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Ethernet Based Online Monitoring System for Power Transformer in a Smart grid

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Abstract—**The electrical substation is an important part of an electrical system. With the advent of deregulation of the power industry, the importance of substation automation has further increased to become a necessity for the next generation modern power grid. The information about the existing conditions of different equipment's in a substation provides a clear picture of the state of its components. In order to regulate the construction of smart grid, a Ethernet based online monitoring system for the power transformer is presented. The application of online monitoring system is based on IEC 61850 standard in the substation. The local data acquisition unit designed by using chips ATmega168A and ENC28J60 which can transfer the data to the monitoring station. This system can easily become a part of substation automation system which measures the parameters accurately and realizes the remote monitoring based on Internet.**

Index Terms—**Ethernet, Embedded TCP/IP, IEC61850, Online Monitoring, Power Transformer.**

I. Introduction

Digital communications have slowly become an indispensable part of the electric utility network. In the bulk power transfer, digital communication infrastructure is an essential ingredient without which large interconnected power systems cannot operate. The power transformer, whose reliability directly determines whether the grid runs safely, affectively and economically. It is one of the most important equipment in an electric grid. Grid economic benefits can be increased by reducing the transformer faults. The online monitoring system can find, analyze and process the faults of the transformer in time to prevent the incidents of the transformer. Nowadays, the reliability of the domestic substations is commonly very low, and the equipments used in the substations cannot guarantee to operate safely. So it is very much necessary to develop an online monitoring system for the power transformer, which will have very important significance to build the smart grid.

There are different methods to monitor the power transformer, such as gas content in transformer oil, transformer partial discharge, trace moisture content in oil, transformer vibration, transformer winding deformation, etc. Ding Jiafeng et al. [1] presented a novel method for micro-combustible gas detection based on an embedded PC104 to monitor the dissolved gas in transformer oil. Zheng Jianxin et al. [2] designed a transformer intelligent monitoring system based on AVR microcontroller ATmage128, but these researches transfer the local signals to upper computers by serial ports, which will degrade the system performance with the increase of data traffic. Liu Chang yu et al. [3] designed a TCP/IP based online monitoring system using some chips such as TMS320VC33, W3100, RTL8201, etc; but the system has only two levels, which doesn't conform to the international standard IEC61850 and is hard to form substation automation systems.

In this paper, a Ethernet based online monitoring system for power transformer is presented. The hardware circuit of the local data acquisition unit is designed by using AVR microcontroller ATmega168A and network chip ENC28J60. The communication method of the process level is designed based on a simplified TCP/IP protocol. The system can accurately measure the parameters and fully monitor the operational status of power transformers.

II. ONLINE MONITORING SYSTEM STRUCTURE OF POWER TRANSFORMERS

There are different faults and incidents which occurs repeatedly in the power transformer. Transformer faults can be classified by using different methods. There are inner and external faults according to the transformer body. According to the fault loop, there are circuit fault, magnetic fault and oil line fault and based on the fault location, there are winding fault, iron core fault, bushing fault, tap changing switch fault, terminal block fault, etc [4]. The main goal of the online monitoring system for power transformer is to monitor the parameter variation in a period and also judge whether the power transformer is in good condition or not.

Ethernet based online monitoring system for the power transformer it has three levels: process level, bay level and station level, as described in Fig. 1. The local data acquisition unit in the process level can be configured by various types of sensors, and can measure the signals of gas and trace moisture in oil, transformer vibration, voltage and current, etc. The monitoring station in the bay level that has the functions of fault diagnosis connects to the spatially distributed data acquisition units through switched Ethernet. One monitoring station is responsible for collecting the data from one power transformer, and stores the data in its database. In the station level, the database server is responsible for collecting the data from all the power transformers in one substation, by using internet the web server releases the operation information of the transformers to outside. And realizes the Internet based remote monitoring. By using IEC61850 standard, the online monitoring system establishes the communication network based on the Ethernet.

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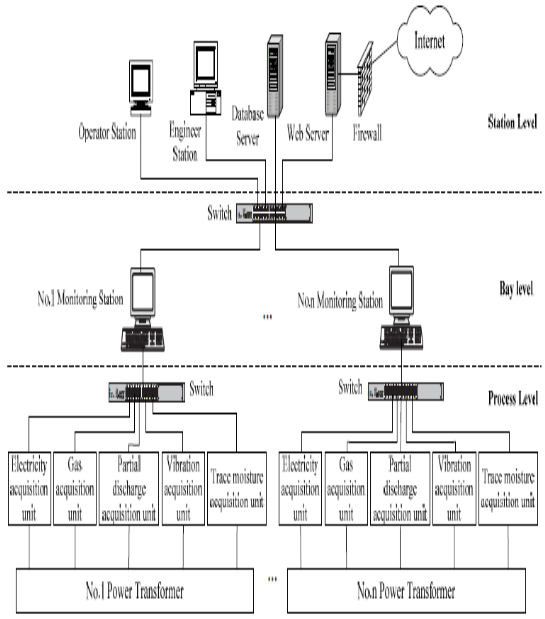

Figure1.Online monitoring system structure of Power transformer

This system collects different types of transformer parameters and realizes the functions of the monitoring and fault diagnosis of complicated devices, Hence this system works as a part of substation automation system.

IEC 61850 has managed to span much of the application space, thus providing solid basis for building reliable and interoperable substation control/protection systems. Because it is Ethernet based, IEC 61850 real-time and ad hoc communications coexist with all of the other protocols necessary for file transfer, engineering access, diagnosis etc.

III. LOCAL DATA ACQUISITION UNIT

Based on signals collected, the local data acquisition unit can be divided into many types, such as electricity signal acquisition unit, gas in oil acquisition unit, partial discharge signal acquisition unit, trace moisture in oil acquisition unit, etc. All different types of data acquisition unit can convert the signals collected to those fit for transmission on the Ethernet, and transfer the data to the monitoring station in the bay level.

As shown in Fig. 2 local data acquisition unit can measure six analog signals. The CPU of the acquisition unit is the ATMEGA168A of ATMEL Corporation. The ATMEGA168A is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. This is ten times faster than conventional CISC microcontrollers. The ATMEGA168A microcontroller provides the following features: 16k bytes of In-System Programmable flash with read-while-write capabilities, 512 bytes EEPROM,1k bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, two 8-bit timer/counters with separate prescalar and compare mode, one 16-bit timer/counter with separate prescalar, compare mode and capture mode, a 6-channel or 8-channel 10-bit ADC according to the different chip packages, a serial programmable USART, a master/slave SPI serial interface, and a programmable watchdog timer with internal oscillator. The chip ATMEGA168A is very much suitable for the small monitoring equipment's. ENC28J60 is a stand-alone Ethernet controller with SPI interface from Microchip Corporation. The ENC28J60,meets all specifications of the IEEE 802.3 and has the MAC module and the PHY module. It incorporates a number of packet filtering schemes to limit incoming packets. It also provides an internal DMA module for fast data throughput and hardware assisted checksum calculation, which is used in various network protocols. The connection betweenENC28J60 with ATmega168A is implemented via an interrupt pin and the SPI, with clock rates of up to 20 MHz, as shown in fig.2.

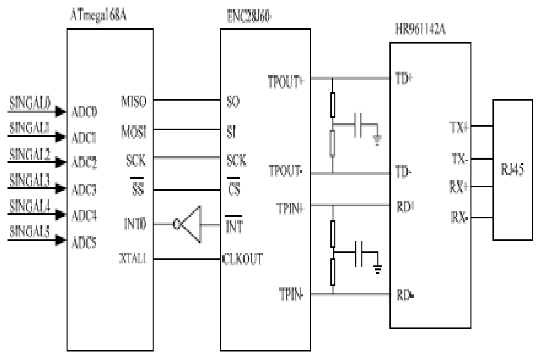

Figure 2. 6 Channel analog acquisition unit

IV. DESIGN OF EMBEDDED TCP/IP PROTOCOL

Most widely used standard TCP/IP protocol put a lot of works to ensure the reliability of data transmission and also controls the data traffic. But in the measurement & control field where there is high demands for the real time this protocol is not suitable .It is very much complicated that it must occupy enormous hardware and software resources, which is also not fit for the situation of embedded data acquisition unit [5,6]. The resources of AVR microcontroller aren't abundant, so the standard TCP/IP must be simplified to meet the demands of local data acquisition unit of industrial control systems.

According to the actual needs of online monitoring system for the power transformer, an embedded TCP/IP is put forward in this paper that has four layers, as shown in Fig. 3

4	Application Layer	Self-defining
3	Transport layer	TCP
2	Network Layer	IP,ARP,ICMP
1	Network interface layer	Ethernet

Figure 3. Simplified model of TCP/IP

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(1) Network interface layer: This layer has the functions of exchange data between the actual physical media and the network layer. This layer contains the physical layer and the data link layer. This layer must realize the CDMA/CD protocols that Ethernet defines.
(2) Network layer: In the standard TCP/IP, the network layer protocols contain IP, ICMP, IGMP, ARP, RARP, etc. IP is the core protocol of TCP/IP that is essential and can't be removed. IGMP aims to support multicast for hosts and routers. In the simplified TCP/IP, the broadcasting mode is adopted, so IGMP can be removed. But ARP, RARP and ICMP have their own purposes and must be kept in the embedded TCP/IP.
(3) Transport layer: This layer specifies how to ensure reliable transfer between two hosts. The standard protocols in this layer have TCP and UDP. TCP is a reliable connection-oriented protocol, while UDP is an unreliable connectionless protocol. In order to provide reliable data transmission, TCP is adopted and UDP is removed in the transport layer in this embedded TCP/IP.
(4) Application layer: The standard TCP/IP has various types of application protocols, such as HTTP, FTP, SMTP, SNMP, DNS and etc, in order to meet the demands of all kinds of users. But in the simplified protocol, the application protocol needn't too complicated, and it will be good when the protocols can transfer and receive data accurately. So the application protocols can be left to define by users.
In the local data acquisition unit presented in this paper, the functions of network interface layer are implemented by ENC28J60 chip, while the functions of network layer, transport layer and application layer are implemented by software programs. When the data acquisition unit works, the AVR microcontroller ATMEGA168A will process the packages transferred from the chip ENC28J60. The processing flow is shown in Fig. 4.
In the Ethernet frame, if the protocol type value is 0x800, the protocol in the network layer is IP, but if the type value is 0x806, the protocol is ARP. In the IP package, if the protocol type value is 1, the protocol in the network layer is ICMP, but if the type value is 6, the protocol in transport layer is TCP. So we can call the appropriate modules according to the protocol type value.

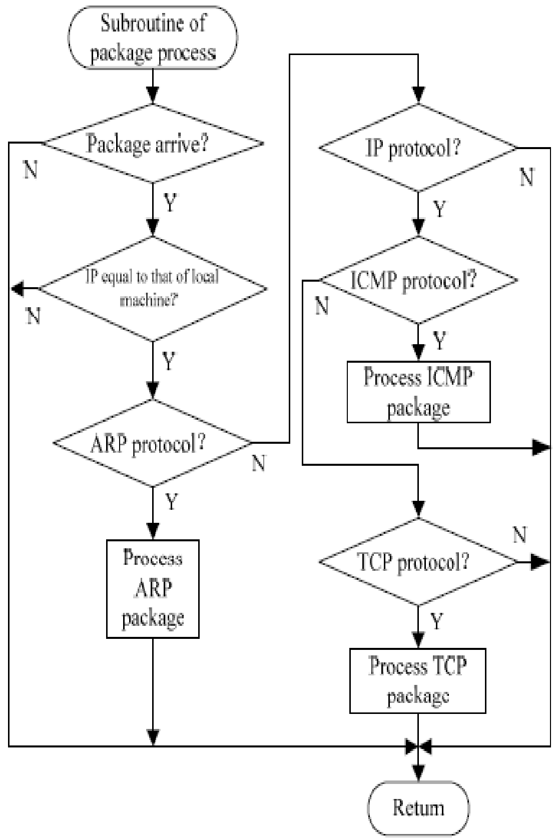

Figure 4.Program flowchart of package process

V. MONITORING SOFTWARE OF STATION

The monitoring station in the bay level is a high performance IPC. It can not only connect to the spatially distributed data acquisition units, but connect to Web server, database server and etc through Ethernet. The development platform is LabVIEW + SQL Server. The heart of the online monitoring system for power transformer is the monitoring software of the monitoring station whose functions are as follows:
(1)Collect's the various operating parameters of power transformer, including the gas and trace moisture in oil, the partial discharge signals, the electrical signals, etc.
(2)Set the operating mode of the local data acquisition unit, such as sampling period etc.
(3)Display the partial and total parameters of the power transformer.
(4)Store and manage the data. In order to easily manage the data including real-time data and historical data, we store the mass data into database that the access control is set.
(5)Data analysis and fault diagnosis. By mass data, we can use information fusion technology to extract the feature vectors and make fault diagnosis.
(6)Transfer the transformer parameters to the servers in station level, and receive the configuration commands from the station level. The monitoring software of the power transformer includes data acquisition module, real-time monitoring module, fault diagnosis module, management module and system login module.

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V. CONCLUSION

The safe and stable operation of power transformers has very important significance to build smart grid. On the basis of analysis of present situation of power transformers, a Ethernet based online monitoring system for power transformer, following the international standard IEC61850, is presented in this paper. A type of embedded TCP/IP protocol, which can save hardware and software resources and reduce costs, is also proposed. The local data acquisition unit, designed by using AVR microcontroller ATmage168A and chip ENC28J60, can be configured by various types of sensors and can accurately measure the various parameters of power transformers. The system can fully reflect the operational situation of the power transformer and easily become a part of the substation automation system in a smart grid.

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