The Necessity of Testing the Optical Fiber Link in the Distributed Control System

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Abstract. With the rise of industry 4.0 and the Internet, a large number of network optical fiber links are applied in the control system of thermal power plants. However, there are no test methods and requirements for optical fiber links in the acceptance test procedures for decentralized control system of thermal power plants. In this paper, the optical fiber medium, field bus type and so on are introduced, and the necessity and method of optical fiber link testing are discussed.

1. Introduction
With the rise of industry 4.0 and the concept of energy Internet, China has put forward the first 10-year action plan of "made in China 2025" to implement the strategy of "manufacturing power", and the integration of industrialization and informatization will reach a new height. In the field of smart grid power supply side, super clean emissions and the research and application of million kilowatt coal unit will be the implementation of the smart grid field is one of the important tasks of action, digital intelligent power plant as plant new construction of power plants and the goal, whether in the process control network and information network and enterprise management network without advanced and reliable digital communication and the use of the network technology, at the same time, due to data transmission channel in the power plant distributed control system of high reliability and real-time requirements, in all kinds of field bus, industrial Ethernet and transmission is rapidly increasing proportion of field devices. How to carry out quantitative test on the availability, reliability and transmission performance of data network in distributed control system is a new problem faced by thermal control professionals. This paper discusses the test project and test technology application of optical fiber link, which is one of the network media.

2. Field network communication medium of distributed control system in thermal power plant
At present, the transmission medium of distributed control system field communication network mainly includes twisted pair, coaxial and optical fiber in thermal power generation industry. With the application of high-speed industrial Ethernet network in industrial communication, the proportion of optical fiber in industrial production control system is increasing rapidly. Due to the advantages of high bandwidth and anti-interference, optical fiber medium is beneficial to meet the requirements of modern industrial production control system for real-time, high-speed, stable and reliable field network communication. Optical fiber medium is often used in the distributed control system of thermal power generation industry in the following aspects:
Optical fiber is used to connect remote operation station, remote node and remote control station.

The DI/DO hardwire of distributed control system (DCS) is directly connected to PLC by optical fiber medium, and the start and stop control of the motor is realized by PLC.

The field communication network topology of DCS is based on the combination of double fiber ring network and industrial Ethernet.

Fiber optic media is used to network DCS in token ring or token bus mode.

Optical fiber is used as the transmission medium of distributed control system fieldbus network.

Optical fiber distributed interface network (FDDI) is used as the communication networking method of distributed control system.

Although different DCS manufacturer will choose different ways of field communication network and field bus network communication protocol, however, optical fiber must be one of the important network transmission medium, how in the construction, maintenance of thermal generator set DCS or test work for performance verification and defect screening of fiber link is the automation of professional and technical personnel to explore new topics.

3. Current situation of field network communication and fiber link test in distributed control system of thermal power plant

3.1. Lack of test procedures for field network communication of DCS and its optical fiber medium

At present, in view of the distributed control system in thermal power plant test mainly refer to DL/T659-2016 "regulations of the acceptance test of the distributed control system in thermal power plant", the specification is released by the National Development and Reform Commission and effective as of July 1 in 2007, the electric power industry standard of the People's Republic of China, mainly defines the coal-fired power plant distributed control system test requirements, functional testing, performance testing, acceptance testing, documentation, anti-jamming capability, availability assessment and reliability assessment, etc. At present, our country industrial technology and the integration of information technology becomes more and more thorough, the use of information and communication technologies in the field of industrial control is crucial, industrial control field of network communication availability and reliability will directly affect the safe and reliable operation of the digital factory and intelligent power plant, in the procedures to increase the network communication of distributed control system and the medium test is a necessary work.

3.2. Lack of unified technical means for field network communication and fiber link performance verification

There are many kinds of fieldbus network standard and protocol system, there is no uniform international standard, and more than 40 kinds of fieldbus network types and communication protocols exist at the same time due to the competition of manufacturers in the field of industrial control. Although the international electrotechnical commission (IEC) attaches great importance to the formulation of fieldbus standard, as early as 1984, IEC/TC65/SC65C/WG6 working group was established to draft the standard of fieldbus, but it only defined the architecture of fieldbus, and the specific implementation of fieldbus was supplemented by the IEC611784 series of standards.
Table 1. The representative fourth edition of IEC61158 covers the following main contents.

| IEC61158 Edition NO.4 | Main definition | OSI layer number |
|------------------------|-----------------|-----------------|
| IEC/TR 61158-1         | General and guidelines | /               |
| IEC 61158-2            | Physical layer service definitions and protocol specifications | 1               |
| IEC 61158-300          | Link layer service definition | 2               |
| IEC61158 Edition NO.4  | Main definition | OSI layer number |
| IEC/TR 61158-1         | General and guidelines | /               |
| IEC61158-400.          | Link layer protocol specification | 2               |
| IEC 61158-500          | Application layer service definition | 7               |
| IEC 61158-600          | Application layer protocol specification | 7               |

Table 2. The main contents the standard IEC61784 for specific implementation of fieldbus include.

| IEC61784 Standard number | Main definition |
|--------------------------|-----------------|
| IEC 61784-1              | Continuous and discrete manufacturing industry control system fieldbus row set |
| IEC 61784-2              | Based on the ISO/IEC 8802.3 real-time application of the communication network additional rules |
| IEC 61784-3              | Functionally secure communications in industrial networks |
| IEC 61784-4              | Information security in industrial networks |
| IEC 61158-600            | Application layer protocol specification |

Table 3. IEC 61158 fourth edition defines the main field bus types.

| Type | Field bus name | On behalf of the company |
|------|----------------|--------------------------|
| Type 1 | TS 61158 field bus | The United States Fisher - Rosemount |
| Type 2 | CIP field bus | The United States Rockwell |
| Type 3 | PROFIBUS field bus | Germany Siemens |
| Type 4 | P-net fieldbus | The Danish Process Data |
| Type 5 | FF-HSE high-speed Ethernet | The United States Fisher - Rosemount |
| Type 6 | Swift Net (revoked) | The Boeing |
| Type 7 | World FIP fieldbus | France's Alstom |
| Type 8 | INTERBUS fieldbus | Germany Phoenix Contact |
| Type 9 | FF H1 fieldbus | The United States Fisher - Rosemount |
| Type 10 | PROFINET real-time Ethernet | Germany Siemens |
| Type 11 | Tc-net real-time Ethernet | Toshiba |
| Type 12 | EtherCAT real-time Ethernet | German BECKHOFF |
| Type 13 | Ethernet Power Link real-time Ethernet | IAONA of the federation of European open networks |
| Type 14 | EPA real-time Ethernet | China zhejiang university central control |
| Type 15 | Modbus RTPS real-time Ethernet | Schneider, France |
| Type 16 | SERCOS, 2 fieldbus | German SERCOS association |
| Type 17 | VNET/IP real-time Ethernet | Yokogawa |
| Type 18 | Cc-link fieldbus | Japan's mitsubishi |
| Type 19 | SERCOS, 3 real time Ethernet | German SERCOS association |
| Type 20 | HART field bus | The United States Fisher - Rosemount |
Based on the situation that many kinds of fieldbus exist at the same time, different decentralized control system manufacturers often choose their own fieldbus types as the field network communication networking method. In the thermal power plant industry, DCS manufacturers such as ABB and Siemens usually adopt Profibus fieldbus, central control adopts EPA industrial Ethernet, mitsubishi adopts cc-link industrial Ethernet, and HITACHI adopts FDDI optical fiber distributed interface network, etc., which objectively brings difficulties for DCS field network communication and media test to unify technical means.

4. Defects and hidden dangers in the field network optical fiber link of DCS

4.1. Fiber connection end face contamination and damage
In the coming pump room such as remote sites, on-site electronic redundancy between CPU and other network communication equipment often connected by optical fiber communication medium, in the system construction, operation process is affected by the construction process and site environment, easy to cause the pollution of fiber connection surface and damage, causing light reflection and attenuation in the process of signal transmission, eventually lead to communication error affecting the operation of DCS field bus network communication and reliability.

![Figure 1. CPU redundant fiber optic cable in distributed control system.](image)

![Figure 2. A defaced optical fiber end face in a DCS communication card.](image)
4.2. Deterioration of fiber link loss performance

Profibus DP is used as the field network communication protocol for the decentralized control system of the unit to network in a certain power plant. Multi-mode optical fiber is used for connection between the electronics and the remote station. The distance between the field equipment and the electronics in the pumping room is nearly 800 meters. Since the remote connector is not cleaned, the connector loss or reflection index cannot meet the standard requirements (see figure 3 below: see the red part).

![Remote site fiber link performance.](image1)

Figure 3. Remote site fiber link performance.

Although the total loss of this fiber link is less than the typical value of 6db@850nm in PROFIBUS specification for multi-mode fiber link, the loss has reached 5.303@850nm, which is close to the limit value. If it is not possible to control the cleanliness of the optical fiber connector and the optical fiber socket between the electronics and the pump room, it will cause greater reflection and additional optical signal loss.

4.3. DCS field network communication and various media tests have not been paid enough attention, and there is a blind spot

At present, due to the lack of test procedures for DCS field network communication in thermal power generation industry and unified test methods for a variety of fieldbus networks, the test items and degrees of DCS network performance and physical links are uneven. Some basic test items such as bus load rate, bus state, signal quality, communication link performance trend, communication message error and retransmission reason, and physical link quality are often the blind spots in the test.

5. Introduction of performance test method for optical fiber link of distributed control system in thermal power industry

5.1. Light source photooptical power meter (OLTS test)

Optical link loss performance verification test is park or LAN installation acceptance and daily maintenance of optical fiber link, a basic testing OLTS method that USES the light source and optical power meter measurement by the energy loss in the fiber link or device under test, to see whether accord with the corresponding loss budget, in this kind of test, mainly to test whether power loss value (attenuation) within the scope of the loss budget limit. In the thermal power generation industry, some industrial Ethernet fiber links applied in decentralized control systems adopt 100base-fx or 1000base-
sx transmission rates. In the field bus, there are also fiber links that adopt FDDI mode to form networks.

The basic principle of OLTS test is as shown in figure 4. The initial (reference) power (Pr) is subtracted from the output power (Po) after the fiber link is added. In other words, the absolute power difference dBm is obtained from Pr-Po, which is the loss value.

![Figure 4. Fundamentals of OLTS testing.](image)

The difference between the output power and the initial (reference) power can be expressed by dBm, that is, Loss (dBm)=Pr-Po; In many cases, the relative number dB is also used to represent its power attenuation characteristics. The calculation formula is: attenuation (dB)=\(|10 \log_{10} \frac{Po}{Pr}|\).

For example, when the output power goes through the optical fiber link, its output power is only half of the initial reference power, that is, the energy loss is 50%. Obviously, Po/Pr=0.5, the attenuation of this optical fiber link can be calculated as follows:

\[
\text{Attenuation (dB)} = |10 \log_{10} \frac{Po}{Pr}| = 3 \text{dB}
\]

According to the principle of testing, OLTS method in actual tests the key is how to obtain the reference input power (Pr) and output power (Po), so you need to product was tested by consistency and accuracy is guaranteed, the connection test instrument baseline needs to be proven use special fiber testing, in order to avoid because of the connection test line error affect the accuracy and consistency of the results.

5.2. Intelligent optical link analysis and fault location test method

Although the OLTS test method can verify the loss performance of the optical fiber link, it needs to connect the light source and the optical power meter at both ends of the fiber link under test, and it cannot locate the fault point and the cause of loss events. Therefore, it has certain limitations in the network test practice of DCS system and is not easy to find defects.

In order to solve these problems, also can use a more intelligent optical fiber testing methods, the party/optical time domain reflection principle of multiple pulse injection test, the purpose is to more intuitive and accurately fiber link for more detailed information, such as length, the entire loss, loss, reflection, return loss, end face, propagation delay, etc., in addition, also can give fault location and the Suggestions to solve the problem. Let's take a look at the following example:

For a certain thermal power unit, the remote I/O of the circulating water pump house between the common thermal power system is connected by optical fiber, with a distance of 795.1 meters. The intelligent optical link analysis tool is adopted, which only needs to be tested at one end of the measured light link (figure 5).

Through the test, it is found that due to the influence of dust and process in the field construction conditions, the connector loss or reflection index cannot meet the standard requirements (figure 3 in red). The fault location can be marked directly by this intelligent optical link analysis method. The damage and contamination of the connector located in the middle of the optical fiber link cannot be detected in time if the traditional OLTS method is adopted, which will lay a hidden danger for the system operation of DCS.
6. Conclusion
In a word, optical fiber is an important transmission medium in distributed control system field network. With the popularization of industrial Ethernet and field bus technology, it is necessary to increase the test items for performance verification and defect analysis of optical fiber link in DCS network.

- Add tests on the performance of distributed control system's field network optical fiber link in the process of technical supervision or maintenance.
- Add test items for network transmission media including optical fiber in the test process of DCS.
- Although the manufacturer of distributed control system in thermal power industry tend to choose a different site communication networking method and field bus network communication protocol, however, as a result of the need of anti-interference and extend the transmission distance, optical fiber in the network has become the one of the important network transmission medium, the link performance and defect of illness after the installation is helpful to safe production.

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