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Study on On-line Monitoring of Mechanic Characteristics for Vacuum Breaker

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Abstract: In order to improve the maintenance level of vacuum breaker and implementation of condition maintenance for breaker, the principle of vacuum breaker online detection is studied. A vacuum breaker online monitoring system is designed, which is divided into the upper machine, lower machine and remote monitor host, a plurality of vacuum breaker can be detected simultaneously. The upper machine is PC, lower machine by using dsPIC30F5015 development board is constituted on-line monitoring module, the industrial field bus (CAN-bus) is adopted between the upper and lower machine implementation of real time transmission. Experiments show that, the on-line monitoring system for mechanic characteristics of vacuum breaker can be realized mechanic characteristic parameters on-line detected, the monitoring target of breaker is completed. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Vacuum breaker, Mechanic characteristics, On-line monitor, microcontroller, Industrial field bus.

1. Introduction

The reliability of vacuum breaker is decided in the very great degree on the reliability of mechanic operation system. The two World Survey on power grid reliability of high voltage breaker by International Conference and accident statistics analysis made in China of the high voltage switch shows that: most fault of breaker (70 % main faults and 86 % secondary faults) is occurred in mechanism, mainly relates to the operating mechanism, monitoring device and auxiliary device [1]. Because the breaker cost is only a small part of the loss, the mechanic characteristics of vacuum breaker test is an important item of factory inspection of manufacture and user maintenance test. The traditional way to reduce the fault is the regular maintenance of vacuum breaker, but for the mechanical performance of vacuum breaker operation is unable to grasp the bad, and the pertinence is not strong maintenance and parts replacement, not only wasting time, wasting money, but also affected the breaker original stability, and even affecting the normal operation of vacuum breaker, increased accident rate. The reliability of vacuum breaker is decided in the very great degree of reliability of the machinery operating state, so the implementation of on-line monitoring on the mechanic characteristics of vacuum breaker [2], the operation status grasped timely, to understand its operation characteristic changes and the change trend, change the "maintenance" for "on line

monitoring maintenance", on the reliability and security of equipment operation to improve power system, maintenance costs decline, providing repair personnel repair arguments, reducing labor intensity of repair work, improving the management of equipment operation intelligence, etc., it has the very vital significance, development of vacuum breaker mechanic characteristic testing will drive the breaker intelligent process.

2. The Principles of On-line Monitoring for Mechanic Characteristics for Vacuum Breaker

Vacuum breaker is a kind of high voltage breaker, it is named for its quenching medium and arc insulation medium contact gap are high vacuum. It is divided into indoor and outdoor types according to the conditions of use. It is mainly made up of frame, arc quenching chamber (vacuum bubble) composition and operating mechanism. The circuit breaker body is made up of insulating system, electric circuit, the seal and the shell. The whole structure is three-phase common box. The conductive loop consists of conductive clips, import and wire pole, import line insulation supporter, soft connection with the vacuum interrupter. Mechanism for electric storage, electric switch, at the same time with manual function. The whole structure is composed of energy storage system, the storage instructions, the tripping and closing coil, closing spring, overcurrent release, manual switching system, auxiliary switch and other components.

The energy storage process: when the power of energy storage motor is turned on, the motor drives the eccentric wheel to rotate, the crank arm and the connecting plate swing are driven through the eccentric wheel closing to the roller, promote energy storage a swing, when the pin and the ratchet wheel on the sleeve of the plate against the later, the two movement, Closing spring hanging in the energy storage shaft sleeve is elongated. The energy storage shaft sleeve is fixed by a positioning pin to maintain the storage energy state, at the same time, the turning arm of energy storage shaft sleeve push the travel switch to cut off the power supply of energy storage motor , and the energy storage pawl is raised, reliable detachment and ratchet.

Closing operation process: when the organization received the closing signal (switch is off, have energy storage state), core of closing electromagnet is sucked downward movement, pulling the positioning piece to the counter clockwise rotation, releasing energy storage to maintain, closing spring drives the energy storing sleeve clockwise rotation, the cam pressing transmission shaft, the plate and the rocker arm are driven movement, so that the rocker arm on the half shaft, the mechanism in the closing state. At this time, interlocking device lock positioning piece, so that the positioning piece cannot counterclockwise rotation, to achieve agency marketing objective, ensure the organization operating in not closing position switch.

The opening operation process: after the breaker closing, tripping electromagnet received signal, the core is pulled, the top rod of brake release is pushed upward movement, the trip shaft is made rotate. The top rod is driven upward movement. The plate bending and half axle is pushed clockwise to drive. The half axle and the rocker arm trip, the circuit breaker completed tripping operation under the action of opening spring.

According to the "national standard of high voltage circuit breaker", operation characteristics or setting value of needs to record and calculate in the mechanical characteristics test were more, the characteristic parameters of users and manufacturers are most concerned about is: the moving contact of the travel time curves, the current – time waveform of the opening and closing coil, speed of the opening and closing, time of the opening and closing, etc. [5].

Parameter on-line monitoring for mechanical characteristics of vacuum circuit breaker in the opening and closing process consists of time parameter, velocity parameter and displacement parameter, the conversion relationship between the three is S=VT, that is the two can be achieved third, so the time parameter and displacement parameter can be chosen as the measuring object. The time parameter is determined according to the position of vacuum circuit breaker action time in the opening and closing operation, it combined with the displacement parameters of each sequence points, the speed of mechanical characteristic parameters can be gotten. The signal needs to capture in the online monitoring system is as the following: 1) opening and closing the command signal; 2) opening and closing coil current signal; 3) the current and voltage signal of main circuit; 4) displacement signal of vacuum circuit breaker dynamic contacts; 5) the state variable signal of vacuum circuit breaker auxiliary contact.

The opening and closing coil current is DC signal, and the AC signal, and the requirement of real-time measurement, the Holzer current sensor can be used as an online monitor, it is high accuracy, linearity, dynamic characteristics and good electrical performance, wide frequency band, small volume, closing coil loop through the core, the lord will not affect the normal operation system of vacuum circuit breaker, the measuring circuit and the output circuit are isolated from each other, the transformer is only applicable to 50 Hz frequency measurement and shunt cannot lack isolation detection [6].

The short circuit of current breaker opening is a loop current of power system, it is difficult to measure in laboratory conditions, the main circuit current signal to monitored, SK04AI-1000 open Holzer current sensor can be used, it’s output current signal is changed into a voltage signal by matched resistors for MCU sampling.

The main circuit voltage of vacuum circuit breaker can be measured with 0.5 level voltage transformer, output voltage of the secondary side is 100 V, output voltage signal amplitude with two level voltage transformer is 5 V after the circuit processing into a suitable signal for MCU sampling.

Measuring the insulating rod moving contact stroke signal of breaker can be installed linear displacement sensor in dynamic contact or moving contact, but the structure of the vacuum circuit breaker (voltage level below 40.5 kV) is compact, in the switch cabinet may self as a whole, the available space in the small, the sensor is arranged near the movable contact and the insulating rod, space is narrow; if the sensor is arranged in the movable contact, there is the problem of high voltage isolation [7]. Therefore, the angle displacement sensor can be installed in the operating mechanism of the driving shaft, through the measurement of circuit breaker rotary shaft switching angle displacement time curve, indirect linear displacement - time curve of the movable contacts. Measurement of dynamic contact displacement signal can be used ZKT-22B incremental rotary encoder.

The state signal of vacuum circuit breaker auxiliary contact is the high level of "1" or "0", which processing by external interruption of the MCU, in order to ensure the real-time signal transmission and avoid damaging the MCU system, the signal is isolated with the MCU by Optical coupler TLP521-4.

3. Design of the Hardware

The design of online monitoring system of vacuum circuit breaker consists of three parts – upper machine, lower machine and remote monitor host, a plurality of vacuum circuit breaker can simultaneously online monitoring, the block diagram shown in Fig. 1. The upper machine is PC, the controlling procedures of upper machine can be completed the monitoring and management of circuit breaker monitoring process by programming software, The lower machine online monitoring module by using dsPIC30F5015 development board as the core. Real time and high speed transmission is realized by using the industrial field bus CAN-bus between the upper machine and the lower machine, the upper machine can be measured data to the remote monitoring computer to realize the data accumulation and sharing of information through the internet.

The hardware structure diagram of online monitoring module as shown in Fig. 2, the dsPIC30F5015 development board is used as the core, peripheral hardware interface circuit. SP03 magnetic balanced Holzer sensor is used to detect the current signal of tripping and closing coil in the operating mechanism, ZKT-22B incremental photoelectric encoder is used for measuring dynamic range signal contact, SK04AI-1000 retractable Holzer sensor is used to measure three-phase current in main circuit, Voltage transformer is used to measure the three-phase main circuit voltage. Pulse signal of photoelectric encoder is connected with the QEI interface of MCU by the internal counter to count. Status change signal of auxiliary contact is connected with MCU interrupt port through optocoupler TLP521-4 isolation. The Analog signal is processed by appropriate pretreatment circuit into the MCU Interface, analog to digital conversion by high-speed A/D MCU internal, measurement data uploaded to the upper machine by CAN bus.

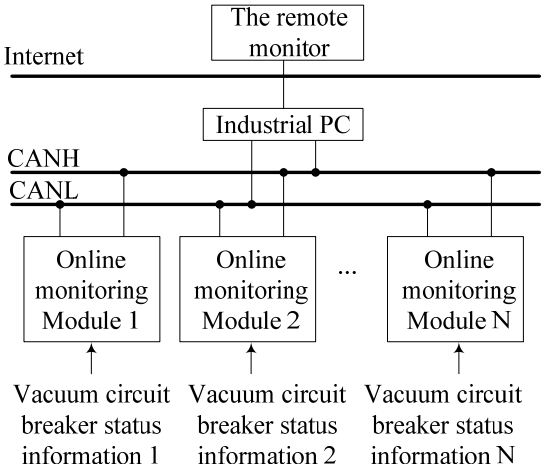


Fig. 1. Structure diagram of vacuum circuit breaker online monitoring system.

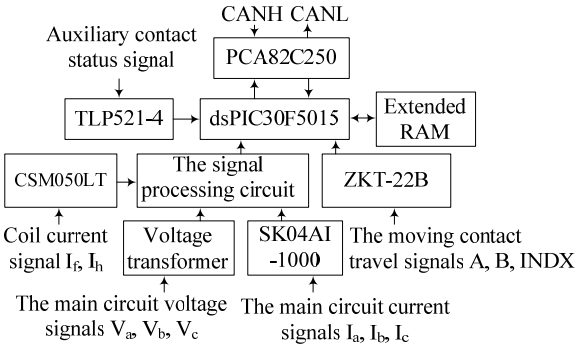


Fig. 2. The hardware structure diagram of online monitoring module.

DsPIC30F5015 development board is to build based on 16 bit microcontroller dsPIC30F5015 as the core, containing: a CAN bus transceiver; 8 PWM motor controllimg, including a PWM output LED indicator; a standard RS232 serial port, 8 green SMD LED lights; a external crystal oscillator (standard 4 MHz), internal frequency doubling; a LCD interface, it can be connected with 128×64 small screen dot matrix; 16 channel 10 bit ADC, it can be configured for 12 bit A/D, multiple channels can be sampled at the same time, the a road is connected with the temperature sensor MCP9700A; a 24LC64EEPROM,it can be used for I^2C experiment;

a reset circuit and reset button, 2 keys has the level change of interrupt function; a power supply interface, it contains the protection circuit and power indicator, voltage conversion, power supply voltage range of external is DC 5~12 V (dsPIC30F5015 working voltage is 2.5~5.5 V); a MIN USB power supply interface with short circuit protection function; a ICSP debugging programming interface; 2 SOP (standard Operation Procedure) from the arid region, it can be realized DIY experiment; 53 I/O pins of the dsPIC30F5015 are separately derived.

The vacuum circuit breaker opening, and closing coil lead wire cross the measuring aperture of CSM050LT Holzer current sensor, the measurement range is 0~50 A, rated output is 0~50 mA, the linearity is 0.1 %, accuracy is 0.7 %, the working voltage is ±15 V DC, the bandwidth is DC~100 kHz, the response time is less than 1 μs, the operating temperature range is -25~85 °C, through core diameter is 20 mm, size is 68×58 ×22 mm.

Vacuum breaker main circuit breaking current was turned into a peak current signal of 100 mA by using SK04AI-1000 Holzer current sensor, it is transformed into a voltage signal by matching resistor. The measuring range is 0~1000 A, rated output is 0~100 mA, the linearity is 0.2 %, accuracy is 0.5 %, the working voltage is 12 V DC, the bandwidth is 20 kHz, the response time is less than 1 μs, the operating temperature range is -20~70 °C, through core diameter is 20 mm, size is 46×52×25 mm.

The three-phase main circuit voltage is AC signals, it is converted to 5 V voltage signal by a level 2 voltage transformer, it is changed to AC 2.5 V bipolar voltage signal by potentiometer adjustment, it is transformed into 0~4.8 V sine unipolar signal suitable for MCU processing by filtering amplifying circuit and lifting voltage circuit.

The time tripping signal of vacuum breaker is obtained indirectly by measuring the ZKT-22B photoelectric encoder mounted on the shaft of the rotary motion, four times frequency pulse signal are normally designed to improve the detection resolution, incremental encoder interface is provided by the QEI module of MCU dsPIC30F5015, QEI is composed of orthogonal decoder logic circuit and up / down counter. The input signal is filtered by the programmable digital noise filter at the input terminal. The pulse signal of incremental photoelectric encoder can be directly linked to the MCU interface, module function can be flexibly configured simply by programming, pulse signal processing circuit need not be designed. ZKT-22B photoelectric encoder supply voltage for the DC 5 + 0.25 V, current consumption ≤100 mA, frequency response is 0~100 kHz, each output pulses for the 5001500P/R, absolute angle error of A, and B phase ≤ 0.2T, periodic error≤ 0.05T, where T=360°/N (N is pulse number of each output).

The transmission shaft and the breaker auxiliary contacts are linked in the actuator for vacuum distribution equipment, auxiliary contact position is corresponding to the position of the breaker. The position state signal acquisition of breaker is determined by the state information acquisition of auxiliary contacts. The normally closed auxiliary contacts of vacuum breaker are series connected in input circuit by the optical coupler TLP512-4, low pass filter is configured to filter out the high-frequency disturbance by T type RC network. Three outputs of optical coupler are respectively connected with the MCU external interrupt to realize complete isolation between the quantity switch interface and MCU. The principle of circuit is: the normally closed auxiliary contacts are closed when the vacuum breaker is in the off state, signal is input by the RC network of optical coupler, light emitting diode coupler luminous, photosensitive triode, the outputs low "0"; The normally closed auxiliary contact is disconnected when the vacuum breaker in the closing state, the light-emitting diode does not emit light, the photosensitive triode is cut off, the output is high level "1", so the status signal acquisition of vacuum breaker is completed.

Due to the sampling signal very fast and the acquisition of the monitoring system more, only dsPIC30F5015 internal 2K×l6bits data memory is not enough, need for external memory. DsPIC30F5015 development board comes with a 24LC64EEPROM, while the switching process of the vacuum breaker within 200 ms, so the number of sampling data is 16000 × l6 bits or 32000 × 8 bits, 24LC64EEPROM capacity can meet the requirements.

The lower machine of vacuum breaker online monitoring device for mechanical characteristics will collect data according to a transmission mode uploaded to the upper machine, and then the data analysis is completed by the upper machine system. At present, RS-232 and RS-485 commonly is the means of communication. Because communication distance of the RS-232 is short (according to the EAT/TAl-232 standard, is only 15 meters), and point-to-point communication can only be used , multipoint communication network can not be directly set. The communication network of RS-232 node is consisted in order to extend the communication distance of RS-232, the signal converter of RS-232/RS-485 is used. However, due to the limitation of RS-485 itself, In practical application, bus efficiency is low, the real-time performance of the system is poor, the reliability of communication is low, network engineering debugging is complex, the transmission distance is not ideal, the nodes of single bus connecting is small, application is not flexible [8, 9]. The CAN bus is selected as the monitoring communication module, CAN (Controller Area Network) can complete the digital communication between the field monitoring unit and the management of equipment or contacts between the field monitoring communication unit and higher management network as an effective distributed communication field bus, The CAN transceiver PCA82C51 can realized CAN communication interface function.

4. Design of the Software

The design of the software includes two parts as main program and function module program. The main program mainly completes the system self checking, initialization, fault handling and the coordination of various functional modules and other functions. Each function module procedure completed signal sampling, storing, calculation and output control, display and other functions, it mainly includes closing sampling procedures and opening sampling procedures, A/D interrupt service program and write data subprogram, switching interrupt service program, CAN communication program, upper machine processing program, etc.

The main program flow chart shown in Fig. 3.

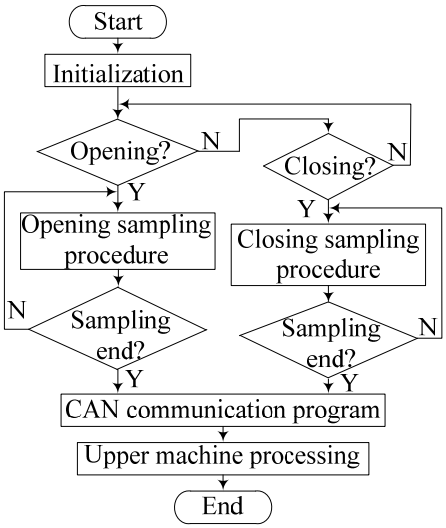


Fig. 3. The main program flow chart.

Power on, the MCU begin to work. first, the system initialization is performed, including the definition of input and output ports; setting module WTD, A/D, QEI, CAN, timer; setting the status symbol; initialization of variables and constants. Vacuum breaker action, first opening / closing mark is judged, and then the opening sampling procedures or closing sampling procedures is called to switch, digital/analog sampling. Then judged whether the sampling time reaches the preset value, if it reaches the setting value, the CAN communication procedures is called, the sampled data is uploaded to the upper machine, the data is processed by the upper machine; the setting value is not reached, then continue sampling.

Closing the sampling procedure as shown in Fig. 4.

Opening the sampling procedure as shown in Fig. 5.

Closing the sampling procedure is mainly collected the current, voltage, travel signal of the moving contact and other signal during closing, in addition, the starting and transposition point used for mechanical properties calculation are special recorded, it including the starting time of the closing coil current and the position of movable contact, the first phase closing time and location, three-phase full closing time and position location. Timer1 is used as the absolute clock system, Timer2 is used as system clock timing and position of moving contact acquisition, a time is recorded every 100 μs. The function of opening the sampling procedure is similar to closing sampling procedure, but the record of the object is slightly different, the record is mainly the starting time tripping coil current and the movable contact position, the first phase of auxiliary time and position of the contact state changes, time and location of the three-phase auxiliary contact state changes except the current, voltage, travel signal of the moving contact, etc.

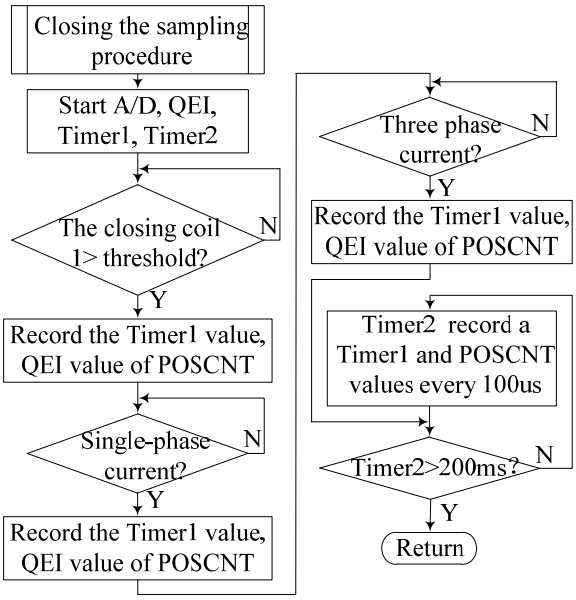


Fig. 4. Closing the sampling procedure.

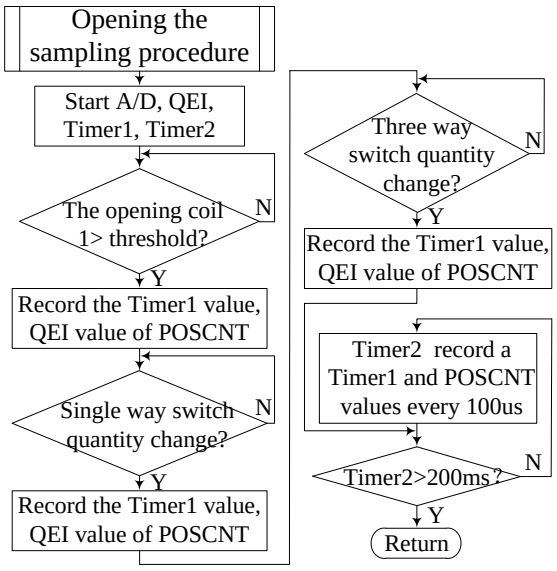


Fig. 5. Opening the sampling procedure.

A/D interrupt service routine is mainly completed the voltage and current analog signal acquisition. Once the interrupt, first of all to protect the scene, analog is converted to digital quantity in accordance with the symbol shaping output format, address and data of dsPIC MCU is 16 bits, so the output data of A/D will be converted into high 8 bits and low 8 bits of data, and then the subroutine of writing data is invoked, the address also want to do the 8 high bits and low 8 bits processing [10].

There is close contact between the status signal of auxiliary contacts and the conversion point, Acquisition is interrupted, once the state changed, that is from high level to low level or from low level to high level, the system time and the movable contact position is recorded.

CAN communication program mainly includes the CAN module initialization, sending data and receiving data procedures. The CAN module initialization begins in the main program including the completion of the mode register, controlling and status register, transmitting buffer register, receiving buffer register, baud rate controlling registers, interrupt status and controlling register definition. The data of sent to the CAN bus is automatically completed by the CAN controller of the MCU, to be sent the information frame is sent to the sending buffer of the CAN controller to start sending commands . CAN data is received by interrupt mode and the rest in the main program loop execution, the information from the CAN bus to the CAN receiving buffer is done automatically by the CAN controller, the receiving program only need to read the information received from the receiving buffer.

CAN bus is used to realize the communication with the upper machine, the functions of the upper machine is the processing of data acquisition, parameter calculation, curve display and query of historical data, print, etc.

5. The Experimental Results

Monitoring function can be verified in the system debugging process. The device is used to test the mechanical properties in vacuum breaker. Mechanical properties are detected during the test, the data is transmitted to computer analyzing and displaying by CAN bus. The mechanical properties are tested in the VSI 12 kV single coil indoor permanent magnetic vacuum breaker, mechanical characteristic factory parameters of the breaker [11, 12] is: the closing time is less than 70 ms, the opening time is less than 50 ms, the closing speed is 0.5~0.8 m/s, opening speed is 0.9~1.2 m/s, opening distance is 10~12 mm, ultra stroke is 2.7~3.3 mm. The measured mechanical properties parameters is: the closing time is 30~40 ms, opening time is 25~30 ms, closing speed is 0.5~0.75 m/s, opening speed is 1~1.15 m/s, opening distance is 10~11 mm, ultra stroke of contact is 2.8~3.3 mm, the current of closing coil is 120~135 A, current of opening coil is 11~16 A. Data show that, the mechanical characteristics of online monitoring system can be reflected the actual monitoring function in 3 aspects of time, displacement, speed. The monitoring objectives are achieved.

6. Conclusion

Mechanical characteristics online monitoring system of vacuum breaker is combined DSP and CAN field bus, the new device such as Holzer current sensors, incremental rotary photoelectric encoder and DsPIC30F5015 development board is adopted, it overcome the past monitor sensor installation difficulties, low life, the low dynamic response, it has a good practical value and application prospect.

Acknowledgements

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