400 kV AC substation

Outdoor AIS AC substations
High-voltage components
Circuit breakers
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1. Introduction

This standard specifies the minimum requirements for outdoor AIS circuit breakers for the 400 kV voltage level.

2. Standards and regulations

The circuit breakers shall be in compliance with the following standards and regulations.

- Outdoor AIS AC substations common conditions and technical requirements for high voltage apparatus, ETS-50-00
- IEC/EN 62271-1 ‘High-voltage switchgear and control gear’ (Common specifications)
- IEC/EN 62271-100:2001 ‘High-voltage switchgear and control gear – Part 100: High-voltage alternating current circuit breaker’
- IEC/EN 61000 ‘Electromagnetic compatibility (EMC)’
- Other standards referred to in the above standards.

3. Functional requirements

The circuit breaker shall be:

- SF$_6$ puffer type.
- Have an operation counter.

Closing of a circuit breaker shall only be possible if the circuit breaker can be opened immediately thereafter (CO-operation).

3.1 Operating mechanism

The circuit breakers shall have a spring-operated mechanism. Hydraulic or pneumatic operating mechanisms are not accepted.

The individual circuit breaker poles shall be mechanically independent.

Both the opening and the closing operation shall be spring-operated.

It shall be possible to charge the spring-operated mechanism manually in the event of power failures.

3.1.1 Motor drive

A safety switch shall be installed in the motor circuits in accordance with DS/EN 60204-1.

3.2 SF$_6$ gas

SF$_6$ gas leaks shall be ≤ 0.5% per year.

There shall be indicators showing the amount (density/ pressure) of the SF$_6$ gas in the breaking chambers and other parts of the circuit breaker. The indicators shall display absolute values of the amount (density/ pressure) of SF6 gas in the SI units bar or MPa. The indicators shall be made of UV resistant material.
The SF₆ gas monitoring system shall include an alarm and a blocking function. The blocking function shall apply to all trip circuits. Refilling of SF₆ gas shall be easy and accessible from the ground, meaning that no ladder or lift is needed in order to refill SF₆ gas or to read the SF₆ gas amount.

3.3 Insulators
The circuit breaker shall have composite insulators with soft sheds i.e. made of silicone rubber.

3.4 Circuit breaker operational modes
Each individual breaker pole shall have a local change-over switch for selection of the command location. The switch shall have three possible settings: Local – Remote – 0 (0 = blocked).
The change-over switch shall have free contact sets for remote display of the selected change-over switch position.

Each individual breaker pole shall have a clearly marked operating device for local manual opening and closing.

3.5 Closing and trip coils
There shall be one closing coil and two trip coils. The two trip coils shall be mechanically, electrically and magnetically independent of each other.

The two trip circuits shall be galvanically and physically separated. No components shall be included in both circuits. It shall be possible to connect the cables for the two trip circuits on separate terminal blocks.

An error in the circuit breaker’s control circuit, for example a permanent open/close command, shall not result in ‘pumping’ of the circuit breaker.

4. Technical requirements
In addition to breaking short-circuit currents, the circuit breakers shall also be suitable for switching of shunt reactors, filters and shunt capacitors.

4.1 Ratings
Nominal voltage: 400 kV
Nominal current: ≥3150 A
Rated short-circuit breaking current: 40 kA
Rated duration of short-circuit current: ≥ 1 second

4.2 Circuit breaker class
The circuit breaker shall be a C2 class in a System with low impedance neutral earthing (effectively earthed grid) according to IEC 62271-100 (4.107)

4.3 Rated operating sequence and Kₚₚ factor
The circuit breaker shall be able to perform one- and three-pole reclosure.
Rated operating sequence: O-t-CO-t'-CO,
Where 
  \[ t = 0.3 \text{ s.} \]
  \[ t' = 3 \text{ min.} \]

First-pole-to-clear factor: \[ K_{pp} = 1.3 \]

4.4 Break time

The rated break time as defined in IEC 62271-100 (3.7.135) shall be \( \leq 40 \text{ ms} \).

4.5 Point of wave switching (POW)

The individual poles of the circuit breaker shall have constant opening and closing times enabling POW switching.

If POW is not used, the simultaneity for the three poles shall be \( \leq 5\text{ms} \) as specified in IEC 62271-100.

4.6 Alarms

If nothing else is specified, the following alarms shall as a minimum be available from the circuit breakers.

- Alarm for motor protective switch (triped)
- Alarm for spring motor (disconnected)
- Alarm for heating (disconnected)
- Alarm for spring-operated mechanism, not charged
- Alarm for gas level (1) if the circuit breaker chamber shall be refilled ‘SF\(_6\) level 1’
- Alarm for gas level (2) in case of insufficient gas amount in the circuit breaker chamber, the circuit breaker is blocked ‘SF\(_6\) level 2’

Alarm contacts shall be NO.

4.7 Auxiliary contacts

Each circuit breaker pole shall have 8 NO and 8 NC auxiliary contacts for position indication.

Auxiliary contacts shall synchronously follow the main contact’s movement and accurately reflect its open and closed positions.

All auxiliary contacts shall be terminated in terminal blocks in the control cabinet.

The contacts shall be designed for 220 V DC \( \pm 15\% \), and the contacts shall be able to break a current \( I_n \geq 2 \text{ A} \) (\( L/R \geq 20\text{ms} \)).

4.8 Connection of measuring equipment

The circuit breaker shall be prepared with terminals for measuring operation times. This shall include the option of connecting measuring equipment to determine movement.

4.9 Physical dimensions

High-voltage 400 kV terminals shall be placed approx. 8 m above the foundation.
The individual circuit breaker poles shall not be wider than 1 m.

4.10 **High-voltage terminals**
For 400 kV high-voltage terminals, one of the following is preferred:

Plate terminals with 3x3 14 mm holes and 40 mm hole center spacing.  
See appendix 7.1 Figure 1.  
Material: Aluminum or aluminum alloy.

Plate terminals with 2x4 14 mm holes and 50 mm hole center spacing.  
See appendix 7.1 Figure 2.  
Material: Aluminum or aluminum alloy.

4.11 **Switching of shunt reactors, filters, cables and shunt capacitors**
It shall be possible to switch reactive components at a voltage 1.3 times the rated voltage.

4.12 **Control voltage**
220 V DC ± 15%.

4.13 **Control cabinets**
The control cabinet shall have one 230 V AC, 10 A socket. The socket shall be protected by a RCBO (Residual Current Breaker with Overcurrent).

All cabinets shall have an IP55 protection rating.

Each control cabinet shall be fitted with heating elements for 230 VAC, 50 Hz.  
Heating elements shall not be protected by a RCBO (Residual Current Breaker with Overcurrent).

The control cabinet shall be accessible from the ground, meaning that no ladder or lift is needed in order to work or do maintenance in the control cabinet.

5. **Design requirements**
Dynamic forces during switching shall be specified for dimensioning of rigidity and strength of foundations and supporting steel structures.  
The supplier shall state strength and rigidity requirements.

5.1 **Mechanical endurance class**
The circuit breakers shall be of the M2 mechanical class (10,000 operating cycles).

5.2 **Corrosion protection**
External parts shall be made of corrosion-resistant materials. Steel components shall be stainless or hot-dip galvanized. If surfaces are processed, they shall be protected in a permanent way. Combination of materials with different electrochemical potential shall be avoided, unless sufficiently protected from moisture.

5.3 **Earthing**
The earthing shall be constructed with two-holes for cable lugs on each frame or structure.

Cabinets of insulating material shall have a common earthing terminal to which all internal
separate metal parts shall be connected. There shall be terminals for protective earthing of control cabling.

5.4 Position indicators
The circuit breaker position shall be indicated mechanically at the circuit breaker poles or at the operation mechanisms.

5.5 Location of control cabinet and SF6 gas filling nozzle
The control cabinet and the SF6 gas refilling nozzle shall be located on the frame, with respect to the circuit breaker poles, as shown in appendix, in Figure 3 and Figure 4 in appendix 7.1.2.

5.6 Circuit breaker support
Support must be included, the dimensions of the support structure shall be compatible with the footprint shown in Figure 5 and Figure 6 in appendix 7.1.3.

6. Documentation
The circuit breaker shall be accompanied by the following documentation: data sheets for unit and equipment stating manufacture, type, description, drawings, including:

- Breaking capacity
- Current chopping and DC current breaking capacity
- Accumulated breaking capacity
- Temperature as a function of load
- Times, movement diagram
- Test certificates
- Mechanical data, strength, deflection, etc.
- Equipotential curves
- Detailed drawings
- Operating manuals
- Maintenance manuals
- Instructions for disposal
- Spare parts
7. Appendices

7.1 Appendix 1

7.1.1 Drilling plan – high voltage terminals

Figure 1: Drilling plan 3x3 14 mm holes and 40 mm hole center spacing

Figure 2: Drilling plan 2x4 14 mm holes and 50 mm hole center spacing

7.1.2 Control cabinet and filling nozzle, with respect to breaker poles

Figure 3: Top view

Figure 4: Side view
7.1.3 Foundation and footprint for circuit breaker

Figure 5: Foundation top view and footprint.

24 mm bolts are used in the foundation.