ISSN 2706-655X Vol.5, Issue 10: 70-76, DOI: 10.25236/IJFET.2023.051011

Research on Mechanical Characteristics of Circuit Breaker Operating Mechanism under Extreme Cold Condition

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Abstract: *SF_6 gas is widely used in high voltage equipment because of its excellent arc extinguishing performance and high electric resistance.At present, 80% of the domestic production of SF_6 gas is used in the power industry, especially in the 110kV and above voltage level of power equipment, SF_6 gas plays a crucial role.Operating mechanism is the power part of SF_6 circuit breaker opening and closing operation, and directly controls the opening and closing operation of circuit breaker. Its reliable operation is very important for the correct operation of circuit breaker.In extremely cold environment, spring operating mechanism may occur short-circuit between coil turns, coil core card, open and close brake card, coil loop contact bad faults;The hydraulic spring operating mechanism may have the defects of transmission rod sticking, short circuit between coils, bad contact between coils, insufficient energy storage caused by the poor sealing of the main valve and the oil cylinder, which affect the operation of the operating mechanism.Based on this, this paper builds a circuit breaker operating mechanism under the condition of cold simulation test platform, the circuit breaker hydraulic spring operating mechanism in cold region simulation test, study the mechanical characteristic of the high voltage circuit breaker and the relationship between the environmental temperature, to obtain operating mechanism points switching curve is the key feature of the mechanical properties such as affected by temperature. The indexes and methods for evaluating the on-off characteristics of high voltage circuit breaker under low temperature are proposed.*

Keywords: *SF_6 circuit breaker, extremely cold environment, operating mechanism, on-off characteristics*

1. Study on jamming fault mechanism of SF_6 circuit breaker operating Mechanism

For a long time, the relevant research institutions at home and abroad have done a lot of work on the reliability of circuit breakers.Working Group wG13.06 of CIGRE conducted two worldwide surveys on the reliability of HV circuit breakers[1].The first survey was conducted on 77,892 circuit breakers of 63kV and above operating in 1964[2].The second survey was conducted on SF_6 circuit breakers with single voltage of 63kV and above operating from January 1978 to December 1991[3]. This survey was supported by 132 power companies in 22 countries, and 70,708 circuit breakers were investigated[4].The two surveys, conducted by CIGRE, totalled 148,600.The faults are classified as major failures (MF) and minor failures (MF) [5]. The major failures are major failures that result in the loss of basic performance of the circuit breaker and must be removed from the grid or require emergency repair[6]. The rest are minor failures.Combined with major and minor faults, the failure rate of operating mechanism is 44.5%.In the second investigation, the statistical results of circuit breaker failures are: 75% of the failures involve operating mechanism, electrical control and auxiliary circuit, because operating mechanism faults account for 64.8% of all failures, in which operating mechanism mechanical faults account for 43.8% of all failures, secondary partial faults account for 21% of all failures.Domestic fault statistics of circuit breakers show operating mechanism faults account for 66.4% of all faults.The results indicate that the failure of operating mechanism is the main cause of unplanned outage of circuit breaker, which is basically consistent with the investigation results abroad.

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In extremely cold environment, the main reason for operating mechanism sticking is that the lubricating oil between shaft and bearing is not easy to establish a layer of oil film with moderate viscosity and thickness, resulting in the decline of lubrication ability. The three-phase SF_6 circuit breaker and its operating mechanism are shown in the Figure 1.

Figure 1: SF_6 circuit breaker and operating mechanism

The reasons mainly include the following two aspects:

a) In extremely cold environment, the thermal insulation system of the mechanism is damaged, and the decrease of temperature leads to the increase of lubricating oil viscosity, thick oil film, poor flow performance, and it is not easy to cover the friction parts.

b) The sealing performance decreases in extremely cold environment, and external impurities enter the system to pollute the lubricating oil and destroy its lubrication ability.

In extremely cold environment, spring operating mechanism operating mechanism may occur coil turns short circuit, coil core card astringent, open and close switch card, coil loop contact poor faults; The hydraulic spring operating mechanism may have the defects of transmission rod sticking, short circuit between coils, bad contact between coils, insufficient energy storage caused by the poor sealing of the main valve and the oil cylinder, which affect the operation of the operating mechanism.

2. Research on the applicability of SF6 circuit breaker operating mechanism under extreme cold condition

2.1. Spring operating mechanism

Since the oil-free transformation of circuit breaker, SF_6 circuit breaker is widely used in 35kV, 110kV and 220kV circuit breakers, and its operating mechanism mostly adopts spring operating mechanism. In pneumatic operation spring, hydraulic operation spring or full operation spring, operation spring is an important part to determine the performance of SF_6 circuit breaker, its performance will directly affect the technical and safety performance of circuit breaker.Because the spring in the circuit breaker is in the compression and stretching of the variable load of work, long-term use will inevitably appear fatigue phenomenon, in the process of operation caused by spring in the opening and closing of reject and misoperation accidents and even spring fracture.In recent years, there have been many circuit breaker failures caused by deterioration of operating springs. Figure 2 is the field diagram of spring fracture. The spring fracture is divided into three sections and there are two fractures. The marked point is one of the parts of spring fracture.The fracture is roughly at an Angle of 45° to the tether shaft.The broken spring is a cylindrical compression helical spring, which is made of hot rolled round steel with 22mm steel wire diameter. The outer diameter of the spring is 200mm, the inner diameter of the spring is 154mm, and the middle diameter of the spring is 176mm. The spring has 10 turns in total, the pitch is 88mm, and the own height is 545mm.

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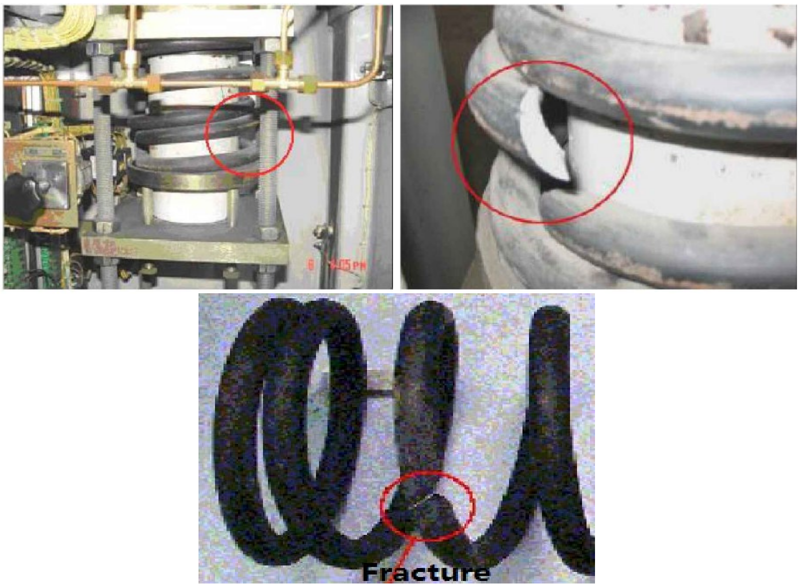

Figure 2: Overall picture of spring broken parts

There are two fractures in broken parts. One is about 2 laps away from the short end of the spring, and the port is fully matched; the other is about 3 laps away from the other end of the spring. Due to disintegration, part of the fracture is lost, and the matching on both sides of the fracture is incomplete.

a) The automatic air circuit breaker controlling the energy storage motor should be closed in the "parting" position.If the motor does not work, check whether the travel switch in the secondary circuit of the energy storage or the intermediate relay contact works normally.Motor polarity connection is opposite, should adjust the correct wiring.If the brush is damaged, it should be repaired or replaced.When the energy storage starts, the motor brush fires and causes the control switch to trip. It is necessary to check whether the terminal voltage of the motor is too high or the motor brush has poor contact. If the problem cannot be solved by cleaning the motor brush with alcohol, the energy storage motor should be replaced.

b) The control loop has wrong connection, circuit break, poor contact, etc., and the contacts and joints of the energy storage loop have problems, which should be dealt with accordingly.Contactor contact is not good, should be adjusted.Energy storage rectifier bridge is broken, the rectifier bridge should be replaced.The energy storage part of the operating mechanism has the phenomenon of blockage, poor coordination, damaged parts, etc., which should be eliminated.The travel switch is cut off prematurely, should be adjusted, and check whether the travel switch contact is burned, burned to be replaced;If the travel switch is damaged, it should be repaired or replaced.

c) The mechanical clutch is damaged and should be adjusted and repaired.Mechanical transmission is damaged, the damaged parts should be checked and repaired.

d) Such faults as motor rotation ceaseless and spring storage failure mostly occur in energy storage mechanism. It is necessary to check whether the paw-pressed spring is tired, broken or falls off first, and replace it if it is damaged.If the pressing spring is normal, use manual energy storage to see whether the bushing rotates. If the bushing does not rotate, the worm gear, worm and other parts in the gearbox are faulty, and the gearbox should be replaced.If the sleeve rotation, the manual energy storage to see whether the pawl into the CAM gap, pawl and gap contact is good, if the contact is good, continue to manual energy storage, should be normal storage can hear "click" a sound;If the contact is not good and the pawl slips, the pawl should be replaced.

e) The motor does not stop when the energy storage is completed, or the motor stops when the energy storage is not completed

Most of the reasons are the improper travel of the travel switch, which cannot or prematurely cut off the energy storage power supply. The travel should be adjusted appropriately, and if it is burned out, it will be replaced.If the electric energy storage fails to be stored or unloaded when the electric energy storage reaches one third of the stroke, but the manual energy storage succeeds, it is necessary to check whether the attached limit pressure spring of the ratchet wheel is loose, resulting in mechanical stagnation. At the same time, check whether the key in the manual and automatic energy storage clutch

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gear of the operating mechanism is cut off, otherwise it should be replaced.

2.2. Hydraulic operating mechanism

Low temperature has a great influence on the mechanical properties of hydraulic mechanism switch. If the maintenance is not well strengthened, it is difficult to ensure the safe operation of hydraulic mechanism circuit breaker in low temperature area.Low temperature environment refers to the external environment temperature below the electric heating starting temperature of the hydraulic mechanism box.The ambient temperature below +5°C is called low temperature environment.

a) Influence of low temperature on oil pressure of hydraulic mechanism

Gas state equation:

$$P_1V_1/T_1= P_1V_1/T_1=\mathrm{C} \tag{1}$$

P1, P2: nitrogen pressure of the pressure storage cylinder; V1, V2: nitrogen volume of pressure storage cylinder; T1, T2: ambient temperature; C: constant.

According to the principle of gas state equation, when the volume of nitrogen is constant, such as T1>T2, then P1>P2. Therefore, when the ambient temperature drops, the oil pressure of the non-operating hydraulic mechanism decreases correspondingly with the decrease of nitrogen pressure.Especially in jiamusi area in winter, the temperature can drop to -30°C - -40°C, the oil pressure reduction is considerable.At this time, the hydraulic pressure will be greatly lower than its rated working pressure, so it will seriously affect the performance of the circuit breaker.

b) The influence of low temperature on the speed and opening and closing of circuit breaker

The influence of low temperature on the opening and closing speed of circuit breaker is shown in three aspects: first, due to the increase of adhesion and cohesion between hydraulic oil molecules and solid wall surface at low temperature, the internal friction of hydraulic oil increases, resulting in the increase of kinematic viscosity of oil.According to experience, every drop of oil pressure 0.1mpa, circuit breaker speed is reduced about 0.02m/s, it can be seen that when the external temperature drops a lot, the circuit breaker speed will have a great impact;Second, low temperature will increase the mechanical resistance of the moving parts of the circuit breaker and affect the speed of the circuit breaker.Third, the reduction of oil pressure reduces the mechanical power of high-pressure oil to promote the working cylinder.A unit has carried out a low temperature test on the speed of DWZ-35 circuit breaker (with CD3-346 electromagnetic mechanism, spring brake), at -24°C, the rigid speed is 1.93m/S.At -30°C, the rigid parting speed is 1.73m/s.The temperature decreased by 6°C, and the hardening speed decreased by 0.2m/S.In short, with the decrease of ambient temperature, the opening and closing speed of the circuit breaker will decrease correspondingly, thus increasing the opening and closing time of the circuit breaker.

3. Test indicators of SF6 Circuit breaker operating mechanism mechanical characteristics

The operation performance of circuit breaker under low temperature condition mainly includes: opening and closing time, opening and closing synchronicity.

Operating mechanism motor, transmission parts and body should use grease, ordinary sealing ring friction resistance at low temperature is 3 ~ 4 times of normal temperature, which greatly affects the switch action characteristics.The opening and closing time can reflect the working condition of the electromagnet itself and the latch or valve controlled by the operating mechanism as well as the transmission mechanism and auxiliary contact connected with it in the operation process.Opening and closing synchronicity is an important index to measure the opening performance of circuit breakers.

4. Mechanical characteristics test analysis of SF6 circuit breaker operating mechanism

The test object is LW30-252L high-voltage AC SF_6 porcelain column circuit breaker (three-phase), equipped with CTY-10 hydraulic spring operating mechanism, and the parameters are as follows:

Rated voltage: 252kV

Rated current: 4000A

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Rated frequency: 50Hz

Rated short-circuit breaking current: 50kA

Rated short circuit switching current: 125kA

Rated short-time withstand current 4s: 50kA

Switching time: ≤30ms

Closing time: ≤90ms

Separating time: ≤60ms

Switching period: ≤2ms

Closing period: ≤4ms

Rated pressure of SF6 gas (20°C): 0.6±0.02MPa (SF6:57%;CF4 :43%)

Operating mechanism: CTY-10 hydraulic spring mechanism

The operating mechanism was placed in different low-temperature environments to carry out opening and closing tests. The temperature was initially set as -10°C, -20°C, -30°C and -40°C, and the specific temperature was determined according to the field temperature. Data were collected for 10 times in each group.

Use the circuit breaker dynamic characteristic tester to measure the closing time, opening time, synchronicity and other data. The test platform is shown in the Figure 3.

Figure 3: The test platform

4.1. Analysis of synchrony changes with temperature

The on-off three-phase synchronization curve with temperature is shown in the Figure 4.

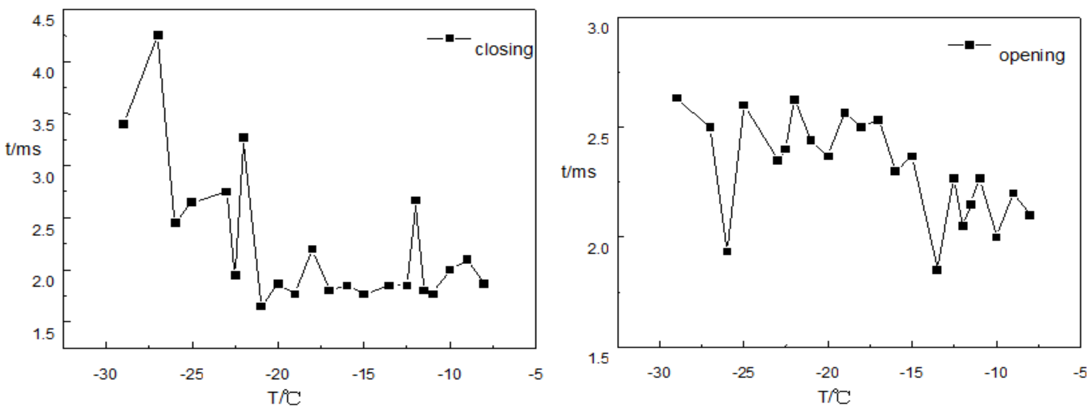

Figure 4: The on-off three-phase synchronization curve

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It can be seen that with the decrease of temperature, three-phase heterogeneity is enhanced, which may be related to the influence of low temperature on the middle B phase switch stroke.

4.2. Analysis of the changing rule of closing time with temperature

The curve of SF_6 circuit breaker closing time changing with temperature is shown in the Figure 5:

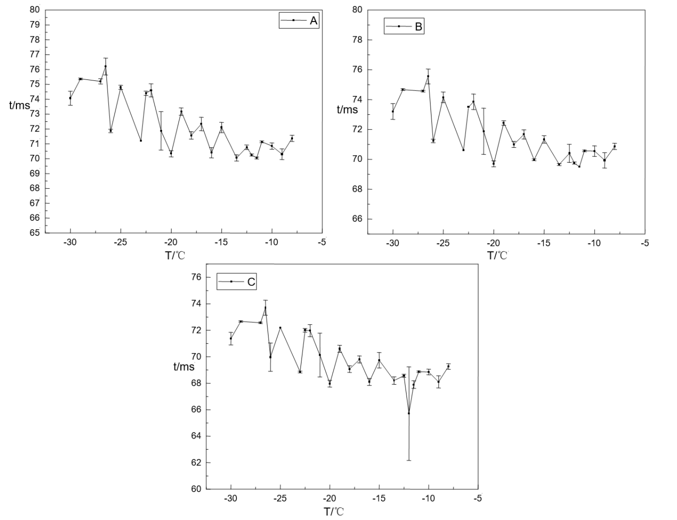

Figure 5: Circuit breaker closing time changing with temperature

As can be seen from the figure, the circuit breaker closing time increases with the decrease of temperature, which is consistent with the theoretical analysis.

4.3. Analysis of the change of opening time with temperature

The curve of SF_6 circuit breaker opening time changing with temperature is shown in the Figure 6:

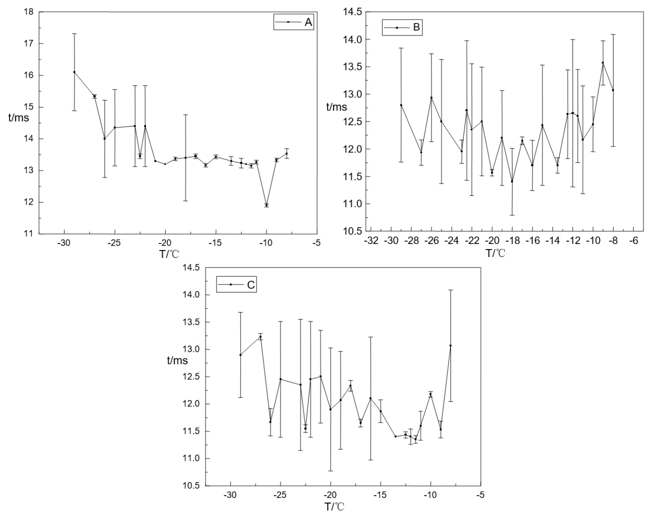

Figure 6: Circuit breaker opening time changing with temperature

As can be seen from the figure, the circuit breaker opening time increases with the decrease of temperature, which is consistent with the theoretical analysis.

5. Conclusion

In this paper, first the SF_6 circuit breaker operating mechanism unsmooth fault mechanism is researched, then the correlation analysis to low temperature adaptability is put forward, finally through a 220 kV SF_6 circuit breaker hydraulic mechanism, the closing time, three-phase synchronism with the temperature change are tested, the results show that with the decrease of temperature, the SF_6 circuit

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breaker opening、closing time and three phase heterogeneity increase, which verifies the correctness of the theoretical analysis. This paper provides data support for the mechanical characteristics analysis of SF_6 circuit breaker in extremely cold area in the future.

Acknowledgement

Thanks for the support of the Science and Technology project of State Grid Heilongjiang Electric Power Co., LTD. "Research on Key Technologies of Field Detection of High-voltage Circuit Breakers in Extremely Cold Regions", Project No. : 522437200033

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