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Application of a New Sensor Circuit Model in the Oil Dissolved Gas Monitoring

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Abstract: The analysis of the composition of dissolved gas composition and concentration in transformer oil is the common method for transformer to performance evaluation and schedule fault type. This paper is based on sensor technology, a vice sensor is proposed to establish bridge sensor circuit to compensate for the traditional gathering of non-linear error, so as to improve the response characteristics of the sensor and the work performance. Then putting this system into field, and the analysis of test data showed that the system can perfectly reflect the insulation performance status of transformer.

Keywords: dissolved gas; online monitoring; bridge sensor circuit; application research

INTRODUCTIONS

With the improvement of transformer capacity and voltage level, more and more attention for the transformer online monitoring and fault alerting is paid to ensure the stability of the substation power supply system[1]. At present, gas chromatography method is widely used to detect the dissolved gas in transformer oil, and this method has a good reflection of the transformer internal fault[2]. A heater is used to suppress the temperature drift of the sensor in the periphery of chromatogram column. But stability and response characteristics of sensor will have an impact in the process of heating to a constant temperature[3]. And some other reason will be also the incentive of test error for the sensor. Such as the difference of the carrier gas concentration, the differences of the twice operating conditions of chromatography and some uncertain changes of sensor for a long time unused. In order to offset measurement error of the main sensor in the same kinds of conditions, a vice sensor is proposed to establish bridge sensor circuit.

SENSOR ERROR ANALYSIS

Sensor errors are mainly the following aspects.
(1) The output of sensor use conventional resistor divider[4], which is shown in Fig. 1.

$$V_{RL} = \frac{V_C}{R_L + R_S + \Delta R_S} R_L \quad (1)$$

Where, V_C=V_H=5V , R_L=10K, R_S is the of resistance sensor,ΔR_S is the change of sensor resistance when the sample gas through the sensor, V_{RL} is the output voltage of sensor. As in formula 1, non-linear change of V_{RL} caused by ΔR_S.

(2) Heating circuit and the measuring circuit in the same structure within the structure of the sensor as shown in fig. 1. Sensor generates a temperature drift without insulation measures.

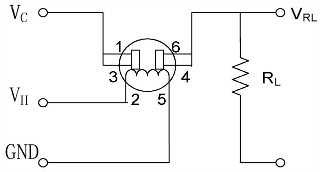

Fig.1 Principle diagram of gas sensor

In order to solve the above problems, in this paper, the following method has been proposed. The structural components of the Carrier gas cylinders - Columns - Sensor has been changed, gas pipe interface from the carrier gas valve to the pressure switch has been divided into two. Gas through the bridge voltage divider circuit build composed of main and secondary sensor, which can effectively compensate for the measurement error of sensor.

SENSOR BRIDGE VOLTAGE DIVIDEER CIRCUIT

Connection structure of column and the bridge voltage divider linear signal acquisition circuit of sensor are shown in Fig. 2. $\triangle R_S$ is negative when the supply of electronic gases through the sensor, so V_o value is collected by the CPU board as follow

$$Vo = U_C - U_A = -(U_A - U_C) \quad (2)$$

referring to Fig. 2

$$U_A = \frac{R_{S1} + \Delta R_S}{R_{S1} + R_{S2} + \Delta R_S} V_{CC} \quad (3)$$

$$U_C = \frac{R_2}{R_1 + R_2} V_{CC} \quad (4)$$

Thus the V_o equation is

$$V_O = \frac{R_{S2}R_2 - R_{S1}R_1 - R_1\Delta R_S}{(R_1 + R_2)(R_{S1} + R_{S2} + \Delta R_S)} V_{CC} \quad (5)$$

Where, R_{S1} and R_{S2} are the size of the resistance value of sensor A and B when the pressure of carrier gas is

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0.3 ~ 0.45MPa. $\triangle R_S$ is the change of sensor resistance when the sample gas through the sensor A. V_{cc} is the operating voltage of the sensor.

In this system V_{CC} = 5V, $R_1 = R_2$ =10K.

Approximate calculation of the equation 3 and 4 as follows

①The differences of static resistance are small for the same batch of gas sensors, so R_{S1} and R_{S2} can be approximately considered equal. We obtain

$$R_{S1}R_1 = R_{S2}R_2 \quad (6)$$

②The denominator of formula（4）$(R_1+R_2)*(R_{S1}+R_{S2})$ is much larger than $(R_1+R_2)\triangle R_S$

Approximating denominator of formula 5 as follow

$$(R_1+R_2)(R_{S1}+R_{S2}+\Delta R_S)=(R_1+R_2)(R_{S1}+R_{S2}) \quad (7)$$

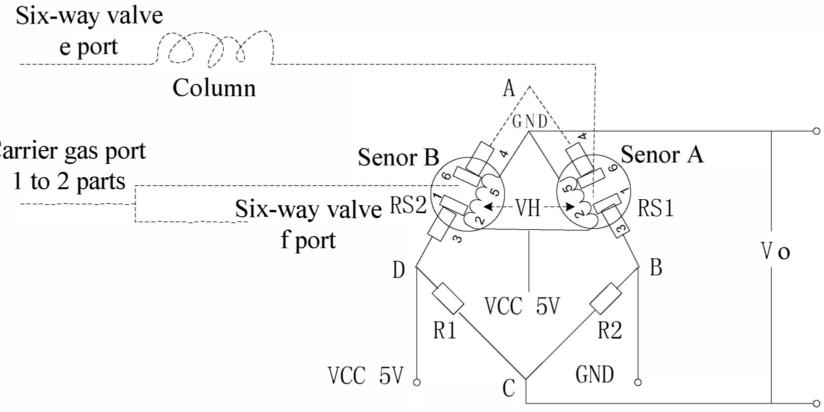

Fig.2 Bridge type acquisition circuit of sensor

So referring to formula 4

$$V_O = -\frac{R_1 V_{CC}}{(R_1+R_2)(R_{S1}+R_{S2}+\Delta R_S)}\Delta R_S = -\frac{R_1 V_{CC}}{(R_1+R_2)(R_{S1}+R_{S2})}\Delta R_S \quad (8)$$

Assuming

$$k = \frac{R_1 V_{CC}}{(R_1+R_2)(R_{S1}+R_{S2})} \quad (9)$$

At last we obtain

$$V_O = -k\cdot\Delta R_S \quad (10)$$

Linear output of the sensor analog signal can be realized in this way.

Then we will solve the problem of temperature drift. Baseline voltage is expressed as

$$Vo = U_C - U_A = \left(\frac{R_2}{R_1+R_2} - \frac{R_{S1}+\Delta R'_{S1}}{R_{S1}+R_{S2}+\Delta R'_{S1}+\Delta R'_{S2}}\right)V_{CC} \quad (11)$$

Formula 4 is written as

$$Vo = \frac{R_{S2}R_2 - R_{S1}R_1 + \Delta R'_{S2}R_2 - \Delta R'_{S1}R_1}{(R_{S1}+R_{S2}+\Delta R'_{S1}+\Delta R'_{S2})(R_1+R_2)}V_{CC} \quad (12)$$

Where, $\triangle R'_{S1}$ and $\triangle R'_{S2}$ are the change of sensor resistance when the sample gas through the sensor A and sensor B.

Because the differences of static resistance are small for the same batch of gas sensors, so the differences are mainly manifested in the dynamic response and linear preserver after the resumption when the sample gas through. Observing formula 12，we obtain that outside temperature and humidity changes, the sensor response inertia and other factors that cause fluctuations in the output signal can be offset by the compensation sensor B in the same conditions when the signal acquisition circuit consists of a bridge circuit using a sensor of the same type. And the error compensation is achieved. The value of V_o near zero when the gas don't through the column. Fig. 3 shows the test curve of oil.

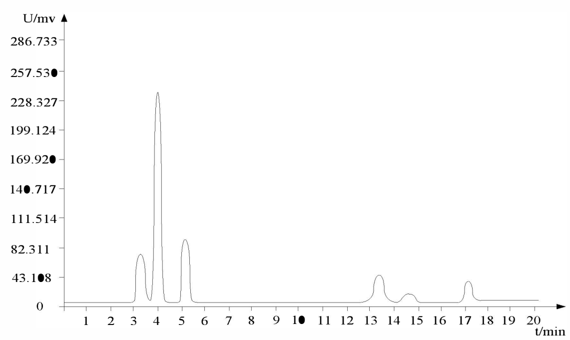

Fig.3 Test curve of oil

Baseline fluctuation in the test curve only depends on the manufacturing process of sensor, which are the differences in the size of the static resistance of the two sensors and the changes of the sensor resistance of the two sensors when the carrier gas through. Accordance with the technical parameters of the gas sensor, the two resistance error is within 0.3%.

Because the error is very small, the sensor response time and recovery time are shortened when carrier gas through the chromatographic column into the sensor A. And resolving power and sensitivity of the sensor are improved. Output signal and the baseline has been to maintain a good equivalent in the PC software between after the end of the crest of a gas and before the advent of another gas waveform because of shorter recovery time. The accuracy of the calculation of the waveform area is improved, and the determination of gas concentrations is closer to the real value.

CASE STUDIES AND DATA ANALYSIS

The design method of sensor is applied to the manufacture of oil chromatography, and Fig. 4 is the structure of oil chromatographic on-line monitoring system, which is used to monitor the site transformer.

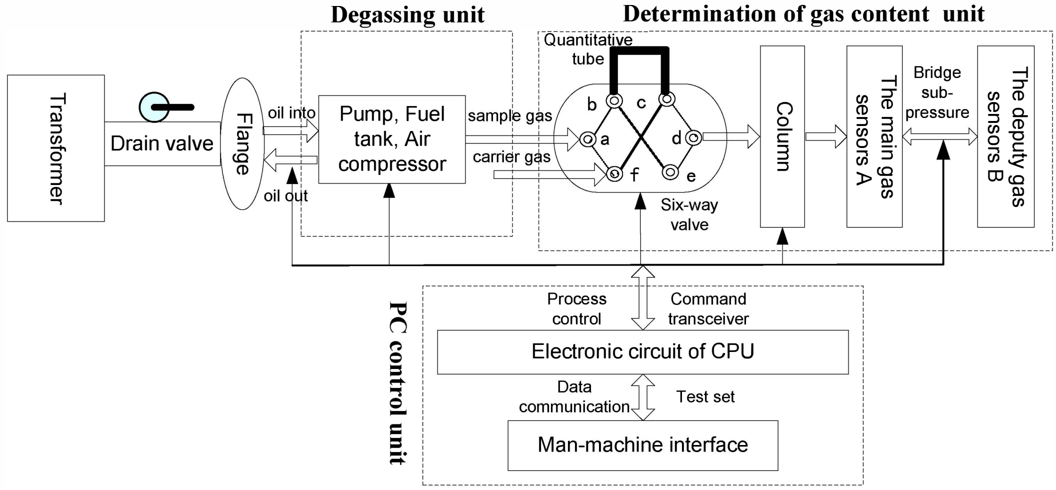

Fig.4 Structure of oil chromatographic on-line monitoring system

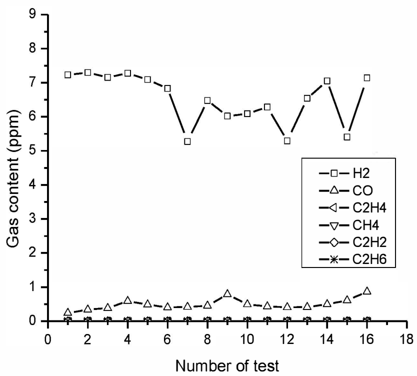

Fig.5 Chromatographic data analysis of a transformer operating normally two year

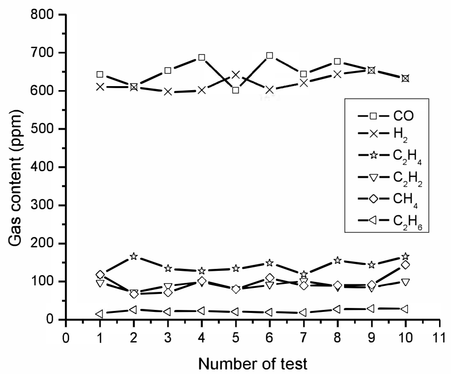

Fig.6 Chromatographic data analysis of a faulted transformer

Fig. 5 shows the analysis data of gas in the insulating oil of transformer for running two years. And the results show that only small levels of H_2, CO and the content of other gases are 0. All the gases don't exceed the security value, and this test result is reasonable for functioning transformer. Fig. 6 shows the chromatographic data of a failure transformer. The content of CO, H_2, C_2H_4 is relatively large, and C_2H_2 is about 100ppm. The results of chromatographic analysis is that CH_4, C_2H_4, C_2H_2, H_2 and the content of total hydrocarbon is more than the standard value several times. The three-ratio method is used to determine the type of fault, which is the high-energy discharge fault. The cause of this failure

Fig.7 Test installation schemes of oil chromatographic

may be due to the discharge of power frequency freewheeling, the arc breakdown of insulating oil between winding and ground, cut ting off the power supply. Then the unbalance rate of DC resistance of the B-phase high voltage winding is 25% when the transformer has been tested. And the B-phase winding is preliminary judged with severe arc fault. When the transformer is dismantled to examine, we find that the neutral point of B-phase high voltage winding is serious short-circuit in the interterm, and some arc discharge traces are in winding, and the damage of transformer is serious.

CONCLUSION

A voltage divider circuit of sensor is designed to ensure the linear output of sensor and complete the error compensation. The schematic of circuit is that a vice sensor B of the same model is used to offset the nonlinear error of the main sensor A. The design of the dissolved gas content online monitoring system is put in the field test, and on-site installation of the equipment is shown in Fig 7. Base on the monitoring data of a normal transformer and a fault transformer, the analysis results reflect the reliability of the system. The improved monitoring devices can accurately determine the gas content in transformer oil, and has major engineering significance.

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