to 2018, the distributed measuring and recording system based on wireless technology for start debugging process of EHV/UHV transformer substation have participated in more than 20 start debugging processes of 500kV EHV substation and two UHV substation, which showed the accuracy, convenience, simplicity and safety of the system when compared with the traditional recorder that has been used for many years.

The voltage node is supposed to connect to the circuit breaker’s terminal with three double-shield short wires, and the voltage signal collected is sent to the upper computer wirelessly. During the experiment, a lot of wire releasing work is saved, and the work efficiency is improved a lot. In addition, it also avoid the risk that the wire of the traditional recorder passing the road will be crushed and broken.

The current probe is supposed to directly attach to the measured line without dismantling any circuit. The node is supposed to be placed near the substation relay room. It is powered by battery and the data is transmitted wirelessly without laying out the wire. The experimental site is relatively simple.
The central master station is supposed to be placed near the substation relay room. A network line is used for power supply and data interaction with the upper machine.

The upper computer only needs a computer with wireless function to complete the data recording.

In the preliminary preparation and final finishing of the experiment, the distributed wireless simultaneous measurement and recording system has obvious efficiency advantages due to its simple structure and few wires. In the data processing, it helps the experimenters save a lot of time with its intelligent and professional automatic computing function.

By converting the measured waveform of the traditional recorder into the waveform format supported by this software, and comparing the test results of the two tools. We can find that the distributed wireless recording system is basically consistent with the traditional recorder in measuring accuracy and waveform accuracy. As shown in the Fig. 5, the waveform of the recorder is on the left, and the distributed wireless measuring and recording system is on the right. Experimental results show that the system meets the technical requirements of start debugging process.

![Experimental waveform comparison.](image)

**Conclusion**

The distributed wireless measuring and recording system for start debugging process has the following characteristics:

1) Wireless digital transmission is realized instead of cables, which improves work efficiency and safety performance.

2) The measuring and recording system is simple in structure, which is easy to carry and use, improving work efficiency and saving manpower and material resources.

3) The micro-open and combined induction probe is adopted for current measurement, which is more secure and convenient.

4) Low interference and high accuracy, which meet the requirements of precision and accuracy of start debugging process.

5) Software customization, which is simple and easy to use, it also can realize intelligent data processing.

The system is compared with the traditional recording system for field experiments, and the results show that the two results are basically consistent, which can accurately reflect the electromagnetic transient change rule. While the distributed wireless measuring and recording system has obvious advantages in installation and disassembly, operation experience and safety.
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