Network Integration of Distributed Optical Fiber Temperature Sensor

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Abstract—The integration of distributed optical fiber temperature sensor with supervisory control and data acquisition (SCADA) system is proposed and implemented. In the implementation of the integration, both the compatibility with traditional system and the characteristics of distributed optical fiber temperature sensor is considered before Modbus TCP/IP protocol is chosen. The protocol is implemented with open source component Indy. The Modbus TCP/IP protocol used in the system is proved to be fast and robust.

Index Terms—Distributed optical fiber temperature sensor, Modbus TCP/IP, supervisory control and data acquisition (SCADA).

1. Introduction

Distributed optic fiber temperature sensor (DOFTS) system can measure the spatial distribution of temperature. Optical fiber is used both as the sensing media and transmission media in the system, so it has many advantages over traditional discrete or electronic sensors, such as long distance spatial distribution monitor capacity, comparatively low cost for single measure point, explosion proof, anti-flaming, radiation-free and so on [1],[2]. Thus, it has been applied in many applications such as bridge health monitoring, oil pipe temperature control and oil well monitoring.

In practice, it is an inevitable trend to integrate DOFTS with control system to cooperate with other sensors. The integration of DOFTS to supervisory control and data acquisition (SCADA) system to automatic real-time monitor and control [2] is one example. Compared with traditional sensors used in SCADA, DOFTS is much more complicated for its complex structure, large amount of parameter to be set and huge amount of temperature data shall be transmitted, so the integration of DOFTS is quite different from traditional sensors. An integration method based on Modbus TCP/IP for data transmission between DOFTS and SCADA is introduced in the paper. In the implementation of the integration, both the compatibility with traditional system and the characteristics of DOFTS is considered.

2. Analysis

2.1 Characteristics of DOFTS

Recently, the application of DOFTS in SCADA system is mostly the simulation of traditional discrete sensors. Fig. 1 is one example. DOFTSs are used as the subordinate system in the whole system. The whole sensing length of each DOFTS is divided into many zones, which contains dozens of sensing points (there is typically one sampling point for each meter of sensing fiber). The parameters to be monitored are set for each zone, such as temperature limit for alarm, temperature change rate and so on. The parameters may be set directly on the DOFTS itself or by other devices such as human machine interface (HMI) in the systems. The upper system in SCADA system can check the status of each zone periodically. If the alarm condition is met in any zone, then the DOFTS may trigger the relay for further processing. The upper system can also check the condition and prepare for other control actions.

![Fig. 1. Structure of DOFTS and SCADA integration.](image-url)

But this is only the simulation of discrete sensors; the advantages of DOFTS cannot be fully utilized. Sometimes, the upper system may need all the temperature data on the sensing fiber for analysis, such as in the three dimension temperature field reconstruction. So the upper system must be able to read the whole data from the sensor.

Until now, most data transmission model is designed for the discrete application with low transmission speed,
short transmission distance and lack of expansibility. For large scale distributed temperature field sensing system, much faster transmission model shall be used. Thus transmission model based on Modbus TCP/IP is proposed and implemented in the paper.

2.2 Modbus TCP/IP Protocol

Modbus protocol is an application level protocol, which is designed to provide a communication solution for industrial automatic control. For its simplicity, feasibility and complete openness, Modbus has been applied extensively and become a de facto standard of data transmission protocol in industrial automatic network.

Modbus transmit data via a Client/Server model as shown in Fig. 2. When the application ask for remote data transmission, client component formats the command and parameters to a standard Modbus request, and sends it to the destination Modbus server. Once the Modbus server received an indication (request), it parses the indication and reacts accordingly. If the request is correct and reasonable, local data will be read and capsulated to a Modbus response, and then sent back to the client. If not, an error message will be sent back instead. Then Modbus client receives confirmation (response), and a transaction is completed.

![Transmission model of Modbus](image)

Fig. 2. Transmission model of Modbus.

Modbus protocol can be implemented over both serial bus and Ethernet. Modbus over serial bus is more suitable for tradition discrete sensors for its simplicity and low transmission speed. The transmission speed of Modbus over Ethernet is much faster, moreover, Ethernet has become the de facto standard of corporate enterprise systems, so it comes as no surprise that it has also become the de facto standard for high speed industry networking. The data should be transmitted for DOFTS is several orders larger than discrete sensors, so Modbus TCP/IP, the Modbus protocol over Ethernet is chosen for the integration of DOFTS with SCADA system.

3. Implementation

3.1 Functions

The Modbus server software module is embedded to the software of DOFTS. Other components in the system can communicate with DOFTS through Modbus TCP/IP protocol as clients.

Three functions of Modbus TCP/IP protocol are implemented in DOFTS: register handling, coil handling and file handling.

Register handling protocol in Modbus TCP/IP is used to read and write temperature alarm parameter (temperature and temperature change rate) of each zone in DOFTS, coil handling protocol is for zone alarm status (on/off) transmission. Parameters to be monitored of each alarm zone, such as temperature limit for alarm, alarm status, can be read by a remote terminal with a Modbus client. This operation simulates the application of traditional discrete sensors. All third part Modbus Client can read the data from our Modbus server on DOFTS, so the compatibility with traditional system is ensured.

But in real distributed application, the client may need all the temperature data distributed on the whole fiber to complete the analysis and control. File handling function in Modbus TCP/IP is used to transmit the temperature data. The data can be transmitted as a whole, or partially for the flexibility of Modbus file transmission protocol. What’s more, the transmission is very fast, temperature data of 10 km of optical fiber (10000 data) can be transmitted within a second. But the clients shall know the format of data to retrieve the temperature information from data transmitted. The data format is very simple; it is just an array of temperature, so very few programming is needed to make full utilization of the advantages of distributed sensor.

3.2 Implementation with INDY

The open source cross-platform component INDY is used to implement the Modbus TCP/IP protocol. Our Modbus client and server are implemented based on IndyTCPClient class and IndyTCPServer class respectively. Since Indy implement TCP layer transaction management and data transmission, IndyTCPServer class is inherited to reconstruct a ModbusServer class by adding member variables and member functions to translate command to TCP message according to Modbus/TCP/IP protocol.

4. Conclusions

Distributed fiber Raman temperature sensor system is a cutting-edge sensor system, which is the product of the integration of fiber-optics, electronics and computer science. The integration of sensors with upper control system is an important trend of modern sensor technology. The Modbus TCP/IP protocol used in our system is proved to be robust and sufficient for the integration of DOFTS and SCADA.

References


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