Condition Monitoring System Designing of GIS Based on Trip/close Coil Current

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Abstract. In this article, the types and characteristics of the faults from GIS were analyzed that the major failures were caused by its operating mechanism and auxiliary control circuits. While a useful parameter to effectively diagnose the mechanical failures of GIS is the trip/close coil current which is accessible and easy-to-measure. A portable system has been designed to monitor the condition of GIS by detecting the coil current. This system was fulfilled with functions like signal sampling, processing, transmitting and performing. DSP and ARM11 carrying WINCE 6.0 have been used to construct the system. The feasibility and reliability were validated through several repeated experiments.

1. Introduction

Because GIS is completely closed design, making the operator can not directly observe the state of the device, only based on the auxiliary contact return signal and the operator's on-site confirmation to determine whether the equipment in place, when the circuit breaker actuator for various reasons such as The transmission mechanism dry jamming, trip/close coil voltage fluctuations may occur after the circuit breaker control and monitoring of the scene after the separation and success, but the actual sub-contact is not in place, causing a major fault, causing the national economy is difficult Restore the loss. How to design a true reflection of the operational status of GIS monitoring equipment, the safe and stable operation of the power grid is very important [1-5].

In view of the current problems of GIS condition monitoring system, this topic cooperates with Dongguan Electric Power Bureau and some equipment manufacturers in Shanghai Jiao Tong University to develop the GIS condition monitoring system. The main object is the operating mechanism of the core component circuit breaker in GIS, mainly for the trip/close coil current, the development of portable hardware monitoring equipment. The research contents in this paper are as follows:

(1) According to the structural characteristics of the circuit breaker in the GIS, the motion and mechanical characteristics of the circuit breaker are analyzed. The current signal of the coil is analyzed.

(2) The hardware system of the portable GIS circuit breaker monitoring system based on DSP and ARM is researched and developed, including the signal acquisition circuit, the signal processing chip selection and design.

(3) To complete the portable monitoring system software system development, control and display interface program design;

(4) Design a fast fault classification algorithm.

2. Current waveform analysis
The typical current waveform of the sub-gate coil is shown in Figure 1 (the current waveform is similar in the case of closing and opening), and the whole process can be divided into five segments by using t0 as the trigger point:

1. Stage 1 (t0-t1): coil current, inductive load, the current in accordance with the exponential rise until the induction of the electromagnetic force is greater than the resistance of the core, the time t3, current reached the first peak i1. The core in the role of electromagnetic force began to move;

2. Stage 2 (t1-t2): coil current induced by the electromagnetic force is greater than the core resistance, the core began to do accelerated movement in coil induced back EMF, so the coil current began to decrease until the core contact To the sub/closing trigger (release), the current decreases to the valley at t2, the corresponding time t2;

3. Stage 3 (t2-t3): the core hit the trip device to stop the movement, the current began to rise in accordance with the index until the core force enough to push the trip device, the process continued until t3 moment, the current close to stability value;

4. Stage 4 (t3-t4): The iron core will push the tripping device to release, the spring will release the elastic potential energy, which will drive the circuit breaker body to move rapidly and reach the stable current value at time t4;

5. Stage 5 (t4-t5): At this stage, the auxiliary switch starts to work, the arc is generated, the voltage increases rapidly, and the coil current decreases rapidly until t5[6,7].

Figure 1 shows the current waveform can be seen, the sub-gate current there are two peaks and a valley, the common characteristics of the parameters in the figure has been marked as t1 - to reach the first peak current Time, i1-peak current 1, t2-valley current time, i2-valley current, t3- time to reach the second peak current, i3-peak current 2, t4-current from peak 2 to start down time, t5 - Minute (closing) gate current decreases to zero.

To further understand the trip/close current waveform, we can divide (co) brake coil circuit is simply equivalent to the circuit shown in Figure 2, sub- (closed) brake coil is the essence of an inductor in series with a resistor from Analysis of the mechanical structure of the above we know that it is received by the coil circuit trip/close command, the power to produce electromagnetic force to promote the core, the top open release to further release the spring energy.

Figure 2. Equivalent Circuit of Trip/Close coil
3. Design and Implementation of GIS Condition Monitoring System

As shown in Fig. 3, a complete GIS state detection system should include sensor sections, data set acquisition and signal conditioning circuits, data processors and fault diagnosis and result display units. The core of this part is the data processor and fault diagnosis and result display unit. Based on this, this chapter mainly introduces the design and implementation of portable GIS state detection system composed of upper computer ARM11 + lower computer DSP. The overall system block diagram is shown in Figure 3.

![Diagram of portable GIS online monitoring system](image)

**Figure 3.** Diagram of portable GIS online monitoring system

The lower position machine selects DSP, its main function module has the ADC module --- uses in the simulation digital signal conversion, the signal processing unit --- carries on the simple signal processing to the gathering data, the lower position machine communication module --- here chooses Serial communication interface (SPI) communication mode. The host computer chooses ARM11 to implement, and based on the stability of Window Embedded CE 6.0 system, the SPI communication module in multi-thread working mode and the MFC (Microsoft Foundation Classes) Of the human-computer interaction interface (Human Machine Interface, HMI). The whole state detection system realizes functions such as data acquisition, signal processing, eigenvalue extraction, upper and lower computer communication, fault detection, human-computer interaction interface and so on. According to the actual needs of GIS state detection, the system software part of the implementation of the main flow chart shown in Figure 4, open the system, upper and lower machine to complete the boot initialization, and establish communication link, and then select the host PC measurement program, and Input the relevant parameters, and then start the test, divided into two parts at the same time: the next crew to receive data, once the switch action, the signal trigger, that is, begin to collect data, data acquisition done after the corresponding signal processing. At the same time, the host computer to maintain the main interface status, receiving the next bit of machine data, and simple processing, this time can switch the interface for waveform display and so on. After the completion of the entire process by the host computer to select whether to reset the system operation, if reset, then return to the initial selection test interface. The overall situation of the system As mentioned above, the specific design of the upper and lower part of the separate and implementation see below[8].

4. Results and Applications

4.1. system test environment

Build the system test environment as follows:

(1) Hardware part: a DSP development board, S3C6410 development board, 10.4-inch resistive LCD display, NF company WF1973 signal generator, Tektronix MSO2014 mixed-signal oscilloscope, the system test site environment Figure 5 shows:
(1) Oscilloscope, signal generator (2) 10.4 inch display, ARM11 development board (left), DSP development board (right)

Figure 4. System test environment-hardware

(2) Software part: Lower computer DSP compilation and debugging environment is Code Composer Studio (CCS) 4.12 version, XDS100USB emulator, PC ARM11 equipped with WINCE 6.0 application compile and debug environment for Microsoft Visual Studio 2005 (VS2005) Figure 5 shows the interface of the debugging software to interact with the development board.

WF1973 signal generator can improve the arbitrary waveform editing function, using its ARB_Edit can edit the output current waveform similar to the sub-gate coil, as the current transformer signal output analog part, the input DSP corresponding ADC interface. In the debugging of this system, the waveform of the analog signal measured by the oscilloscope is shown in Figure 5. The test result will be analyzed in the next section.

Figure 5. Simulated profile of Trip/Close coil current

After powering on the detection system, the initialization of each module is finished. Set up the test parameters of the host computer, click the start test and wait for the trigger signal. Here, simulate the sub-gate operation, press the signal generator output button, the signal trigger, the lower machine start data. The main interface for the start interface for parameter settings, control, etc; trip/close gate, the main interface for the user interface[9,10].

Here Euclidean distance (Euclidean Distance) to make a brief description of the Euclidean distance, also known as the Euclidean distance, the distance is used to obtain n-dimensional space in the distance between two points, the formula is:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

Where xi and yi correspond to the ith coordinate of point x and point y, respectively.

Euclidean distance is usually used to judge the degree of similarity between two points. In this system, as the brief fault diagnosis method in portable equipment, we choose the feature dimension as 6, preset the normal operating point and set a certain threshold for Euclidean distance. When the distance
exceeds the threshold, it displays "fault". If it is less than the threshold, it displays "normal". For the specific fault type and cause analysis, please refer to the software algorithm in the next chapter.

4.2. Test and result
To verify the accuracy of the test results, according to the characteristics of the sub-gate coil current signal, with a programmable signal generator WF1973 to simulate the current waveform, taking into account the DSP's ADC input limit between 0 ~ 3V, while the coil current Time, the time between 30ms ~ 40ms, select the eigenvalues in Figure 1 \{i1, i3, t1, t2, t4, t5\}, corresponding to the man-machine interface \{Ip1, Ip2, Tp1, Tv, Tp2, Tp - peak current 1, Ip2 - peak current 2, Tp1 - time to first peak, Tv - current valley time, Tp2 - time to reach the second peak, Te - current drop Is zero. After the selected parameters were repeated several experiments, the experimental results are basically the same. The experimental results are shown in Table1. The experimental results show that the current error is less than 0.01V and the time error is less than 0.01ms.

| Feature quantity | Ip1 (V) | Ip2 (V) | Tp1 (ms) | Tv (ms) | Tp2 (ms) | Te (ms) |
|------------------|--------|--------|---------|--------|---------|--------|
| Preset value     | 0.860  | 1.470  | 8.10    | 10.12  | 18.40   | 31.50  |
| Measured value   | 0.866  | 1.469  | 8.10    | 10.13  | 18.39   | 31.51  |
| Error            | 0.006  | 0.001  | 0.00    | 0.01   | 0.01    | 0.01   |

5. Conclusion
This paper mainly introduces the design and implementation of portable GIS state detection system. The design of the system and the design and implementation of the hardware and software system are described in detail. DSP part of the ADC module, eigenvalue extraction module, communication module and other functional modules design, ARM11 equipped with WINCE6.0 operating system as the host computer system to complete the signal transmission, system control, human-machine interface display and other functions, Design process and the details of the realization of a detailed introduction, and gives a detailed system software process. At last, the system test environment is set up. The waveform of the current signal is simulated by programmable signal generator, which is used as the output of the current transformer and the input signal of the system. The experiment results are repeated and the accuracy of the system is satisfied. Requirements, verify the design of this portable GIS state detection system is feasible.

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Reference
[1] Kam S, Nielsen S, Ledwich G. A systematic review of a statistical vacuum circuit breaker model for condition monitoring[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2013, 20(2): 620-627.
[2] Razi-Kazemi A A, Vakilian M, Niayesh K, et al. Circuit-Breaker Automated Failure Tracking Based on Coil Current Signature[J]. IEEE Transactions on Power Delivery, 2014, 29, 1, 283-290
[3] Goto K, Sakakibara T, Kamata I, et al. On-line monitoring and diagnostics of gas circuit breakers[J]. IEEE Transactions on Power Delivery, 1989, 4(1): 375-381.

[4] Ukil A, Zlatanski M, Hochlehnter M. Monitoring of HV Generator Circuit Breaker Contact Ablation Based on Acoustic Emission[J]. IEEE Transactions on Instrumentation and Measurement, 2013, 62(10): 2683-2693.

[5] ZHANG Tianchen, HU Yue, LI Qing, HUANG Xingquan, SHENG Gehao, JIANG Xiuchen. Combined Ultrasonic and Electrical Detection System for GIS Partial Discharge Based on Virtual Instrument, 2012, 11: 43-49

[6] ZHANG Yongkui, ZHAO Zhizhong, FENG Xu, GUO Xue. Mechanical Fault Diagnosis of High Voltage Circuit Breakers Based on Opening/Closing Coil Current Parameters, 2013, 02: 37-42

[7] SONG Jingang, Xu Changqiu, ZHU Tongliang. Coil Current Monitoring of SF6 Circuit Breakers based on Waveform Identification, 2011, 03: 65-68

[8] CHEN Jianzhi. The study of HVBC on-line monitoring technique. Electrical Measurement & Instrumentation, 2007, 44(497): 27-30.

[9] LIU Junhua, YAO Ming, HUANG Chengjun, GUO Can-xin, YAO Lin-peng, JIANG Xiuchen. Experimental Research on Partial Discharge Localization in GIS Using Ultrasonic Associated with Electromagnetic Wave Method. 2009, 10: 2458-2463.

[10] Shen Li, HUANG Yulong, QIAN Jiali, Research on mechanical Condition Monitoring for HV Circuit Breakers, 1997, 17(2): 113-117.