Study on Insulation State Detection of Electrical Equipment in Power Plant

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This paper focuses on the hardware design and implementation process of insulation condition online monitoring system. The main control circuit board of the monitoring system uses DSP+CPLD+USB as the data acquisition and control core, and the temperature rise acquisition circuit takes PIC16F877 as the control core. The paper designs the main circuit and control circuit of the whole system, and gives the flow chart of the program. In addition, combined with a solid ring network cabinet production company as the experimental platform, it debugs the insulation on-line monitoring system, and analyzes the experimental results. Finally, the monitoring system is accepted through the company, successfully implementing the on-line monitoring of insulation state.

1. Introduction

Electrical equipment is the most important control and protection equipment in the power system. The condition detection of electrical equipment is the basis of the evaluation of the economic and safety operation of electrical equipment, and it is one of the frontier research fields of the integration of traditional electrical equipment, sensor technology, automatic control, signal processing and other multi-disciplinary knowledge. State detection is, taking the advanced monitoring equipment and diagnosis technology as the foundation, to make a comprehensive analysis judgment and evaluation by using the system engineering method. The objective is to find out the internal situation of equipment, to grasp the nature of the flaw, and to forecast the development trend of hidden danger and the service life of equipment.

Electrical equipment is an important component of the power system, which is also the equipment that has the largest usage amount and most cost in the power system, and its reliable operation directly affects the security and stability of the power system. With the development of electrical equipment, solid insulating materials, for its excellent electrical, chemical, physical and mechanical properties, have a large number of applications in electrical equipment (Guedes et al., 2016; Wiranarongkorn et al., 2017; Rosso Ceron et al., 2017; Makgato and Chirwa, 2017; Mohammad Rozali et al., 2017; Nurariffudin et al., 2017; Bachtrong et al., 2017; Kansha and Ishizuka, 2017; Alias and Abbas, 2017; Mahmood et al., 2017; Shao et al., 2015; Zhang et al., 2015; Rovense et al., 2016; Cucumo et al., 2016). Solid insulation structures such as arc tube, insulation tube, insulator and bushing and other electrical equipment have been widely used. According to the characteristics of insulation, electrical equipment with large solid insulation structure as the major insulator is called capacitive type electrical equipment. According to statistics, insulation failure is the most important cause of electrical equipment accidents, so it is very important to study the insulation monitoring of electrical equipment. In allusion to the solid ring network cabinet insulation monitoring, this paper designed a set of online monitoring systems, for on-line monitoring of solid ring dielectric loss value, leakage current value, bus temperature rise, discharge times, bus voltage, current, and temperature and humidity.

2. System hardware design

The overall design of the system is shown in Figure 1. Through the digital temperature sensor, we acquire the bus and ring net cabinet temperature, and through the digital analog switch, we choose the sensor channel. In this way, we can, according to customer requirements, choose the temperature acquisition channels and

increase the flexibility of the system. In order to solve the problem of high and low voltage isolation involved in bus temperature rise, a new method is proposed to monitor the temperature rise of the ring network cabinet (Khrennikov et al., 2015).

The sensor is composed of a current sensor, a voltage sensor, a digital temperature sensor and a humidity sensor. Leakage current sensor selects permalloy passive feed-through current sensor core, extracting leakage current signal from the device end screen, with resolution of 1uA, the range of 1uA ~ 10A, the output voltage signal, and the working temperature of -20 DEG C. The active voltage sensor is used to extract the voltage from the two sides of the PT, the accuracy is 0.1, the range is from 0 to 1500V, the voltage signal is output, and the operating temperature is -20 to 70 DEG C (Denenberg, et al., 2016).
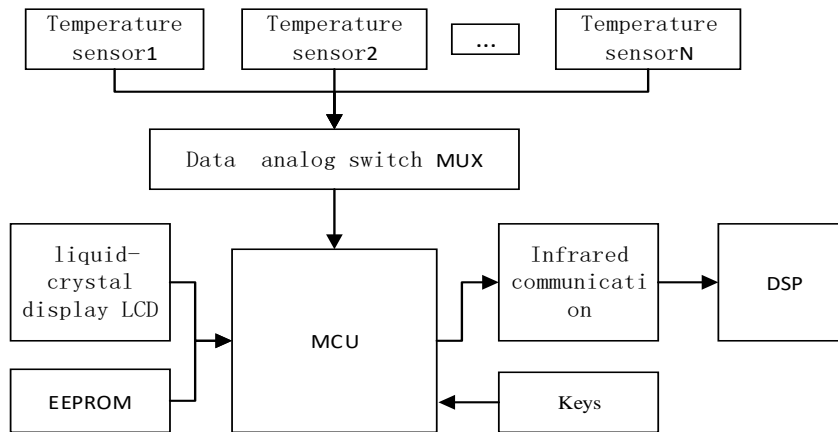

Figure 1: Schematic diagram of whole system hardware design

2.1 Design of online monitoring circuit for temperature rise

Solid ring network cabinet bus bar conductive junction, due to mechanical vibration and other reasons caused by short circuit electric power, electrical and mechanical operation of the wear, makes the contact conditions deteriorate, and leads to the increase of contact resistance. The increase of contact resistance will make the temperature rise, lead to the oxidation of the surface of the contact part, and thus produce sparks, welding and arc discharge, and then cause the insulation damage. On line monitoring of temperature rise is an important means to prevent accidents. The standard configuration of solid ring network cabinet monitored in this paper is the 3 sides cabinets, each side cabinet containing three epoxy sleeves structure. As a result, the temperature monitoring approaches designed in the paper are 10, the 9 road monitors the temperature rise at the connection of each bus, and the 1 road monitors the actual temperature of the cabinet (Gope, et al., 2016). According to the configuration of switch cabinet, we can increase the approaches of the temperature, to meet the needs of different users. The temperature monitoring machine sends the collected temperature to the receiving terminal through the infrared communication method.

2.2 Circuit design of data acquisition unit

The on-line insulation monitoring system has high requirements on real time, so this paper designs the data acquisition unit as the large number of signal acquisition of online monitoring system and high real-time features that the online monitoring system has. The maximum sampling approach for the unit is 16 large ones, and the largest single signal sampling frequency can reach 200 KHz (Khramshin, et al., 2015). When 16 signals collecting at the same time, set the maximum sampling frequency for each 50KHz, and use the DSP+CPLD+FIF0+A/D sampling chip design. Data acquisition unit hardware schematic diagram is shown in Figure 2.

We use TI's TMS320F2812 for DSP in the above figure. The chip has powerful digital processing ability and event management capabilities, and its frequency is 150MHz, which has been widely used in the field of intelligent instruments, industrial control, instrumentation and power electronic technology and so on fields. CPLD chip selects ispLSI1032E, and the chip has 32 GLB, 64 I/O, 4 ORP, 1 GRP, 8 straight inputs and 4 clock input lines. Analog multiplexers use high-precision America AD company analog switch ADG408BR, and the analog multiplexer is 8 selecting 1 Analog Multiplexer.

The sensor signal inputs to the analog multiplexer through the signal conditioning circuit input, and converts through the 2 multiplexers ADG408BR analog-to-digital into converter AD976A. Under the control of CPLD, the amount of 16 analog signal is sample with circulation. The sampling value is directly sent into FIFO, then

start the USB to upload the data in FIFO, and thus realize the high speed real-time sampling. Since between the FIFO and USB, there are 5V and 3.3V signals, we make use of LVC16245 level conversion chip to achieve 5V to 3.3V level conversion.
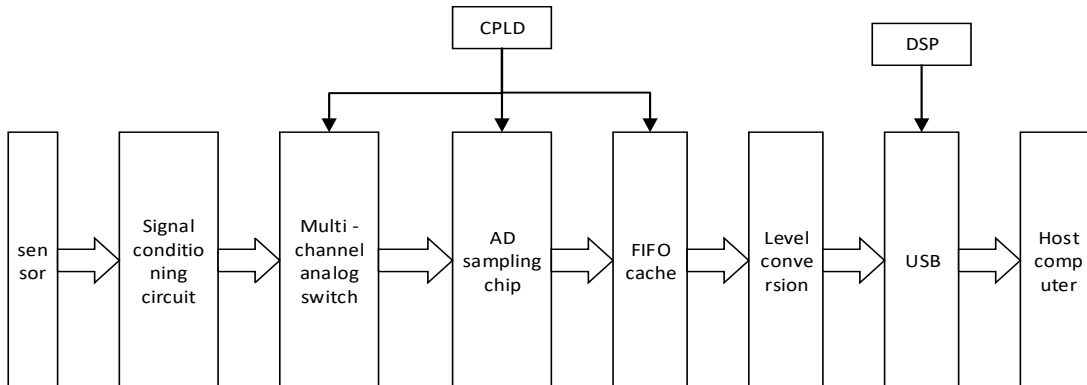

Figure 2: Diagram of data acquisition circuit

3. System software design and Implementation

3.1 Software program design of temperature rise monitoring board
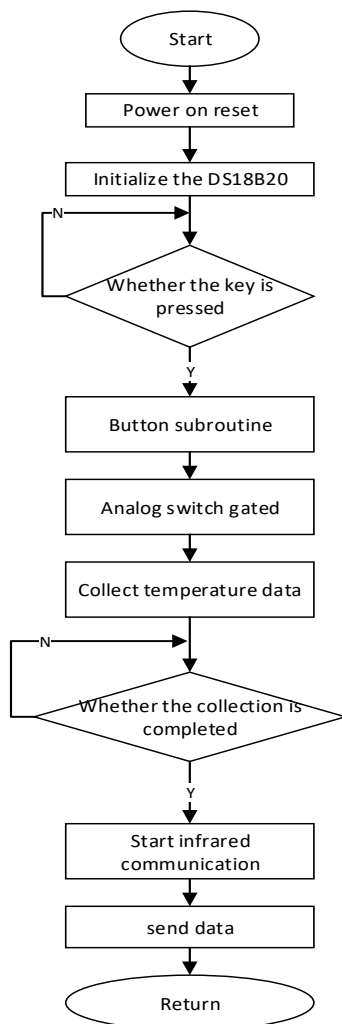

Figure 3: Diagram of data acquisition circuit

Bus temperature monitoring system design uses the analog switch strobe temperature measuring sensor. The monitoring approaches can be set flexibly according to the need of solid ring network cabinet field. The temperature acquisition machine stays at high voltage, so the temperature data is sent to the host computer through the infrared communication so that the isolation can be achieved with high side and low side and thus improve the reliability of the system.

The temperature monitoring program flow chart is shown in Figure 3, and the infrared receiving flow chart is shown in Figure 4. The digital temperature sensor DS18B20 is encapsulated in epoxy resin and it can be installed at the busbar connection, which can be isolated by epoxy resin.
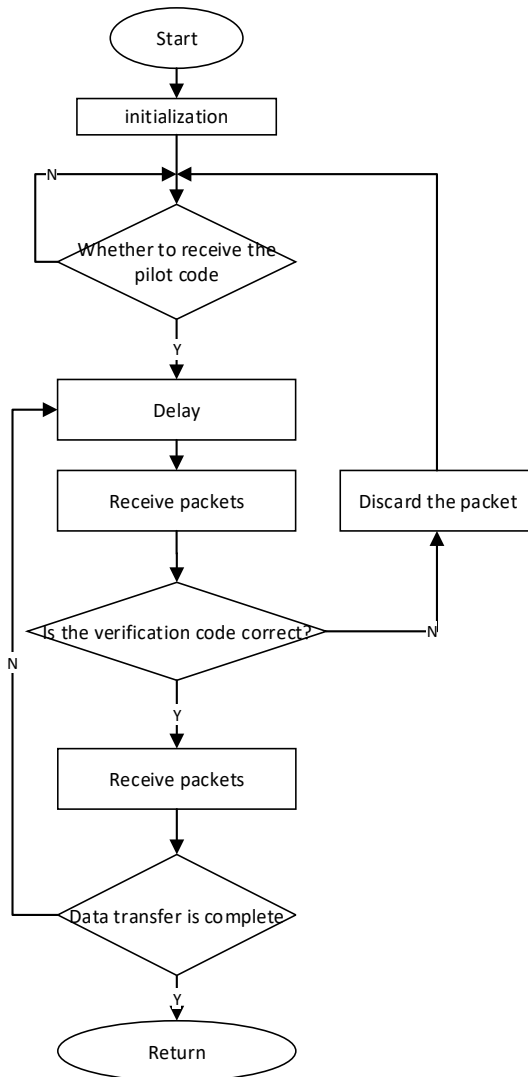

Figure 4: Flowchart of infrared receiver system

3.2 Communication program design

In this design, the baud rate is set to 9600bit, sending 9 bits of data, using Even Parity bit. In the sending subroutine, first of all, send two consecutive number AAH to the host computer, as the check mark for sending the starting data, and wait for the reception. When the host computer correctly received, return to the sixteen 55H. After the calibration is successful, start sending valid data until the end of the transmission. When the serial port receiving module of the micro controller receives the data, an interrupt request is issued, and then the system will response to the interrupt request and enter the interrupt. When the interrupt source is judged, after it is confirmed as the interrupt produced by the serial port module, enter the serial communication receiver subroutine. First of all, determine whether the first two data are binary A1H. If it is, begin to receive; or quit.

3.3 USB software programming

The firmware design in USB part is achieved in Keil u Version2 environment. The software integrated development environment, and integrated the source code editing, project management, program debugging and other parts for the software environment. Through this software, we can greatly reduce the development cycle. In the system, the data acquired by the acquisition unit is uploaded to the machine through the USB. In order to improve the efficiency of data transmission, USB uses SLAVE FIFO model, to make a continuous sampling of multi-channel analog signal through the CPLD internal logic set, and the sampling value writes into FIFO in the CPLD of FIFO. DSP will continue to detect the full signal flag FLAG_C of FIFO. Once the FLAG_C is 1, which is when the data buffer is full, stop data sampling. FIFO uses the ping-pong operation to maximize the data throughput, and realize high speed data acquisition. Through the use of FIFO, the data collection passes by DSP, directly makes data exchange with the host computer through the USB, which can greatly improve the sampling efficiency.

4. Hardware design anti-interference measures

There are many factors that may cause electromagnetic interference in power system operation, such as switching off, radio transmission, lightning and so on. According to the relationship between the electromagnetic interference source and the signal source, the electromagnetic interference can be divided into two types: common mode interference and differential mode interference. In the case of differential mode interference, the effective signal and the interference voltage are connected in series to the on-line monitoring system, and the source of interference is the space electromagnetic field generated by the power line of the signal line. In addition to the signal line, the inherent ripple, drift and noise of the signal source, as well as the poor effect of the power supply and the poor voltage regulation filter may also introduce the differential mode interference. According to these problems, the design of insulation on-line monitoring system needs to fully consider the following three aspects and the means able to be used to reduce the interference, so as to improve the reliability of system monitoring accuracy and operation.

(1) Shielding of sensor. The accuracy of the on-line monitoring system depends largely on the performance of the sensor. As a result, the selection of sensor on-line monitoring system needs to make a strict testing and screening of the transmission characteristic and thermal stability and other aspects of sensor. And for the sensor itself, it is necessary to take the shielding measures. The sensor can be placed in a metal box in double shielding, and the shielding effect of copper and tin metal materials are very good.

(2) Shielding of signal line. The signal transmission line should be as short as possible, if the signal transmission line is longer, it is more easily to be disturbed by the electromagnetic environment. In consequence, we need to use the shielded wire with good performance. In this way, we can use the double layer shield to ensure the shield only one end of the ground, thus reducing the common mode interference produced on the wire loop flow.

5. Conclusions

Capacitance type electrical equipment insulation online monitoring has achieved certain results and valuable conclusions. Based on the performance requirements of the online monitoring capacitive type insulation of electrical equipment, there are still some problems need to be further studied:

(1) In the insulation condition assessment of capacitive electric equipment, the value of the weight of each index also needs a large number of experiments for further optimization. If it is possible to get the statistics distribution status of the state level of capacitive equipment that each index corresponds to, we can further promote the improvement of accuracy of capacitance type electrical equipment insulation evaluation.

(2) The aging experiment, because of experimental conditions, uses the thermal aging experiments, without adding other factors. If we make use of electricity, heat and environmental aging experiments, it will further enhance the accuracy of change of the characteristic parameters in the process of insulation aging, and allow the accuracy of the insulation diagnosis and assessment of the capacitor type electrical equipment further improved.

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228

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