Design and Research of Optical Fiber Signal Analyzer in Embedded System Based on Big Data

Xiao Tao*  
FiberHome Telecommunication Technologies Co., Ltd., Wuhan 430205, Hubei, China  
*Corresponding author e-mail: taoxiao@fiberhome.com

Abstract. With the advent of the era of big data, substation automation technology has reached a certain level after more than ten years of application development. In recent years, in the transformation and construction of the transmission and distribution network, a large number of substations have adopted modern technology, which has greatly improved the technological modernization of transmission and distribution and transformer construction, enhanced the reliability of transmission and distribution and transformer scheduling, and reduced the substation. The total cost of construction and the application of electronic transformers have effectively promoted the research on digital substations. In order to complete the real-time monitoring and testing of the substation system, so as to more quickly grasp the working status of the substation equipment, this paper proposes a research and design of an optical fiber signal analyzer for substation system testing. By analyzing the IEC 61850 protocol, the characteristics of the embedded system and the embedded operating system, the software modular design of the sampling value module of the signal analyzer is carried out, and the analysis of the substation configuration file SCD is designed and realized. The research results show that in practical applications, it is necessary to parse the CID files one by one, which will cause cumbersome work and easy omissions. Based on the above considerations, the SCD configuration file containing the entire site information was finally selected.

Keywords: Big Data, Embedded System, Optical Fiber Signal Analyzer, IEC 61850

1. Introduction

With the development of big data, the development of electronic technology, automation technology, network technology, and the emergence of voltage transformers, current transformers and smart switches, substation technology has undergone profound changes. Traditional substations have been gradually replaced by modern automated substations [1-2]. The technology of signal analyzers has also undergone tremendous changes with the development of substation technology and electronic technology, and a large number of manufacturers have begun to engage in the research of power signal analyzers [3-4].

In the initial stage of substation transformation, because there is no unified-standard communication protocol to regulate the communication mechanism of substations, the communication
protocols adopted by power intelligent equipment on the market are messy and there are great obstacles to the interoperability and interchangeability of equipment. These factors have increased the development cycle and difficulty of the power signal analyzer [5-6], because the development of the signal analyzer needs to be combined with the communication mechanism of the substation, and its development needs to be tailored according to the substation. The cycle and cost of equipment development are not conducive to the mass production of signal analyzers, and to a certain extent also increase the technical cost of the substation [7-8].

In this paper, the most popular signal analyzer in the power industry is studied. First, the IEC 61850 protocol, the characteristics of the embedded system and the embedded operating system are analyzed, and then the software modular design of the sample value module of the signal analyzer is implemented, and the design is realized the analysis of the substation configuration file SCD, the research results show that in practical applications, it is necessary to analyze the CID files one by one, which will cause cumbersome work and easy omissions. Based on the above considerations, the SCD configuration file containing the entire site information was finally selected.

2. Proposed Method

2.1 Advantages of IEC 61850

(1) Support the self-expression of big data; object-oriented data self-description mainly refers to the self-description of these data in a data source itself, so a data transmitted to the receiver will be accompanied by a data source. The data is self-describing, so that the recipient no longer has to perform operations such as physical quality correspondence and scale conversion according to the needs of the transmitted data, which simplifies the operation and management of data processing [9-10]. Because they support automatic description of data, there may be no prior or preset restrictions during data transmission.

(2) Using an abstract communication service interface (ASCI) independent of the network, ASCI separates the application process from abstract communication and provides special communication services for it, and defines abstract communication services, communication objects, and related communication that are not related to specific communication protocols. The realization of the ASCI service is realized by the specific communication service mapping SCSM mapping it to different protocol stacks. If the communication technology develops, the service model can be realized only by changing the SCSM, instead of modifying the ASCI defined in the conceptual standard. Therefore, ASCI can solve the contradiction between the stability requirements of protocol standards and the application of new technologies [11-12].

2.2 Features of Embedded System

(1) An important feature of equipment closely related to "embedding": Since what a device wants to do is to be embedded in the system of a device, it must be required to fully meet the environmental conditions and functional requirements of a certain device For example, the physical size and size of the equipment is small, the reliability of the equipment during normal operation, low cost, and low power consumption.

(2) Features related to "speciality": Since embedded devices are all used in specific environments, their software and hardware systems are different, but both software and hardware are required to be portable, tailorable, etc., to meet the requirements the usability of the system must meet the compactness required by the target system.

This article believes that the biggest feature of embedded systems lies in its huge flexibility and portability. Designers can design the system's software, hardware and functions according to different needs and applications. This is also the main difference between embedded systems and PCs.
2.3 Embedded Operating System

An embedded system is usually a combination of hardware-related basic driver software, system kernel, installation device and driver interface, image and user interface. The so-called embedded operating system is the main body of comprehensive utilization and management of embedded system resources. With their help, users can use various software and other applications more conveniently and safely. Because of the complexity and diversification of the software and hardware environment of embedded operating systems and the application occasions often put forward higher requirements for its real-time performance, the design of embedded operating systems generally needs to fully consider its real-time performance and multi-platform support.

1) VxWorks
Vxworks software is a brand-new micro-kernel structure software developed by windriver company itself. It has many advantages such as rich network protocols, multiple processors supported, good compatibility and reduction functions. vxworks supports multiple major processor architectures such as x86, powerpc, arm, etc. Although vxworks uses environments that are incompatible with Unix, it has won the favor of many users because of its good reliability, real-time, openness and easy-to-operate features.

2) Windows CE
WinCE is a product of Microsoft Corporation. It is a multi-threaded, full-priority, multi-tasking operating system designed for platforms with limited resources. However, its high cost of use has discouraged many users. With the increasingly fierce competition in the embedded operating system market, Microsoft has added a streamlined version of the WinCE system to Windows CE.Net, which has basic functions including real-time operating system kernel and file management system.

3) Linux
Linux is the fastest growing and most widely used. Linux is a powerful and stable operating system that supports multitasking and good real-time performance. Can run on ARM, X86, MIPS and other platforms. Linux itself adheres to the design principle of "free thinking, open source code". It can be said that Linux itself is an operating system of many computer likes and enthusiasts.

According to reports, Linux embedded system has become the second largest operating system in the world, occupying half of the embedded system market, and many users and maintainers. This is inseparable from the cost of Linux system development and its advanced technology, especially for small and medium-sized enterprises, the low-cost threshold of Linux system makes it have more users.

3. Experiments

3.1 Main Functional Indicators of Signal Analyzer
According to requirements, the signal analyzer mainly realizes the functions of acquiring, analyzing, data storage and display of related network signals, and also needs to realize the receiving and sending of two pairs of optical fiber signals at the same time, and the analysis of GOOSE, 9-2 and other messages. FT3 Manchester decoding, etc., and set up the necessary expansion interfaces, such as serial port, USB interface, network port, SD card expansion port, LCD interface, etc., for use. Moreover, in terms of overall system technical indicators, it is also necessary to meet the measurement accuracy and test specifications set by -H. The main technical indicators are as follows:

1) Working environment temperature: -5°C~45°C.
2) Working atmosphere humidity: 50%~80%.
3) The sampling rate of the AD converter is 3G points/s, and the number of conversion bits is 8 bit (using FPGA-based independent acquisition
   Control panel, this article did not make in-depth research on it).
4) Interface quantity and specifications: 2 pairs of multi-model optical fiber connectors (1 out and 1 in), USB port, SD port,
   RS232 interface, Ethernet interface, display interface, etc.
(5) Photoelectric conversion module: used for 100 MBit/s optical fiber multi-mode signal, conversion accuracy 2%.

(6) Display size: 12-inch large-size LCD display.

3.2 Algorithm Research

The core module based on the complex analysis band-pass filter zoomfft. Assuming that the passband frequency of a band-pass filter is \([w_l, w_h]\), let \(w_d = (w_h - w_l)/2\), \(w_e = (w_h + w_l)/2\), then the ideal low-pass filter \(h_d(n)\) is shifted by \(w_e\). Then shift the frequency of an ideal low-pass filter. Then, the complex analysis band-pass filter \(h(n)\) can be obtained.

\[
h_d(n) = \frac{\sin(w_d n)}{\pi n}, n = 0, \pm 1, \pm 2, \ldots\]

\[
h(n) = h_d(n)e^{jw_en} = \frac{\sin(w_d n)}{\pi n}e^{jw_en} \cos w_en + j\sin w_en\]

According to the different combinations of the passband width of the complex analysis bandpass filter and the decimation ratio, there are many ways to refine the spectrum of the same signal, and the same spectrum refinement multiple can be obtained. Suppose the sampling rate of the original signal is \(f_s\), \(N\) is the number of FFT analysis points, and \(D\) is the refinement multiple.

\[
x(t) = \cos(2\pi498t) + \cos(2\pi502t) + \cos(2\pi502.7t)
\]

The signal shown in equation (3) is subjected to a simulation operation of 100 times of spectrum refinement. The sampling rate \(f\) is 2048 Hz, the Hanning window is added, and the number of FFT points \(N\) is 1024. The frequency resolution of 1024-point FFT directly is 2 Hz, and the refined frequency resolution is 0.02 Hz. The simulation result of direct 1024-point FFT spectrum analysis is shown in Figure 1.

![Figure 1. Spectrogram of direct 1024-point FFT](image)

4. Discussion

The parsing of the configuration file is a time-consuming and memory-consuming task. In actual applications, we only need the information about the sampled value in the configuration file. Therefore, the design adopts the configuration of the device when the device is initialized. The file is parsed, and the information related to the sampled value is extracted and encapsulated into an interface for access.
This method has the advantage of only parsing the configuration file once, but can access it multiple times.

Using SCL as the configuration language of the substation, on the one hand, because the hierarchical structure of SCL is just a tree structure, which is consistent with our network, it can well show the structure of the substation case and the detailed content of each level. On the other hand, XML can represent the structure of the device in more detail, so that the XML-based SCL language can be used for the self-description of the device. As long as you have the configuration file, the topology of the substation and the detailed information of each device will be become transparent.

The configuration of the entire substation requires three configuration tools: system description tool, system configuration tool, and IED configuration tool to cooperate with each other. The configuration process of the entire substation is shown in Figure 2.

![Figure 2. Configuration process of substation](image)

It can be seen from Figure 1 that there are four types of files generated during the configuration of the substation. The file only contains the pre-configuration information of a single IED, describing the services supported by the IED device, its functions and preliminary operating parameter settings; the SCD file is a system configuration file, which contains the most complete and comprehensive information of the entire substation automation system Information; the CID file is an IED configuration file, which contains all the information needed to configure an IED, and will be downloaded to the IED for the actual configuration of the IED.

In order to realize the unification of SCL, eight documents are established in the IEC61850 standard to specify the semantic grammar of SCL, restrict SCL, and the schema files for restricting SCL are shown in Table 1. The configuration file composition of the substation is divided into 5 parts through the Schema file. The structure diagram of the configuration file is shown in Figure 2.

| Schema file name                  | Function description                      |
|-----------------------------------|------------------------------------------|
| SCLEnums.xsd                      | Enumeration definition                   |
| SCL_BaseSimpleTypes.xsd           | Definition of basic simple types          |
| SCL_BaseTypes.xsd                 | Definition of basic complex types         |
| SCL_Substation.xsd                | Corresponding grammar for substation      |
| SCL_Communication.xsd             | Corresponding grammar for communication   |
| SCL_IED.xsd                       | Corresponding grammar of IED              |
| SCL_DataTypeTemplates.xsd         | The corresponding syntax definition of the data type template |
| SCL.xsd                           | The subject part of the grammar definition defines the SCL file |

The four types of configuration files existing in the substation will all follow the structure described in Figure 3. According to the information contained in the four configuration files, when parsing the configuration files, you can select the SCD file or the CID file for analysis. The SCD
configuration file contains the configuration information of the entire site. In the actual analysis, all 9-2 sampling value information can be obtained only by parsing this file. The CID file is for a single device, so the entire site must be obtained. For the configuration information of the substation, the CID file of each IED in the substation will be obtained, so in actual applications, the CID files need to be parsed one by one, which will cause complicated work and easy omissions. Based on the above considerations, the SCD configuration file containing the entire site information was finally selected.

![Diagram](image)

Figure 3. SCL configuration file structure diagram

5. Conclusions
In recent years, our country has invested a lot of manpower and material resources in the development of smart grids, and increased investment in capital and technology. In the process of transformation and construction of my country's power grid, a large number of substations have also adopted advanced industrial automation technology, which has improved the modernization of power grid construction. The widespread application of electronic transformers has effectively promoted people's exploration of digital substations, and has caused profound changes in substation automation technology. Corresponding intelligent test equipment came into being. Many large companies have conducted certain research and development in this field. Smart grids and intelligent equipment will surely become an inevitable trend for the power industry to improve economic and scientific development.

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