Calibration analysis of gas relay

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Abstract—Gas relay is the main protective element of transformer internal fault, which can sensitively respond to transformer short-circuit fault, core fault, internal turn to turn short-circuit of winding, insulation deterioration and oil level drop. Therefore, it is necessary to regularly compare and verify the gas relay. This paper briefly introduces the operation principle and calibration method of gas relay, analyzes in detail the reason why there is no specific standard for the calibration of gas relay setting value, and analyzes the factors affecting the flow rate setting value.

1. Introduction

In recent years, transformer tripping faults often occur due to misoperation of transformer gas protection, which reduces the reliability of power system. Because the gas protection device has high sensitivity to the fault of inter turn short circuit and internal insulation short circuit of reaction transformer winding, the cause of misoperation must be thoroughly found out in case of misoperation. However, there are no specific requirements for the calibration of the setting value of the gas relay, and whether the gas relay can operate reliably depends on the accuracy of the setting value. Therefore, the gas relay shall be verified regularly to verify whether the gas relay operates reliably under the setting value.

2. Function and calibration necessity of gas relay

Gas relay (also known as gas relay) is an important non electric quantity protection device in transformer internal fault protection. It is generally installed between transformer oil conservator and oil tank. The protection of gas relay mainly includes gas protection and heavy gas protection.

The light gas protection is mainly a fault early warning. When the equipment is running or has a slight fault, the gas decomposed in the oil rises and is injected into the gas relay. The air pressure decreases the oil level. The light gas contact is triggered and turned on to send a signal. When the gas volume in the relay is excessive, there can be a relay gas nozzle to export and release the gas.

Heavy gas protection is to start the protection element to automatically cut off the transformer when a serious fault occurs in the transformer. When a serious fault occurs in the transformer (especially the fault that other transformer protections cannot act quickly such as inter turn short circuit), the strong gas and high-temperature oil flow generated act on the gas relay, and the dry spring contact of heavy gas protection is connected to trip.

The gas relay needs to be calibrated and set before installation. Since the gas relay is not set according to the requirements of the assembled equipment when leaving the factory, it is a fixed value, and the relay body is qualified, but for the installed transformer, its technical parameters cannot be proved to be qualified; In addition, when the gas relay with the same caliber is installed on the transformer with different capacity and different cooling mode, its heavy gas parameters are different.
When installing a new gas relay, it is necessary to adjust and set the relay according to the transformer capacity and regulations. The status of gas relay shall be confirmed before installation to timely find out the problems during transportation, such as broken reed tube, reduced sealing performance, etc.

During the maintenance of transformer or reactor, the installed gas relay needs to be calibrated and set. If the gas relay does not operate for a long time, it may cause poor contact, change of heavy gas and light gas value, etc; At the same time, with the increase of operation time of gas relay, its components are aging and damaged, such as seal oil leakage, dry reed tube rupture, etc. To sum up, it is very important and necessary to carry out gas relay calibration, which is not only related to the timely detection and treatment of equipment faults, but also can cut off the faulty equipment in time, effectively avoid the further expansion of accidents and reduce the scope of accidents and major losses.

3. Type and operating principle of gas relay

3.1 types of gas relays abroad

In foreign countries, it is mainly hollow float relay, which is divided into single float relay and double float relay. The float structure (i.e. BF type double floating ball gas relay) is widely used now. The upper float acts on light gas protection and the lower float acts on heavy gas protection. As shown in Figure 1:

![Fig. 1 double float relay](image)

1 - upper float; La - lower float; 2 - upper float constant magnet; 2A - lower float constant magnet; 3 - one or two magnetic switches of the upper switch system; 3A - one or two magnetic switches of the lower switching system; 4 - frame; 5 - testing machinery; 6 - baffle

Light gas alarm function: in case of overheating, low-energy partial discharge and other general faults in the transformer, the transformer oil will be heated and decomposed to surge up, the oil level in the gas relay chamber will drop, the buoyancy acting on the upper float will be reduced, the upper float will drop, the lower float will not move, the upper float will drop and drive the action of the upper float permanent magnet, and an alarm signal will be sent when the switch system is touched. As shown in Figure 2:
When oil leakage occurs in the transformer, the oil level continues to drop. When the float moves to a certain extent, the signal is connected and the transformer is turned off, as shown in Figure 3:

Or when serious faults such as arc discharge occur in the transformer, the transformer oil is heated, decomposed and expanded, resulting in oil and air flow, impacting the lower baffle, acting on the lower float, and then the action will shut down the transformer. As shown in Figure 4:
3.2 domestic gas relay types
QJ type gas relay is mainly made in China. QJ type relay adopts open cup structure for light gas and baffle type magnetic contact structure for heavy gas. Light gas alarm function: when minor faults such as overheating and low-energy partial discharge occur in the transformer, the transformer oil is the gas generated by overheating decomposition, which floats up and concentrates on the top of the gas relay. When the gas reaches a certain volume, the oil level in the gas relay cavity drops, the buoyancy of the open cup decreases, the measuring cup sinks, and the magnet on the measuring cup also rotates and drops, then connect the reed contact and send out an alarm signal; Heavy gas protection is that when serious faults such as arc discharge occur in the transformer, the transformer oil decomposes rapidly to produce a large amount of gas, which is released to the oil conservator through the gas relay. The formed oil flow and air flow reach a certain flow rate and impact the baffle. The baffle action drives the lower magnet to connect the lower reed contact and start tripping. As shown in Figure 5:

For domestic baffle gas relay, try to explain the function of lower float of double floating ball relay, which is replaced by baffle. The action principles of the two are similar, but the baffle structure will not act when the oil level in the cavity drops. It will act only when oil flow or air flow impact is generated in case of internal fault of the transformer, so the baffle type will not misoperate in case of oil shortage of the transformer.
4. Gas relay calibration
According to the national standard, the gas relay shall be calibrated before installation, relay misoperation, refusal to operate, after maintenance and when necessary, as well as during transformer overhaul. In addition, the routine calibration cycle of gas relay shall not exceed 5 years. Before installation and routine verification items of gas relay include: appearance inspection, insulation resistance inspection, withstand voltage test, tightness verification, flow rate setting value verification, gas volume setting value verification, dry spring contact conduction verification, etc., mainly including flow rate setting value, gas volume setting value and dry spring contact conduction verification. The calibration of imported gas relay is also more than that of domestic gas relay, but this project is not required in the national standard. In addition, the type inspection also includes waterproof performance test, resistance test and reverse oil flow test.

5. Cause analysis of no specific standard for gas relay calibration
The calibration of gas relay has no specific requirements for the national standard of flow rate setting value. The value of setting value generally refers to the factory required value of the manufacturer as the reference standard for calibration and comparison of setting value. The protective effect of gas relay mainly depends on whether the setting value of gas relay meets the requirements, the specific reference value given by the load manufacturer and the installation position can effectively play a protective role. The setting value of operating flow rate is generally affected by transformer capacity, installation position, relay type, inner diameter of connecting pipe, cooling mode and local temperature change.

5.1 transformer capacity, regional climate and other factors
The capacity value classification of transformers generally includes: 1000KVA and below, 1000KVA ~ 7500kVA, 7500kVA ~ 10000kva, 10000kva and above, 200000kva and below, 200000kva and above, 500kV transformers and on load voltage regulating transformers. In general, the larger the capacity of the transformer, the more transformer oil will be required. When the oil filling time is limited, the corresponding oil filling rate will be greater. In Xinjiang, especially in mountainous Gobi, the temperature difference between day and night is large, which will lead to the thermal expansion and cold contraction of transformer oil. Under a certain temperature rise, transformer oil will expand and produce a certain flow rate of high-temperature oil flow in gas relay, which is easy to cause the error of gas relay. Moreover, under the same temperature rise, different transformer oil capacity and different expansion volume of oil will lead to different oil flow rates. The reasons are as follows:

Transformer oil expansion: oil expansion = temperature rise * oil expansion coefficient * oil volume

Taking one main transformer in 220 kV substation as an example, one main transformer in AC 220 kV substation has 51.3 tons of oil, No. 45 oil and 30 cubic meters of conservator capacity. It is natural oil circulation air-cooled cooling. The average temperature difference in summer in Turpan in 2019 is 17 degrees.

Oil expansion \(1 = 17 \times 0.0007 \times 30 = 0.357m^3 = 357l\)

Under the same climatic conditions, the oil volume of one main transformer in the adjacent 110kV substation is 20.29t, No. 45 has, and the oil conservator capacity is 10m3. It is natural oil circulation air-cooled cooling. The average temperature difference in summer in Turpan in 2019 is 17 degrees.

Oil expansion \(2 = 17 \times 0.0007 \times 10 = 0.119 m^3 = 119 L\)

In Xinjiang, the pipe diameters from 110 kV, 220 kV and 750 kV transformer oil conservator to the main body of the transformer are 80mm, so different oil flow velocities will be generated.

Similarly, for the 220 kV main transformer with the same capacity of 30 cubic meters, the temperature difference between day and night in Turpan mountain area can reach more than 20 degrees. In some areas of Northern Xinjiang such as ILI, the temperature difference between day and night is less than 10 degrees, the difference between the good expansion of variable delay oil is greater than 0.21 cubic meters, and the difference in flow rate is also very great.
5.2 Installation position and relay body mechanism factors
The gas relay is generally installed between the transformer oil conservator and the oil tank. In addition, it is also installed on the collar height seat and the on load switch. The gas relay installed on the casing riser seat has only light gas protection, while the on load switch has only heavy gas protection. Therefore, the gas relay installed on the casing riser seat does not need to calibrate the flow rate setting value. On the other hand, the relay installed on the on load switching light can provide a protection, and the setting value of action flow rate is generally 1.0 m/s. Generally, relays are divided into domestic and imported ones. Most of the imported ones are of double floating ball structure, and most of the domestic ones are baffle gas relays. Both of them have little impact on the setting value of action flow rate. The pipe diameter from 110KV, 220kV and 750kV gas relay oil conservator to transformer body in Xinjiang is 80mm.

5.3 Influence of transformer cooling mode
The cooling mode of transformer is generally divided into natural or air cooling and forced oil circulation. During forced oil circulation of transformer, slight negative pressure will be generated during the operation of submersible pump, which is easy to cause air to enter the transformer through the gap at the poorly sealed part, and finally enter the gas relay, resulting in light gas action. And the forced oil circulation cooling efficiency is higher. Under the same temperature change, it can effectively reduce the impact of temperature rise to a certain extent.

Table 1: Setting values of operating flow rate under different conditions

| Transformer capacity (kVA) | Inner diameter of connecting pipe (mm) | Cooling mode                      | Setting value of operating flow rate (m/s) |
|----------------------------|---------------------------------------|-----------------------------------|-------------------------------------------|
| 1000 and below             | 650                                   | Natural or air cooling            | 0.7~0.8                                   |
| 1000~7500                  | 650                                   | Natural or air cooling            | 0.8~1.0                                   |
| 7500-10000                 | 4>80                                  | Natural or air cooling            | 0.7~0.8                                   |
| Over 10000                 | 4>80                                  | Natural or air cooling            | 0.8~1.0                                   |
| Less than 200000           | 4>80                                  | Forced oil circulation           | 1.0~1.2                                   |
| 200000 and above           | 4>80                                  | Forced oil circulation           | 1.2~1.3                                   |
| 500kV transformer          | 4>80                                  | Forced oil circulation           | 1.3~1.4                                   |
| On load voltage regulating transformer | 4>25                 | Forced oil circulation           | 1.0                                        |

6. Conclusion
Gas relay is a very important non electric quantity protection device for transformer. The adjustment of gas relay setting value plays a key role in whether the gas relay can operate reliably. If it is too sensitive, misoperation may occur, resulting in unnecessary power failure; if the setting value is too high, it will not protect the transformer. Therefore, in order to ensure the accuracy and reliability of its protection action, it is necessary to conduct comparison and calibration tests on it regularly. The
setting value of the verified key action flow rate is different under different circumstances and
different installation positions. The detection and research of setting value is very important for the
calibration of gas relay.

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