IOP Conference Series: Materials
Science and Engineering

PAPER • OPEN ACCESS

Exploration of Properties of Organic Insulation Materials in Power System

To cite this article: Geng Dai 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **493** 012085

Exploration of Properties of Organic Insulation Materials in Power System

Geng Dai

School of Management, Tianjin University of Technology, Tianjin, China

972593241@qq.com

Abstract. In order to effectively monitor the leakage current on the surface of organic materials, based on the existing research status, the relevant research results at home and abroad are analysed profoundly, and a more advanced system is designed to measure and monitor the leakage current on the surface of organic materials. The hardware circuit (main control circuit, differential amplifier circuit, filter circuit, power supply circuit and communication interface circuit) and software system (main program, data acquisition subroutine, data processing subroutine, communication subroutine, etc.) of the monitoring system are designed, respectively. Generally speaking, some researches are carried out on the carbonization and leakage current measurement of organic materials, and it also lays a theoretical foundation for the follow-up related research.

Keywords: organic materials; insulation; carbonization; detection system.

1. Introduction

Organic insulating materials have been widely used in the field of electrical insulation [1]. With the advantages of low cost, simple fabrication, good mechanical and electrical insulation strength, a large number of applications of organic insulating materials can be seen in transmission and transformation lines of various voltage levels and various transmission and transformation equipment, which also plays an important role in the safe operation of the power grid.

However, in practical applications, the surface of insulating materials is always being polluted. Absorbing water in the air will form a wet contamination zone on the insulating surface, which provides a conductive path between the high voltage electrode and the ground electrode, and the surface resistance decreases. As a result, a high surface leakage current and energy distribution will be generated. A dry zone will be formed further at the moisture reduction point, where all applied voltage converges to form an arc discharge. The molecular chains on the surface of materials are broken, carbon elements are precipitated, parts of the carbon remain on the surface of materials to form a carbonized conductive circuit, and parts of it become gas, which will form small pits on the surface of materials. If carbon remains on the surface, the insulation surface will be broken down when the remaining insulation is insufficient to withstand the voltage of the system [2], and even if the volatilization of carbon disappears, the mechanical strength of insulation will be reduced.

2. Research status at home and abroad

Literature [3] points out that the carbon paths of thermosetting materials start at the ground electrode and then gradually develop to the high-voltage electrode, but the carbon paths of EX (epoxy resin) are continuous, and the carbon paths near the ground electrode are wider than those rising to the high-voltage end; on the contrary, the carbon paths of PC (polycarbonate) are discontinuous in some places, while the top of carbon paths of EX is also wider than that of the ground electrode. Nowadays, when electrical equipment is used outdoors, it is affected by acid rain sometimes.

In 2000, Wuhan High Voltage Research Institute of State Grid established an intelligent AC/DC leakage current monitoring workstation for polluted insulating equipment, which continuously monitors and records the duration and peak value of leakage current pulse of polluted insulating equipment. The monitoring data are transmitted from a dedicated data transmission line to the upper computer for call and analysis, and they can also be transmitted to the computer hard disk for preservation at any time to view [4].

3. Design of insulation monitoring system for organic materials

3.1. Hardware design

The basic structure of the hardware system is shown in Figure 1. Temperature sensors and humidity sensors are digital sensors, and processors can read their values directly. Leakage current enters the system through small current transformers. After amplification by I/V conversion differential amplifier circuit, it enters the Butterworth filter circuit for filtering, and then it enters the processors. The processor transmits the leakage current value, temperature and humidity data to the upper computer for analysis and processing, and the upper computer judges the insulation status of the insulation material. If there is insulation damage, the processor immediately alarms and outputs them to LCD display.

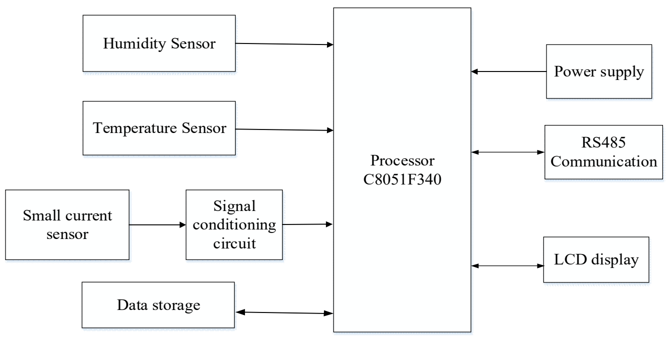

Figure 1. Basic structure diagram of organic material insulation state monitoring system

Signal acquisition and conditioning circuit design. Single-turn core-piercing current transformer is used to collect the current signal, which can isolate the primary side equipment and the secondary side equipment. In addition, the current sensor selected is BCT-2 zero flux core-piercing small current transmitter, which has excellent anti-electromagnetic interference ability, temperature characteristics and linear characteristics, and fully meets the measurement requirements of the system.

Because differential amplifier circuit can suppress common-mode signal and zero-drift phenomena very well, the differential amplifier circuit composed of three operational amplifiers is adopted. Among them, the amplifier needs to satisfy the following conditions: bias current l_B is far less than the measured current I_i; input impedance R_i is far greater than feedback resistance R_f; offset voltage Vos and drift are small; open loop gain Ad and common mode rejection ratio are large.

The operational amplifier used in this design is OPA129 of TI Company. The specific performance and numerical settings are shown in Table 1.

Table 1. OPA 129 performance parameter

Main performance	Numerical value / unit
Input bias current	30/fA
Input offset current	30/fA
Input offset voltage	0.5/mA
Input offset drift	$3/uA/$ ℃
Common mode rejection ratio	118/dB
Open loop gain	120/dB
Input resistance	1/Ω

Filter circuit design. The two-order Butterworth low-pass filter is used here [5,6]. The filter has a relatively flat corresponding frequency curve, which begins to decline in the resistance frequency region, finally tends to be flat near zero and eventually reduces to zero. From the Potter on the amplitude of the logarithmic diagonal frequency, it can be found that there is an inverse proportion relationship between angular frequency and amplitude.

Data processing and communication module design. Processor chooses 8-bit microcontroller C8051F340 produced by silicon labs. There are abundant analog peripherals embedded in C8051F340: 10-bit ADC with conversion speed of 200ksps; two comparators; internal voltage reference; power-on reset/power-off detector. It also has high-speed 8051 CPU core and pipelined instruction structure, and 70% of the instruction execution time are one or two clock cycles. There are 48MIPS and 25MIPS two versions, extended interrupt system. It has 4352 or 2304B data RAM, 64 or 32KB FLASH: programmable within the system, sector size of 512 bytes.

Communication interface circuit. This system is equipped with a RS485 serial interface [7]. RS485 interface has many advantages, such as multi-site connection and long transmission distance, and it can effectively reduce noise, so it has become a more common serial port. RS485 interface adopts half-duplex mode, which requires two wires. Therefore, twisted pairs are used to transmit data in engineering applications.

This design chooses MAX481 CSA as transceiver chip and the chip has low power consumption. If the input current of the chip is low, it will cause self-shutdown. The fastest speed of data transmission is as high as 250Kbps. After C8051F340 is powered on and reset, it is necessary to set and configure the registers of the serial port, including the baud rate of receiving and sending data. In this design, it is set to 9600bps, parity-free bit, 1-bit stop bit and 8-bit character data. In addition, the interface protection part is also set up, which is conducive to improving the reliability of RS485 communication.

Power circuit design. Design a DC (Direct Current) power supply circuit. Because the switching power supply module contains various harmonic disturbances, it is necessary to design a DC power supply circuit used for power supply of the system device. C8051F340, LCD module needs + 3.3V power supply, analog operation amplifier OPA129, LM324 and TLC074 need voltage of ±12V. The voltage regulator chip TPS54231 of TI Company is used to convert the + 12V voltage to + SV voltage, then the + SV voltage is converted to + 3.3V voltage by using LMZ10500, and the positive voltage is converted to negative voltage by uisng ICL7660 chip.

3.2. Software design

The software part of the system is written in C language, and the development environment is Keil u Vision4 produced by Keil Software Company of the United States.

Main program design. The main program flow chart of the lower computer is shown in Figure 2. The system initialization includes clock initialization, chip initialization, digital I/O port, timer initialization, LCD initialization, flash storage module initialization, etc. The main part of the software, namely the data acquisition and processing part, adopts modular design, which mainly includes A/D conversion, storage, calculation and transmission of the collected data.

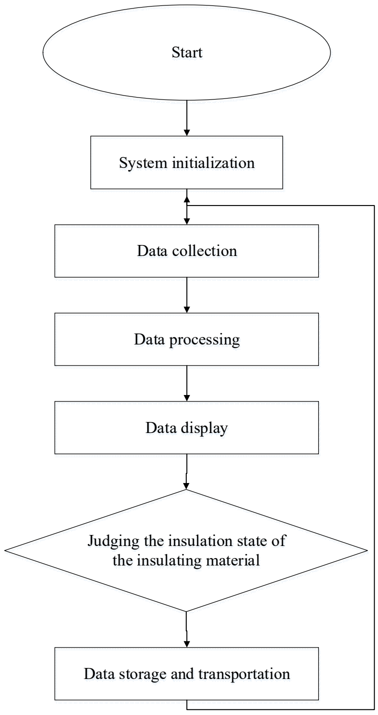

Figure 2. System main program flow chart

When the system is powered on or reset, the system must be initialized, including the initialization of the internal operation of the chip and the initialization of various peripherals, so that the main control chip and peripherals can be ready in a pre-set way. The initialization of the internal content of C8051F340 chip includes clock configuration, watchdog settings, register settings, interrupt settings, etc.

Data acquisition subroutine design. After the initialization of the main program, the leakage current of the insulation material is sampled. Sampling subroutine first sets the register of A/D conversion module, then sets the sampling frequency and the sampling channel, and begins to sample the input signal. Set a fixed period sampling point of 20, then the sampling frequency is 20x50=1kHz. Every collection point will be stored in the buffer, and it will be processed after all the collection of 20 points is completed.

Data processing subroutine design. When the A/D sampling subroutine completes the acquisition of the semaphore, the main program processes data immediately. In addition, digital smoothing is added to the software part. The programming idea is to collect the current n times continuously (20 times in this system), arrange these data from small to large by bubble sorting method, remove the maximum and minimum values, and then calculate the average value after summing up the other parts. The treatment principle is shown in Formula (1), and if $X_1 \le X_2 \le \cdots \le X_{20}$, then there is:

$$Y(k) = \frac{X_2 + X_3 + \cdots X_{19}}{18} \tag{1}$$

Communication subroutine design. In order to facilitate staff to inquire about the operation status of insulation materials, communication inquiry and parameter setting tasks are added to the program. In this communication program, ASCII code [8] is chosen as the data frame format. The specific operation is to transmit ASCII code which divides a hexadecimal number into two bytes. According to the frame format of hexadecimal system itself, sometimes the same bytes as the end and start bits appear in the valid segment of the frame, resulting in errors in receiving the frame. If ASCII code is used as frame format, the above problems can be effectively solved.

Table 2 gives the format of the request frame (upper computer and lower computer), while the format of the response frame is similar to that of the request frame.

Table 2. Request frame format

Serial number	Name	Number		Description
		ASCII code	Hexadecimal bit	
1	Frame start bit	SOH	01H	Frame start bit
2	Address	“0”-“9”	30H-39H	High address
3		“0”-“9”	30H-39H	Low address
4	Command type	“R”	52H	Command high
5		“W”	57H	Command low
6	Parameter number	“0”-“9”	30H-39H	Parameter high byte
		“0”-“9”	30H-39H	Parameter low byte
6+n	Data (n bytes)	“0”-“9”	30H-39H	
6+n+1	End of text	ETX	03H	End of text
6+n+2		“0”-“9”	30H-39H	Inspection and high position
	Test sum	“A”-“F”	41H-46H	
6+n+3		“0”-“9”	30H-39H	Inspection and low position
		“A”-“F”	41H-46H	
6+n+4	End of frame	EOT	04H	End of frame

4. Design of insulation condition diagnostic subroutine

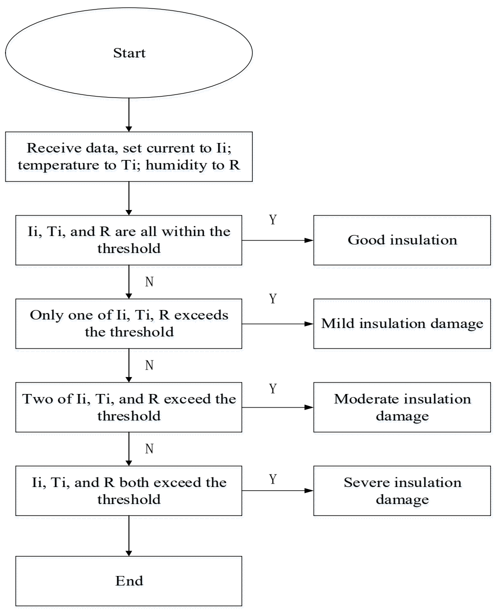

Figure 3. Insulation status diagnostic subroutine flow chart

As the surface temperature of organic materials reaches 100℃, the carbonization phenomenon of insulating materials will occur. If the leakage current value of insulating material surface reaches 0.7mA and the relative humidity of air exceeds 70%, the surface temperature of organic material will increase rapidly, and thus the degree of carbonization will be achieved. Therefore, the leakage current, temperature and air humidity will affect the carbonization of insulating material [9,10]. Therefore, it is necessary to monitor these three values in order to achieve the purpose of protecting organic materials. The block diagram is shown in Figure 3.

5. Conclusion

The background and significance of the research on carbonization of organic materials are introduced, and on this basis, the research status of the monitoring system of carbonization and insulation of organic materials at home and abroad is introduced. In the process of measuring leakage current, because the leakage current value is small and there are many disturbances, the extraction and measurement of leakage current signal has become a key breakthrough. A small current transformer is used to collect the leakage current signal, and a differential amplifier circuit is used to measure the leakage current signal. The overall design of hardware system platform is briefly described, and each module of the hardware circuit is analyzed and designed. At the same time, the software design and development of insulation monitoring system for organic materials is introduced. In general, some researches on organic material carbonization and leakage current measurement have been done.

References

[1] Teyssedre G, Laurent C. Advances in high-field insulating polymeric materials over the past 50 years[J]. IEEE Electrical Insulation Magazine, 2013, 29(5), pp. 26-36.

[2] Chandavong S, Tonmitra K, Kaewrawang A. The Flashover Phenomena due to Water Drops on Insulating Surface under DC Electric Field[J]. Advanced Materials Research, 2014, pp. 962-967.

[3] Vieille B, Casado V M, Bouvet C. About the impact behavior of woven-ply carbon fiber-reinforced thermoplastic- and thermosetting-composites: A comparative study[J]. Composite Structures, 2013, 101(15), pp. 9-21.

[4] Jin F, Zhou Y, Liu Z, et al. Characteristics of the Surface Discharge Process in Oil-paper Insulation Under Combined AC-DC Voltage[J]. High Voltage Engineering, 2015, 41(6), pp. 1965-1973.

[5] Rosales E B O, Ibarra F S. A 100Hz Low-Pass 2nd Order Sallen-and-Key Active Filter: A Design Proposal[J]. IEEE Latin America Transactions, 2014, 12(2), pp. 73-77.

[6] Yan Q, Wu X, Yuan X, et al. An Improved Grid-Voltage Feedforward Strategy for High-Power Three-Phase Grid-Connected Inverters Based on the Simplified Repetitive Predictor[J]. IEEE Transactions on Power Electronics, 2016, 31(5), pp. 3880-3897.

[7] Pavlov V, Baystrukov K, Golobokov Y, et al. KTM TOKAMAK OPERATION SCENARIOS SOFTWARE INFRASTRUCTURE[J]. Nuclear Engineering & Technology, 2014, 46(5), PP. 667-674.

[8] Jacobs P, Dimitrijevic I. An embeddable data acquisition system: interim report[J]. 2015, pp. 1-85.

[9] D'Angelo L, Verdingovas V, Ferrero L, et al. On the effects of atmospheric particles contamination and humidity on tin corrosion[J]. IEEE Transactions on Device & Materials Reliability, 2017, PP(99), pp. 1-1.

[10] Su Z, Yao M, Chen J, et al. Effects of annealing temperature, ambient humidity and temperature on dielectric properties of sol–gel-derived amorphous alumina thin film[J]. Journal of Materials Science Materials in Electronics, 2017, 28(1–4), pp. 1-7.