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Analysis and Discussion on the Current Situation of SF₆ Relay Temperature Compensation Mode

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Abstract: The power industry requires regular inspection and meter reading of SF₆ gas density in circuit breakers, transformers or gas-insulated switches (GIS) filled with SF₆ gas. There is a deviation in the data copied by each operator. The general density meter has a temperature compensation device, but the current product only accurately compensates for the rated pressure value of the device, and the temperature compensation accuracy for other pressure values is poor. The technology involved in this paper is to transmit the density and temperature of SF₆ gas in the power equipment to the monitoring background in real time. According to the state equation between SF₆ gas temperature, pressure and density, the online value is dynamically compensated in real time on the software. In this paper, the key points of the technology are discussed in depth, which proves its feasibility and practicability.

1. Introduction

In the substation, SF₆ gas-filled circuit breakers, transformers or gas-insulated switches (GIS) are usually installed on-site with the SF₆ gas density meter. By patrolling the meter and recording the site temperature, it is judged whether the air pressure in the equipment is normal. This is an effective means to ensure that the equipment medium has a certain insulation strength and the equipment is leaked.

At present, the SF₆ gas density inspection and meter reading are human factors, and the data of each operation and maintenance personnel is biased. The general density meter has a temperature compensation device, but the current product only compensates accurately for the rated pressure value of the equipment. However, the accuracy of temperature compensation for other pressure values is poor, especially when the pressure value is low and the temperature is different from 20 °C. If a density meter without temperature compensation function is encountered, manual calculation is needed, and the calculation formula of manual compensation is complicated, time-consuming and labor-intensive.

Based on the above situation, the density meter for the SF₆ gas-filled electric equipment in the substation is inaccurate due to the temperature compensation. The SF₆ gas density and temperature in the electric equipment are transmitted to the monitoring background in real time according to the SF₆ gas temperature. The equation of state between pressure and density, the device that compensates the online value in real time in software, can accurately track the gas density at different temperatures without interruption. [1-4]

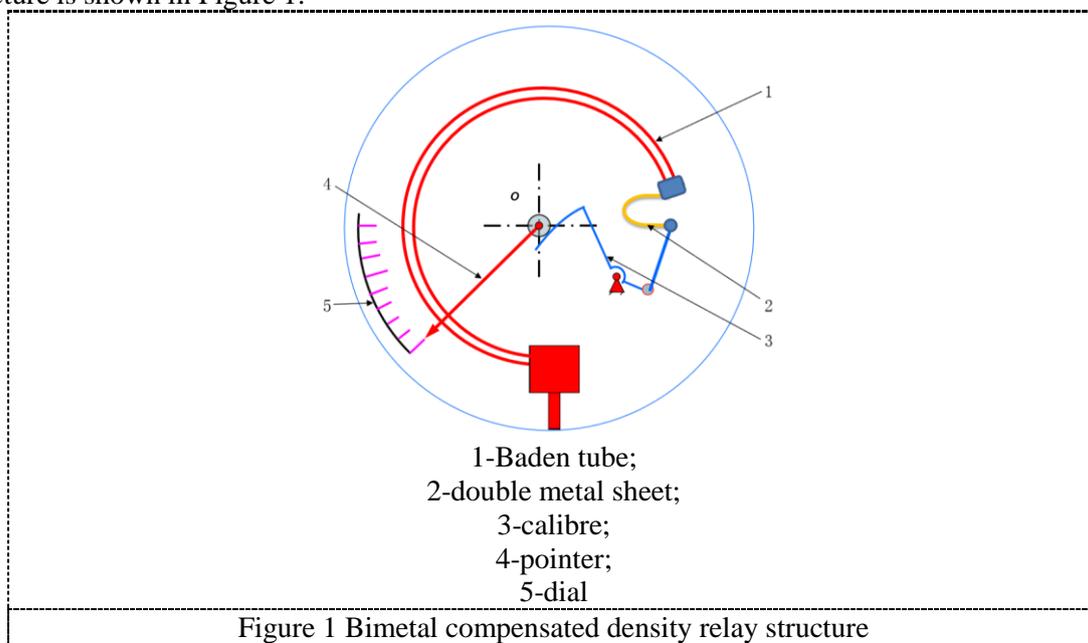


2. Analysis of current situation of SF₆ relay temperature compensation mode

According to the compensation method, in the SF₆ electrical equipment, the SF₆ gas is sealed in a fixed container, and its density is constant when there is no air leakage. In practical engineering applications, the gas density is known that the absolute pressure value at 20°C is the same as other gases, and it increases with the increase of temperature, and decreases with the decrease of temperature. In order to correlate pressure with density, the gas pressure must be temperature compensated, and the measured pressure at various temperatures is converted to a pressure at 20°C, to obtain the corresponding gas density. At present, there are usually two methods for temperature compensation of gas density relays: bimetal compensation and standard gas compensation. At present, the density relays in the grid operation are basically temperature compensated, and generally use bimetal compensation. [5-7]

2.1. Bimetal compensation

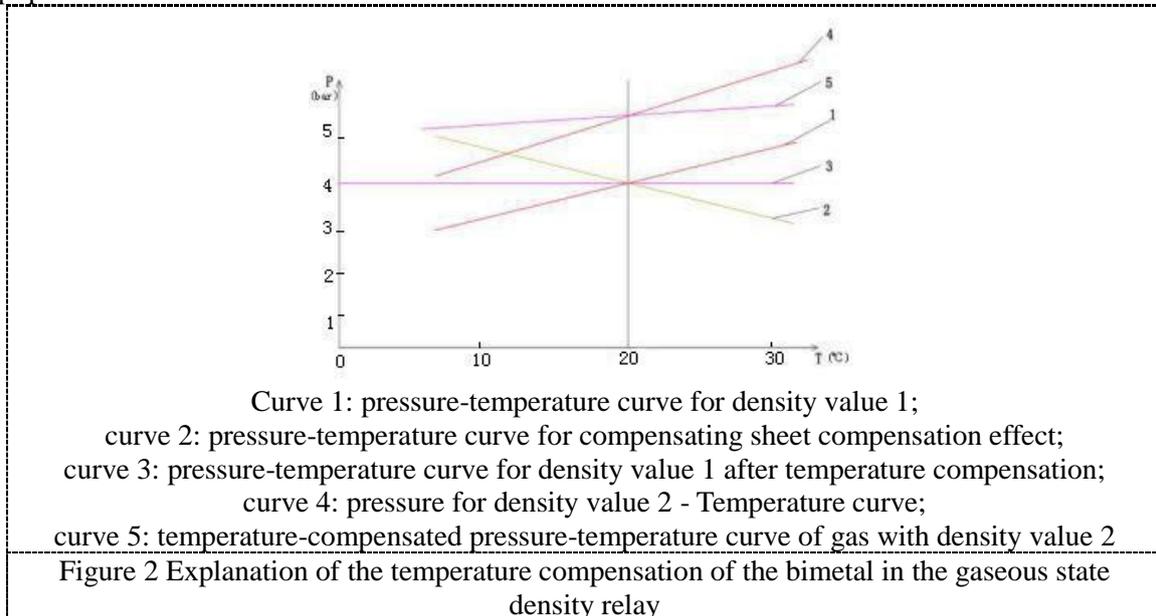
The bimetal compensated density relay generally uses a Baden tube for its pressure measuring component, a bimetal for temperature compensation, and a metal sensor for a temperature sensor. Its structure is shown in Figure 1:



The main working principle is based on the elastic pressure sensing element Baden tube, which uses bimetal (temperature compensating element) to modify the changing temperature and its pressure accordingly, so that it can reflect the change of SF₆ gas density. Specifically, as shown in Figure 2, the density of the SF₆ gas in the closed container is constant when the air is not leaking, but the pressure is increased as the temperature increases, and decreases as the temperature decreases. The actual pressure-temperature characteristic curve is shown in curve 1 of Figure 2. The function of the bimetal is to compensate the gas pressure according to the temperature change. The pressure-temperature characteristic curve of the compensation effect is shown in curve 2 of Figure 2. The pressure-temperature characteristic curve of the synthesis of the Baden tube and the bimetal (temperature compensating element) is shown in curve 3. The pressure-temperature characteristic curve after the synthesis of curve 1 and curve 2 is the curve 3 in Figure 2, and the curve 3 is the density value 1. The temperature-compensated pressure-temperature curve reflects the density value of the gas.

From the above, it can be seen that the density value of the SF₆ gas to be measured can be displayed on the dial by the Baden tube, the bimetal, the movement, and the pointer under the action of the gas pressure of the measured medium SF₆. If the air leaks and the density value drops to the

alarm or blocking value, the relay will issue a corresponding alarm or blocking signal to monitor the density of the SF₆ gas in the electrical equipment to ensure safe and reliable operation of the electrical equipment.



Usually, the density relay has only one bimetal and can only accurately compensate for gas density values within a certain range. Since the pressure-temperature curves of different density values are different, if the same compensation parameter is used at different density values, the compensation error will occur, which can be seen from curve 3 and curve 5 in Figure 2, if the temperature compensation of density value 1 is Zero deviation, then there must be a deviation in the temperature compensation of density value 2. Density relays generally use a range from rated pressure to blocking pressure, so there must be temperature compensation deviation outside the rated pressure.

When gas leakage occurs in the device, the density will decrease. Because the temperature compensation parameters are different at different densities, the bimetal compensation component is still adjusted according to the original temperature compensation parameters, causing compensation errors, resulting in compensation errors. The density relay indication value is different from the actual density in the equipment. When the actual value is less than the indicated value, the insulation of the operating equipment may be broken down, and the density relay has no alarm condition, which in turn has a greater hazard to the operating equipment.

The key factors for the temperature compensation accuracy of the bimetal compensated density relay are: (1) the matching degree between the bimetal and the Baden tube according to its pressure-temperature characteristic relationship under specific parameters. In practical applications, the matching relationship is difficult to calculate accurately. Generally, it is difficult to achieve high-precision temperature compensation through trial and error; (2) Linearity between the tube end displacement and the pressure of the Baden tube in the temperature range of use. The relationship must be selected from the excellent performance of the Baden tube; (3) in the temperature range of use, the linear relationship between the end displacement of the bimetal and the temperature, must use the excellent bimetal.

2.2. Standard gas compensation

The standard-gas compensated density relay has a complicated structure and a large volume of equipment, so it is less used in the power industry. Generally, the pressure measuring component adopts a bellows, and the temperature compensation adopts a sealed standard gas, and its structure consists of a sealed air chamber, a tube, the signal triggering mechanism, the micro switch, and the display unit.

Generally, this density relay has only one standard air chamber, which can only compensate the gas density value under the corresponding pressure, while the density relay generally uses the range from the rated pressure to the blocking pressure, so there must be temperature compensation deviation.

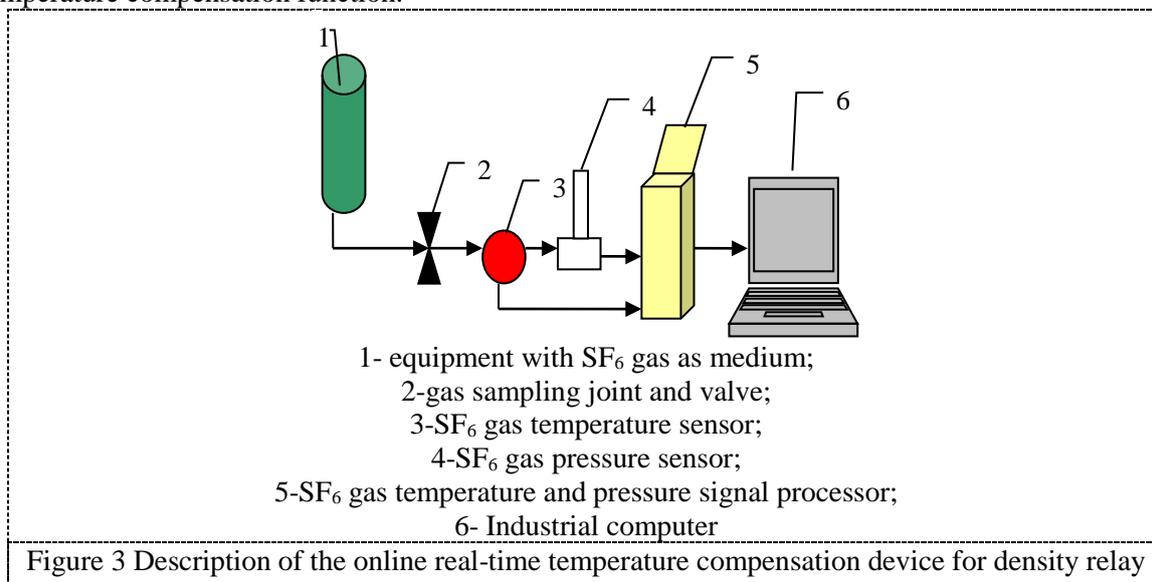
The key factors of the temperature compensation accuracy of the standard gas-compensated density relay are: (1) The accuracy of the inflation pressure of the standard air chamber, as long as it is accurately inflated, it is easy to achieve high-precision temperature compensation. (2) The sealing performance of the standard air chamber in the temperature range of use, because of this type of density relay, the process is complicated, the welding process is many; (3) the performance of the bellows in the temperature range of use; (4)The gas pressure of the standard chamber cannot be liquefied within the temperature range.

3. Discussion on online real-time temperature compensation of SF₆ relay

3.1. Feasibility of online real-time temperature compensation

The online real-time temperature compensation device can transmit the temperature and density of the SF₆ gas to the monitoring platform in real time, and the temperature compensation for density data based on real-time temperature. The current manual meter reading and compensation error are changed, the workload is reduced, and the gas density is accurately tracked.

The technical solution to solve the technical problem is: a temperature compensation device for the density of SF₆ gas in the substation is shown in Figure 3, the device is composed of equipment using SF₆ gas as medium, gas sampling joint and valve, SF₆ gas temperature Sensor, SF₆ gas pressure sensor, SF₆ gas temperature and pressure signal processor, industrial computer; SF₆ gas as the medium of the device's output port is connected to the gas sampling connector and valve, the valve is connected to the SF₆ gas temperature sensor, the temperature sensor output port The SF₆ gas pressure sensor is connected, and the temperature sensor and the pressure sensor output port are connected to the temperature and pressure signal processor through a cable, and the temperature and pressure signal processor is connected to the industrial computer for monitoring, thereby realizing the real-time temperature compensation function.



The device is used for temperature compensation of SF₆ gas density in a substation. The temperature and density value of SF₆ gas can be monitored on the circuit breaker, transformer and GIS equipment with SF₆ gas as the insulating medium in the substation, and the density value can be online. The device can compensate the density value online and store the value, so as to achieve accurate display of gas density value, observe the change of gas density, and realize the function of alarm and blocking on the monitoring platform.

3.2. Online real-time temperature compensation implementation

When the online real-time temperature compensation device of SF₆ gas density works, the SF₆ gas in the circuit breaker, transformer or GIS equipment to be monitored in the substation is connected to the SF₆ gas temperature sensor through the sampling valve and the joint, and then the SF₆ gas temperature sensor is connected. The gas is connected in series with the pressure sensor, and the temperature and pressure signals obtained in the field are transmitted to the signal processor through the cable, converted into an analog signal of 4-20 mA, and then the analog signal is connected to the industrial computer, and the temperature and pressure value of the SF₆ are respectively converted. According to the equation of state between SF₆ gas temperature, density, and pressure, the Betty-Bridgeman equation:

$$\begin{cases} P=(R*T*B-A)\rho^2+R*T*\rho \\ A=73.882\times 10^{-5}-5.132105\times 10^{-7}\rho \\ B=2.50695\times 10^{-3}-2.12283\times 10^3\rho \\ R=5.69502\times 10^{-4} \end{cases} \dots\dots(1)$$

In the formula (1): P is the absolute pressure of the gas, the unit is bar; R is a constant; T is the temperature, the unit is K; ρ is the density, the unit is kg/m³; A and B are variables related to the density ρ . Using the SF₆ temperature and pressure values measured in the field, the unique gas density value can be obtained, which is the conversion value at 20°C required by the relevant standards of the power industry, thus achieving accurate monitoring of SF₆ gas density and avoiding equipment malfunction.

3.3. Benefits of online real-time temperature compensation

The temperature compensation device of SF₆ gas density changes the current manual meter reading and manual compensation error, which greatly reduces the workload and accurately tracks the gas density to realize intelligent monitoring of electric equipment.

4. Conclusion

The author elaborates the current temperature compensation status of SF₆ gas density relay of power equipment, and proposes a device for real-time temperature compensation of SF₆ gas density, which can monitor the density of SF₆ gas in circuit breaker, transformer or GIS in real time, and temperature compensation is performed on the gas density data according to the real-time temperature, which achieves accurate tracking, avoids unplanned outage caused by equipment malfunction, and ensures safe and reliable operation of the equipment.

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