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Research on partial discharge monitoring system for high voltage switch cabinet based on UV sensor

Jiang Yue-Xin[1*], Huang Yun-Long[1], Liao Yin-Sheng[2]

[1]Information and engineering academy of Quzhou College of Technology, Zhejiang Quzhou, (CHINA)

[2]Ju Hua Group CO.Zhejiang Quzhou, (CHINA)

E-mail: jyx66765@sina.com

ABSTRACT

In view of the status quot that partial discharge in high-voltage electrical equipment causes significant impacts on the safe operation of the power system, an ultraviolet endoscopic system of power equipment based on embedded system is presented. It consists of ultraviolet endoscopic probe, embedded computer system and Communication module. The system combines ultraviolet discharge detection and video endoscopic technology for special electrical equipment internal environment and can telemonitor ultraviolet discharge of power equipment. The system can run reliably and effectively to prevent the power accident caused by the discharge, which is proved by the simulation and high-voltage discharge test.

KEYWORDS

Ultraviolet sensor; Embedded; USB camera; Partial discharge.

INTRODUCTION

With the development of power industry and increase in the demand of grid load, power system is required to generate and supply electricity safely and stably during its operation. Malfunction of high voltage switch due to its aging and other factors will impact on safe and stable operation of power system. And the fault of insulation system is difficult to be found in routine maintenance. Traditional preventive maintenance for electrical equipment needs more people and power-off operation.

It is necessary for not only predictive repair but also safe and reliable operation of power equipment to monitor its insulation. Most faults in power equipment are insulation fault caused by insulation deterioration due to electrical stress or resulting from mechanical and thermal effect or interaction with electric field. Power quality and supply reliability will eventually be affected. At the present stage periodic preventive test for switchgear in distribution network should be carried out according to the requirements in "Preventive Test Code for Electric Power Equipment". But preventive test is limited in economy, technology and field use. According to statistics, the accidents caused by insulation degradation accounted for 68% of total number of accidents and 74% of total accident capacity [1].

In order to prevent major accidents, it is very important to monitor the state of power equipment and diagnose fault.

UV endoscopic system to monitor the state of power equipment, with advanced embedded computer technology, image acquisition technology and photoelectric detection technology, can collect image and detect ultraviolet pulse in power equipment.

These basic functions can solve some problems of insulation monitoring of power equipment and lay a good technical foundation to develop an endoscopic image intelligent analysis system in the future.

OVERALL DESIGN OF INSULATION MONITORING SYSTEM FOR HIGH VOLTAGE SWICH CABINET

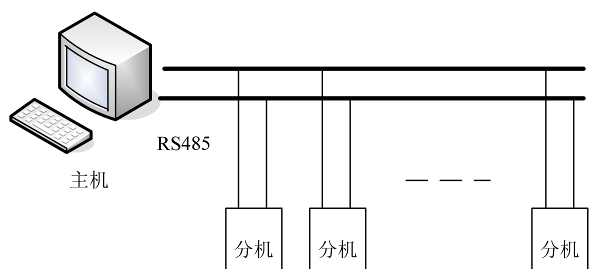

Figure 1 : Insulation monitoring system of high voltage switch cabinet

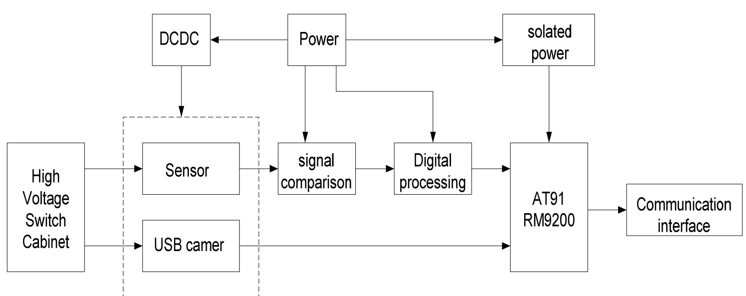

Figure 2 : Structure diagram of monitoring extension

UV endoscopic online monitoring system in high voltage switch cabinet is shown in Figure 1, mainly composed of a monitoring host, some monitoring extensions and a RS485 network. The system will assign a fixed address for each switch cabinet extension and the host will communicate with each extension in turn. Communication contents are handshake command, the instruction set by the host to start an extension to monitor discharge signal and discharge information within a period of time detected and returned by an extension. A monitoring extension mainly includes a power supply module, an ultraviolet sensor, a signal and digital processing module as well as a communication interface module, as shown in Figure 2.

The system operates as follows: if there is partial discharge in power equipment, UV sensor will detect ultraviolet light produced by partial discharge and ultraviolet signal will be input to MCU after being processed by control circuit. Then embedded computer system will read serial data from MCU. And finally, the number of UV pulses in a certain period of time will be calculated by UV endoscopic system software and displayed on LCD. At the same time, LED lamp on USB camera will provide light for video image acquisition. The staff can see discharge point in power equipment clearly and determine the position of fault point accurately. Embedded system will send an alarm signal to the host if the number of UV pulses detected in a certain period is greater than a pre-set value. And then the staff will check or repair this power equipment accordingly combined with video image displayed on LCD.

HARDWARE DESIGN OF INSULATION MONITORING SYSTEM FOR HIGH VOLTAGE SWICH CABINET

Hardware system mainly includes three parts: an embedded computer board, an ultraviolet endoscopic probe and a communication module.

Hardware design of embedded computer board

At present, state monitoring device for power equipment develops to be more convenient, flexible, portable and small with low cost, large capacity of data storage and friendly man-machine interface. And embedded computer system is the core technology. Combined with the characteristics of this project, an embedded computer board is successfully developed which can operate stably[2]. Its core device is AT91RM9200 processor of ATMEL with powerful function, peak instruction execution speed of 200MIPS, the frequency of 180MHz and many integrated peripherals. So the embedded computer board can satisfy the needs of state monitoring of power equipment. The real object is shown in Figure 3.

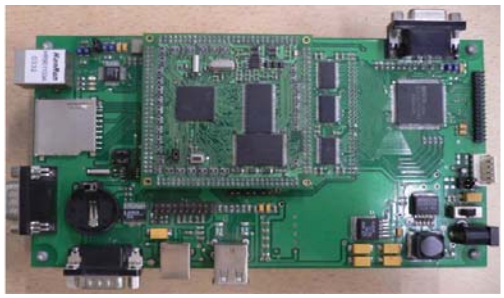

Figure 3 : ARM9-based embedded computer board

Design of UV endoscopic probe

Overall structure of UV endoscopic probe

According to the requirements and special testing environment of insulation detection for high voltage switch cabinet, an UV endoscopic probe is developed[3] [4], which mainly includes an USB camera with LED lamp and an UV sensor. Micro USB camera of Vimicro is used as image sensor and R2868 of HAMAMATSU is adopted to be UV sensor. The detection process is presented as follows: UV endoscopic probe is placed into switch cabinet, transformer or other electric equipment to be detected and UV sensor will detect ultraviolet light produced by partial discharge if it occurs in power equipment. UV signal is input to MCU through control circuit and then to an embedded computer system through serial port; at the same time, LED lamp on USB camera can provide light for video image acquisition. Then USB camera will transmit image data acquired through USB interface to embedded computer system.

USB camera

There are some special environmental constraints for monitoring of power equipment. For example, relatively narrow monitoring place requires that UV endoscopic probe should be small enough to monitor the discharge of power equipment, therefore micro CMOS camera should be selected to meet this requirement.

UV sensor and its drive circuit

UV sensor is the key device for UV detection of power equipment and its model must be chosen reasonably to meet the requirements for sensitivity and environmental noise as well as adapt well to special environment of power equipment monitoring. UV sensor is mainly used to monitor the discharge of power equipment remotely, which requires very high sensitivity. R2868 ultraviolet sensor of HAMAMATSU is selected according to special environment of power equipment monitoring. Its channel wavelength band is UV-C 185-260nm in solar blind region to effectively avoid the interference of sunlight or other light sources. It has high sensitivity of 5000 pulses/min.

Drive circuit for ultraviolet sensor is shown in Figure 4[5]. Its operating voltage must be high voltage of 300-350VDC, otherwise ultraviolet sensor cannot work normally. A DC-DC high voltage DC module with input voltage of 5VDC and output voltage of 300-350V which can be adjusted through input resistance is used. The sensor will be in a high impedance state and do not discharge if there is no ultraviolet radiation. Its anode voltage is equal to applied high DC voltage. The output is high level and LED goes off. The sensor will discharge with the current provided by charged capacitor C1 if ultraviolet is generated due to power equipment discharge and transient current on resistor R3 will be generated to output low level and light LED. 74HC14 is used to shape this pulse to obtain stable output waveform. As quantity of electric charge on discharge capacitor C1 is reduced, the potential of anode gradually decreases to be lower than discharge sustain voltage, then the discharge stops. After that, external power supply continues to charge capacitor C1 and anodic potential increases gradually to reach starting voltage. At this moment, UV sensor will discharge again if it receives ultraviolet produced by power equipment discharge.

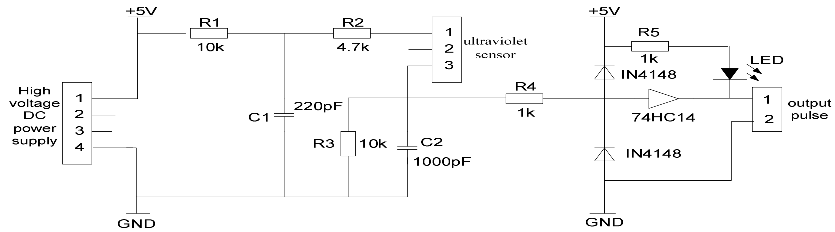

Figure 4 : Drive circuit for UV detector

Design of communication module

Centralized monitoring computer communicates with each extension by SNMP[6] to access and view real-time data in the form of web page remotely or locally. Network administrator can, at any node in the network, retrieve and modify information, locate fault as well as accomplish fault diagnosis, capacity planning and report generation.

The host can communicate with underlying extension monitoring system through RS-485/CAN communication interface. Liquid crystal display interface provides friendly man-machine interface for users to set parameters. When the measured index exceeds the standard, the monitor will automatically, according to the preset threshold, upload alarm or blocking signal to remote monitoring center (workstation) or directly activate the alarm and lock the device.

SOFTWARE DESIGN OF INSULATION MONITORING SYSTEM FOR HIGH VOLTAGE SWICH CABINET

Overall design

UV endoscopic system of power equipment adopts multi thread structure[7], in which, main thread is chiefly used to respond graphical user interface and data acquisition thread is mainly to collect UV data and image data, and then send a message to main thread for graphic display, compare the number of UV pulses captured in a certain period of time to the preset safe number of pulses and send a warning signal to the host through communication module if it is greater than the safe number of pulses. So the staff can check or repair this power equipment accordingly[8]. Combined with the image displayed on LCD of embedded computer, the staff can clearly observe the condition in power equipment and accurately locate fault point. The software flow of the system is shown in Figure 5.

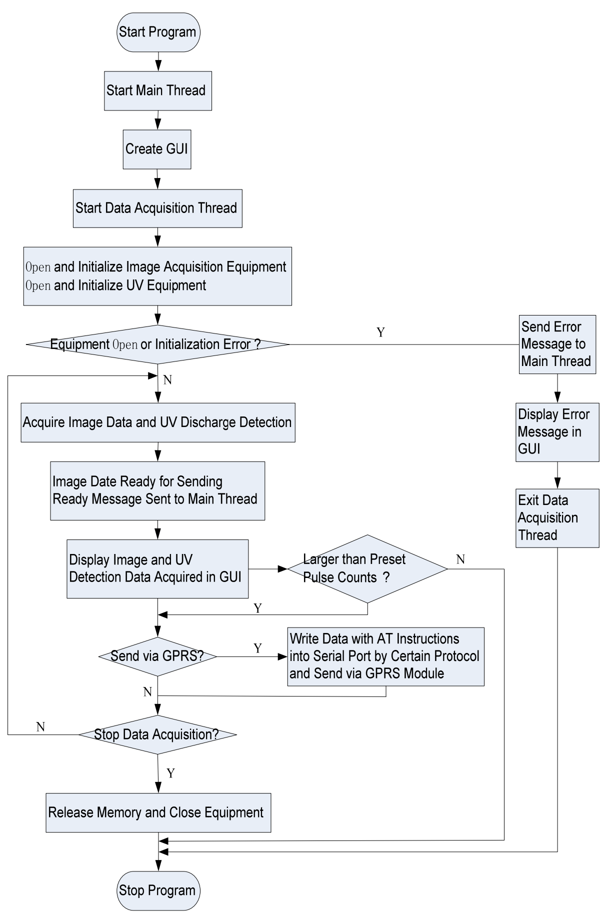

Figure 5 : Flow chart of system software

Software design of UV pulse detection

The block diagram of UV pulse detection software is shown in Figure 6. Its major functions are to start UV detector[9], read serial data from MCU to embedded computer as well as draw the waveform and display the value in graphical user interface.

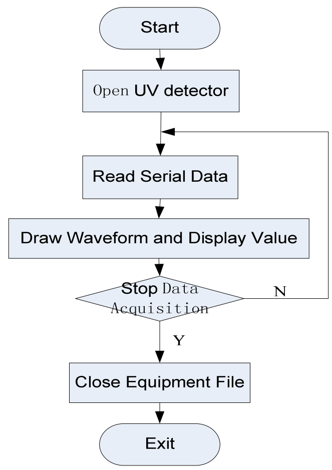

Figure 6 : Block diagram of UV detection

EXPERIMENTAL RESULTS

In order to verify the feasibility and accuracy of the method, the experiments were carried out in the substation. The ultraviolet discharge detection experiments were carried out in 220kV substation of Zhejiang province Quzhou city by selecting 7 points including isolating switch and the grounding switch, a coupling capacitor, transformer bushing etc.,numbered 1-7. In winter and summer is tested. measuring position are on the ground, each test time is 30 s, each detection point experiments were repeated 7 times and took the average of 7 measurements as the number of pulse of UV detection point. The experimental results show in Figure 5 and Figure 6. Set the alarm threshold is 12, when the UV monitoring to the pulse number is greater than 12, the system sends a warning signal to the operating host, when the host receive this information, the operating personnel will maintenance and processing the equipment. In the case of the alarm data to June, statistical the alarm table as shown in TABLE 1[10].

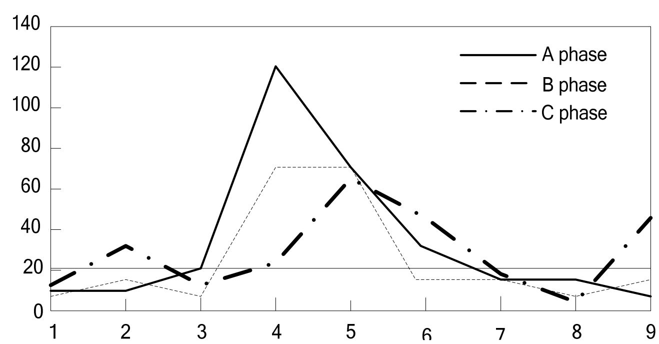

Figure 7 : Count of UV pulse in 30 s at substation(Nov)

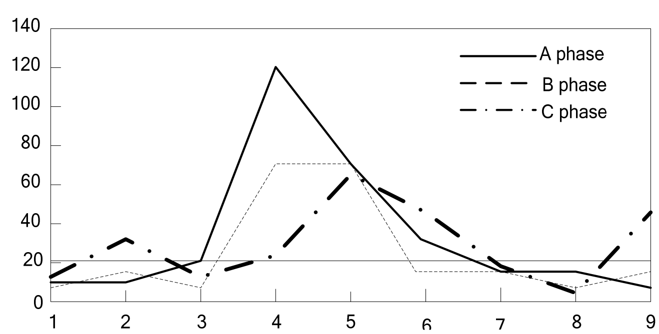

Figure 8 : Count of UV pulse in 30 s at substation(Jun)

TABLE 1 : The results of monitoring

Monitoring points		1	2	3	4	5	6	7	8	9
If the alarm	A	not	not	not	yes	yes	yes	not	not	not
	B	not	not	not	yes	yes	yes	not	not	not
	C	not	yes	not	not	yes	yes	not	not	yes

1)It can be learned from the experimental data above, that the obtained UV pulse number is different in the different detection point. Because the different of electrode structure and the shape of equipment is caused the consistent UV pulse discharge number of detection point. At the same voltage the cause of inconsistency of discharge intensity is the uniformity of the distribution of the electric field. Summer discharge strong position in winter is still strong,

2)The test results in summer and winter show that the consistent of discharge, discharge summer discharge strong position in winter is still strong.

3)When the UV monitoring to the pulse number is greater than this he threshold, the system will send a warning signal to the host,the operation staff will detect the operation situation of preparation.

4)Research and experiments show that: the system can detect the UV pulse discharge of high voltage electric power equipment, to determine the discharge of high-voltage power equipment. This methods can be detected in the ground and is convenient to detection.

CONCLUSIONS

In this article, an ultraviolet endoscopic system which can be used for special endoscopic environment in power industry has been developed with ultraviolet image acquisition, ultraviolet discharge detection and GPRS transfer function. Its feasibility has been proved with simulation test and high-voltage discharge test. The system is convenient, small and powerful with low cost. As embedded computer monitoring terminal is improved continuously, it has very realistic significance to use embedded remote terminal in UV endoscopic system. It can prevent accidents caused by ultraviolet discharge in power equipment, reduce the loss of national economy and has a certain role in promoting the development of China's power industry.

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