REQUIREMENTS TO SF_6 CIRCUIT-BREAKERS IN VERY COLD CLIMATE

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SF_6 circuit-breakers are the main type of circuit-breakers for the electrical networks with voltage level of 110 kV and above. Their extensive use is determined by high dielectric and arc extinguishing properties of SF_6 gas as circuit-breaker filling medium.

Keywords: low temperature, gas pressure, gas mixture, nitrogen, freon, heating devices, test methods.

Since the early 80s, SF_6 circuit-breakers became widely used in 6-220 kW voltage classelectric power systems

INTRODUCTION

Outside circuit-breakers should be able to operate at low ambient (air) temperatures. IEC 62272-1 [1] specifies the minimum ambient temperature for outdoor circuit-breakers under normal service conditions as minus 40 °C and under special service conditions (for very cold climate) as minus 50 °C. According to the Russian standard GOST 15150 [2] the minimum ambient temperature at operation is minus 45 °C for moderate climate locations and minus 60 °C for cold climate locations. The minimum ambient temperature limit (the probability of which is lower than 0.00001) is minus 60 °C for moderate climate and minus 70 °C for cold climate.

At such low temperatures guaranteeing the performance capability of SF_6 circuit-breakers becomes a significant problem. The dielectric and arc quenching performances of SF_6 gas depend on its density which is usually characterized by the pressure at the reference temperature of +20 °C[1]. Usually before being put into service, circuit-breakers with rated voltage of 110 kV and above are filled with SF_6 gas to rated pressures within the range of 0.5–0.8 MPa; the minimum pressures (or blocking pressures) are within the range of 0.43–0.7 MPa accordingly. The ratings of circuit-breakers should be verified at the minimum SF_6 gas pressure, and all the qualification tests (according IEC – type tests) are carried out under this pressure. However at low temperatures a part of SF_6 gas condensates and its pressure falls.

Dependences of SF_6 gas pressure on temperature are given in the form of curves in the IEC standard and in the information of the manufacturers of circuit-breakers and other SF_6 equipments. The deviations in values of pressure reach up to 5%. The dependences from IEC 62271-4: 2013 [3] are given in fig.1. Since this standard does not consider the temperatures below minus 50 °C, the curves in this figure were supplemented with the data relating to the temperatures of minus [55-60 in the form of curve] °C, received from the booklet "Sulphur Hexafluoride" [Solvay Fluor, 2006]. The IEC standard gives the reference to this booklet as to the source data.

The maximum actual values of SF_6 gas pressure for the above indicated minimum temperatures from minus 40 °C to minus 60 °C can be determined from the condensation curve in fig.1. The maximum actual values of SF_6 gas pressure at the reference temperature of +20 °C can be determined from the dependence curve of pressure on temperature relating to the same condensation density of SF_6 gas.

The actual and reference pressure values are essentially lower than the pressures at which the circuit-breaker qualification (or type) tests were carried out (the interlocking pressure).

At present two methods are applied in order to guarantee the performance capability of outside circuit-breakers at low temperature conditions namely SF_6 pressure reduction and SF_6 heating for rising its temperature.

If the SF_6 pressure reduction method is applied, then the gas mixtures of SF_6+N_2 or SF_6+CF_4 with increased total pressures are used in order to keep the circuit-breaker rating characteristics [4]. The mixed gases are used principally in live tank circuit-breakers, where the heating possibilities are limited, and sometimes in dead tank circuit-breakers. At condensation the SF_6 partial pressure sets in not higher than it is indicated in Table 1 at the corresponding minimum temperature. The total mixed gas pressure is set on the level which guarantees the circuit-breaker rating characteristics. In Russian practice the pressures from 0.7 to 1.2 MPa are used for the above mentioned gas mixtures.

Unfortunately the GOST and IEC standards do not establish requirements for the test methods for mixed gas circuit-breakers. The test volume and the methods are usually set by an agreement between the circuit-breaker manufacturer and the consumer. As a rule, the manufacturers perform the qualification (or

SF_6 PRESSURE AT LOW TEMPERATURES

Temperature, °C	SF_6 pressure, MPa	
	actual	at the reference temperature +20 °C
-40 °C	0.34	0.47
-45 °C	0.29	0.39
-50 °C	0.23	0.32
-55 °C	0.17	0.23
-60 °C	0.13	0.19

Table 1

[1] Hereinafter the pressure is expressed in absolute terms at the reference temperature of +20 °C.

WIND LOAD AT LOW TEMPERATURE

Temperature, °C	-42	-50	-60
Wind speed, m/s	20	7	3

Table 2

DEPENDENCE OF PRESSURE ON TEMPERATURE FOR DIFFERENT DENSITIES OF SF_6 GAS IN CLOSED VOLUME

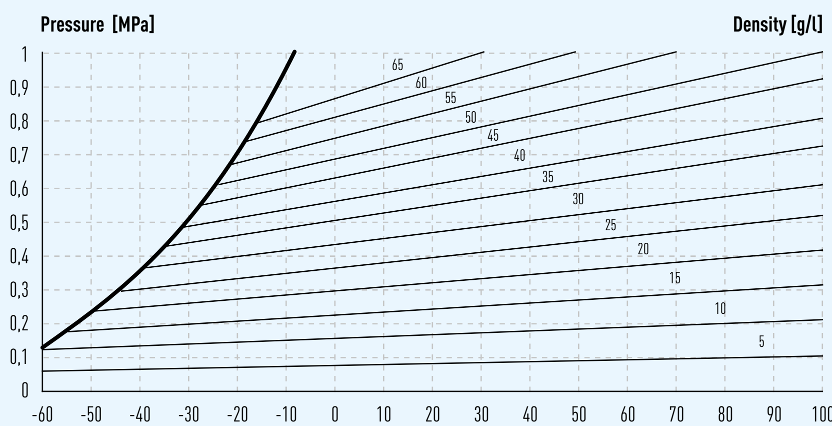

Fig. 1

type) tests of SF_6 circuit-breakers in full amount according to the GOST or IEC and additionally some rating tests are repeated with gas mixtures. The repeating of all type tests in full amount for different gas mixtures leads to significant increase in the type tests scope, complication and costs. Defining the necessary scope of type tests for mixed gas circuit-breakers the manufacturers are guided by their experiences from mixed gas applications and by Working Group CIGRE Guide [4].

Due to increase in number of the circuit-breaker types and installed pieces filled with gas-mixtures, the task of test standardization for such circuit-breakers becomes very relevant. No doubt such circuit-breakers should pass dielectric tests, short-circuit making and breaking tests in test-duties T100s and T100a, short-line fault tests, out-of-phase tests, capacitive current switching tests and switching of shunt reactor tests. When the standard for mixed gas circuit-breakers will be developed it is reasonable to consider questions about necessity of other tests including short-circuit breaking tests in the tests-duty T10, T30, T60, short-circuit making tests, mechanical tests and temperature-rise tests.

For SF_6 dead tank circuit-breakers, an effective method to ensure their performance at low temperatures is the application of electrical heating devices [8]. As a rule the heating devices are located at the lower part of circuit-breakers around the tank. A heating device should maintain the SF_6 temperature on the level that is higher than the condensation temperature. In this case, the SF_6 density remains on the level indicated by the manufacturer and it is not required to repeat the qualification (or type) dielectric tests as well as the short-circuit making and breaking test.

Choosing the heating device power, it is necessary to take into account the likelihood of the wind which substantially reduces the temperature of uncovered circuit-breaker parts together with the SF_6 gas contiguous to them. The wind speed data from different areas with cold climate have allowed to determine the plausible wind loads corresponding to different minimum temperatures.

The power of the heating devices for the circuit-breaker tanks at an ambient temperature of minus 60 °C (and with the wind load) should be very significant: from 7 to 12 kW for circuit-breakers of 110 kV and from 9 to 16 kW for circuit-breakers of 220 kV. For the SF_6 circuit-breakers of 500 kV, the power of the tank heating devices can achieve up to 18 kW. The power of the heating devices for operating mechanism cabinets or control cabinets is about 200 to 700 W.

The circuit-breaker performance in conditions of low temperatures and wind loads is checked in special climatic chambers which are able to ensure the required wind speed. Since the most distant part from the circuit-breaker heater is the SF_6 gas volume in the top part of dead tank circuit-breaker bushings, the SF6 condensation is most likely to occur exactly in this part of bushings. Therefore circuit-breakers should be tested together with installed bushings of the required insulation rating. A bushings replacement with smaller ones in order to fit the circuit-breaker into the test climate chamber is unacceptable and a test chamber size for the circuit-breakers of 330 and 500 kV should be large enough. The test procedure should give the possibility to determine or to evaluate the SF_6 gas temperature in the top part of the bushings.

The circuit-breaker heating should be switched on when the ambient temperature falls below a certain value indicated by the manufacturer. The premature switching-on of the heating can lead to temperature rise of some circuit-breaker parts above an admissible level according to GOST 8024 [5]. The thermal time constant of circuit-breaker heating system after switching-on should ensure that no condensation of the SF_6 occurs in conditions of possible sharp decrease in ambient temperature and presence the wind. According to GOST 15150 [2], the ambient temperature change can achieve up to 40 °C in 8 hours. It is expedient to establish a requirement for determining the temperature-rise time constant of circuit-breaker heating system after switching-on.

GOST R 52565 [6] and IEC 62271-100 [7] establish the permissible duration of disconnecting the supply of all circuit-breaker heating devices equals to 2 h. During this interval, occurrence of the alarm is acceptable but lock-out is not. The experience in testing circuit-breakers at very low ambient temperatures and wind loads shows that this requirement is too severe. It results in additional increase in the heating devices power which is high enough even without the requirement to allow circuit-breaker operation during the disconnection of all heating devices. This problem requires separate consideration and perhaps the adjustment of the test methods for low temperatures.

Fig. 2. Live tank SF_6 circuit-breaker. For low temperature use, it is filled with gas mixture

At very low ambient temperatures and wind loads exceeding the test loads, it is possible that the circuit-breaker performance can be guaranteed neither with the gas mixture nor with the heating devices. In these cases the circuit-breakers should be installed indoors.

RESUME

1. In order to guarantee the performance of SF_6 circuit-breakers in very cold climate conditions, the following measures are used in Russian practice:

INFORMATION

DEAD TANK GAS-INSULATED CIRCUIT BREAKERS

Dead tank gas-insulated circuit breaker are much smaller than their oil counterparts, have one common switch per 3 poles and built in power current transformers. The arc blow-out methods used in the gas-insulated circuit breakers vary depending on the rated voltage, rated breaking current and operating features of a particular location.

INFORMATION

DEAD TANK SF_6 CIRCUIT-BREAKER.

There are a few types of SF_6 circuit-breaker. By the method of the electric arc extinguishing tank SF_6 circuit-breaker are following:

– circuit pufferbreaker where the desired SF_6 mass flow through the nozzles of the compression arc control device is created in the course of the mobile part of the breaker.

– breaker with electromagnetic air blast, in which electric arc extinguishing is provided by rotation it on ring terminals under the effect of a magnetic field produced by the current shutdown.

– breaker with chamber of high and low pressure, in which the machinery of the air blast through the nozzles of the arc control device is similar to an air arc control device.

– auto generating breaker where the desired SF_6 mass flow through the nozzles of the compression arc control device is created by heating and gas pressure increasing of SF_6 gas by electric arc in a special chamber.

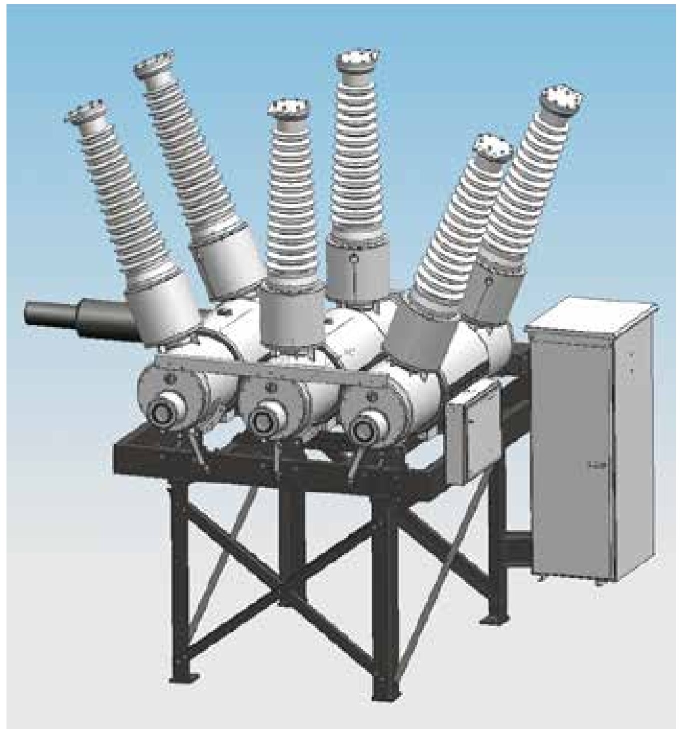

Fig. 3. Dead tank SF_6 circuit-breaker with heating devices installed on each pole tank for low temperature use

– SF_6 pressure reduction with application of gas mixtures of SF_6+N_2 or SF_6+CF_4;
– installation of electrical heating devices.

2. It is necessary to develop requirements for test methods for the SF_6 circuit-breakers filled with gas mixtures of SF_6+N_2 or SF_6+CF_4.

3. It is necessary to develop standards regulating requirements for designs and test methods for SF_6 dead tank circuit-breakers with electrical heating devices at low temperatures and wind load conditions.

4. Under very low temperatures and severe wind load conditions, it is expedient to install the SF_6 circuit-breakers indoors.

REFERENCES

1. IEC 62271-1 High voltage Switchgear and controller – Part 1: Common Specifications.
2. GOST15150-69 Machines, instruments and other industrial products. Modifications for different climatic regions. Categories, operating, storage and transportation conditions as to environment climatic aspects influence.
3. IEC 62271-4 High voltage Switchgear and controller – Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures.
4. CIGRE, Working Group 23.02, Task Force 01. Guide for SF_6 Gas Mixtures (Application and handling in electrical power equipment).
5. GOST 8024 Alternating current apparatus and devices for voltages above 1000 V. Temperature rise at continuous duty. Norms and test methods.
6. GOST R 52565 Alternating current circuit-breakers for voltages from 3 to 750 kV. General specification.
7. IEC 62271-100 High voltage Switchgear and controller – Part 100: Alternating current circuit-breakers.
8. Kovalev V.D., Borin V.N., Seryakov K.I. Method of SF_6 switching devices tests at low temperatures // Energy of Unified Grid. – 2014 #2 (13), p. 38–44.