CIRCUIT-BREAKERS
245 - 420 kV

Introduction

This English text is to be regarded as a translation of the Swedish guideline. The Swedish text and the interpretation thereof shall govern the contract and the legal relations between parties.

This guideline is mainly based on Swedish Standard SS-EN 62271-100. This guideline specifies appropriate choices when multiple alternatives are available. The guideline also contains additions and clarifications of the standard. The guideline specifies the requirements which, together with the applicable standard, are valid for the design and testing of circuit-breakers for rated voltages 245 - 420 kV.

The guideline is, in relevant parts, also applicable for by-pass switches for series capacitors.
<table>
<thead>
<tr>
<th>Revision</th>
<th>Change notes</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Changed test voltage for 82.5kV from 325kV to 380kV in section 4 ratings.</td>
<td>2010-03-03</td>
</tr>
<tr>
<td>4</td>
<td>General changes, mainly in chapters 5 and 9. Insulator test removed.</td>
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</tr>
<tr>
<td>5</td>
<td>This edition applies only to 245-420 kV. Porcelain insulator removed and only composite accepted. General text clarifications. Breaking time changed. Appendix 4 current controlled switching changed.</td>
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</tr>
<tr>
<td>6</td>
<td>General changes, mainly in chapters 8 and 9. Chapter 5.1 and 5.3, old requirement only allowing N₂ as gas mixture has been changed. Bolt as a HV terminal removed. Old Appendices 2, 3 and 6 removed. New Appendix 3.</td>
<td>2017-10-02</td>
</tr>
</tbody>
</table>
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1 General

1.1 Applicable standards
Applicable Swedish Standards are valid. When there is no Swedish Standard, European Standards (EN) and IEC Publications shall apply. The latest edition shall be applied.

Where circuit-breakers offered do not in every detail fulfil the stipulated standards and applicable additions from guidelines, deviations shall be specified.

Applicable standards and guidelines:

SS 401 03 10 Switchgear, controlgear and fuses - Vocabulary
SS-EN 62271-1 Common specifications for high-voltage switchgear and controlgear standards
SS-EN 62271-4 High-voltage switchgear and controlgear - Part 4: Handling procedures for sulphur hexafluoride (SF6) and its mixtures
SS-EN 62271-100 High-voltage switchgear and controlgear - Part 100: High-voltage alternating-current circuit-breaker and other applicable parts
SS-EN62271-102 High-voltage switchgear and controlgear - Part 102: High-voltage alternating-current disconnectors and earthing switches
SS-EN62271-108 High-voltage switchgear and controlgear - Part 108: High-voltage alternating-current disconnecting circuit-breakers for rated voltages of 72.5 kV and above
SS-EN 62271-109 High-voltage switchgear and controlgear - Part 109: Alternating-current series capacitor by-pass switches
SS-EN 62271-110 High-voltage switchgear and controlgear – Part 110: Inductive load switching
SS-EN 62271-203  High-voltage switchgear and controlgear - Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV

IEC TR 62271-302  High voltage switchgear and controlgear – Part 302: Alternating current circuit-breakers with intentionally non-simultaneous pole operation

IEC TR 62271-310  High voltage switchgear and controlgear – Part 310: Electrical endurance testing for circuit-breakers of rated voltage 52 kV and above

SS-EN 60529  Degrees of protection provided by enclosures (IP code)

SS-EN ISO 1461  Hot dip galvanized coatings on fabricated iron and steel articles

SS-EN ISO 10684  Fasteners - Hot dip galvanized coatings

SS-EN 10250-4  Open die steel forgings for general engineering purposes – Part 4: Stainless steel

SS 421 01 67  Design of outdoor substations - Wind and ice loads

IEC TS 60815-1  Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles

IEC TS 60815-3  Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems

SS-EN 60059  IEC standard current ratings

SS-EN 61462  Composite insulators – Hollow insulators for use in outdoor and indoor electrical equipment

RN 1978  Standard for tubes

AFS 2016:2  Arbetsmiljöverkets föreskrifter om enkla tryckkärl (National Board of Occupational Safety and Health. Ordinance concerning Simple Pressure Vessels)

AFS 2016:1  Arbetsmiljöverkets föreskrifter om tryckbärande anordningar (National Board of Occupational Safety and Health. Ordinance concerning Pressurized devices)
AFS 2005:2  Arbetsmiljöverkets föreskrifter om tillverkning av behållare, rörledningar och anläggningar (National Board of Occupational Safety and Health. Manufacturing concerning Pressurized devices)

AFS 2005:3  Arbetsmiljöverkets föreskrifter om besiktning av trycksatta anordningar (National Board of Occupational Safety and Health. Testing concerning Pressurized devices)

SS-EN 50052  High voltage switchgear and controlgear – Gas filled cast aluminium alloy enclosures

SS-EN 50064  Wrought aluminium and aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear

SS-EN 50068  Wrought steel enclosures for gas-filled high-voltage switchgear and controlgear

SS-EN 50069  Welded composite enclosures of cast and wrought aluminium alloys for gas-filled high-voltage switchgear and controlgear

SMS 1645  Pressure gauges. Needle valves. Male ends and flange for testing connection PN 64

SMS 1647  Pressure gauges. Needle valves. Male ends and flange for testing connection PN 160
2 Service conditions

2.1 Ambient temperature
It shall be stated at which conditions the breaker shall be installed on site and which temperature interval that is applicable. For indoor installation +40 °C to -25 °C is stated. In normally heated rooms -5 °C can be accepted as lower limit.

For outdoor installation a lowest ambient temperature of -40 °C is stated in south and central Sweden and -50 °C in the north of Sweden. The highest ambient temperature for outdoor installation is +40 °C.

2.2 Ice and Wind
For outdoor installation ice thickness class 20 mm shall apply i.e. the circuit-breaker shall be possible to operate with a layer of 20 mm of ice.

For normal applications, a wind pressure of 700 Pa against a cylindrical surface shall apply. This corresponds to a wind velocity of 34 m/s. For equipment at exposed locations, e.g. coastal or mountain areas, a higher wind pressure might be necessary. Dimensioning shall then be done with a wind pressure in accordance with SS 421 01 67.

2.3 Pollution
For installations in a dirty and/or salty environment, reinforced requirements for corrosion protection and creep distance of insulators will be specified. See sections 5.5 and 5.6.

3 Definitions
Definitions are specified in applicable standards.

4 Ratings
The ratings specified in this clause are not applicable for series capacitor by-pass switches. The ratings for such switches are project-specific and may vary from case to
case. Examples are given in SS-EN 62271-109. Ratings for by-pass switches shall be specified in the request for tender.

### 4.1 Rated insulation level

#### 4.1.1 Circuit-breakers in air-insulated substations

For circuit-breakers in air-insulated substations, the following insulation levels shall be used:

<table>
<thead>
<tr>
<th>Rated voltage kV (r.m.s.)</th>
<th>Rated short duration power frequency withstand voltage kV (r.m.s)</th>
<th>Rated lightning impulse withstand voltage kV (peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>to earth, between phases and over open pole</td>
<td>across isolating distance</td>
<td>to earth, between phases and over open pole</td>
</tr>
<tr>
<td>245</td>
<td>395</td>
<td>460</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rated voltage kV (r.m.s.)</th>
<th>Rated short duration power frequency withstand voltage kV (r.m.s)</th>
<th>Rated switching impulse withstand voltage kV (peak)</th>
<th>Rated lightning impulse withstand voltage kV (peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>phase to earth</td>
<td>across open pole and isolating distance</td>
<td>phase to earth and open pole</td>
<td>across isolating distance</td>
</tr>
<tr>
<td>420</td>
<td>520</td>
<td>610</td>
<td>1050</td>
</tr>
</tbody>
</table>

For details on the values within brackets see SS-EN 62271-1, Table 2a.

For the rated voltage 420 kV the rated switching impulse withstand voltage (peak) between phases is 1575 kV.
4.1.2 Circuit-breaker in gas-insulated switchgear

The following insulation levels shall be used for circuit-breakers in GIS:

<table>
<thead>
<tr>
<th>Rated voltage kV (r.m.s.)</th>
<th>Rated short duration power frequency withstand voltage kV (r.m.s)</th>
<th>Rated lightning impulse withstand voltage kV (peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>to earth, between phases and over open pole</td>
<td>to earth, between phases and over open pole</td>
</tr>
<tr>
<td></td>
<td>across isolating distance</td>
<td>across isolating distance</td>
</tr>
<tr>
<td>245</td>
<td>460</td>
<td>530</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1050</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1200</td>
</tr>
</tbody>
</table>

For details on the values within brackets see SS-EN 62271-203, Table 3.

For the rated voltage 420 kV the rated switching impulse withstand voltage (peak) between phases is 1575 kV.

4.2 Rated frequency

The rated frequency is 50 Hz.

4.3 Rated current

The rated current should preferably be chosen from the following values from the R10 series in SS-EN 60059: 2000, 2500, 3150, 4000 A.

4.4 Rated duration of short-circuit

The rated duration of short-circuit for circuit-breakers is 1 s.

4.5 Rated short-circuit breaking current

The rated short-circuit breaking current shall be chosen from the R10 series in SS-EN 60059. One of the following values should preferably be chosen:

31.5, 40, 50, 63 kA
4.5.1 DC component of the rated short-circuit breaking current

The dc component shall be determined in accordance with SS-EN 62271-100 § 4.101.2. Normally the time constant is 45 ms but for circuit-breakers near generation a higher value on the time constant may be necessary. In this case a time constant 60 ms should preferably be used.

4.5.2 Transient recovery voltage

In most cases the values specified in SS-EN 62271-100, § 4.102.3 and § 6.104.5 are sufficient and shall be verified by the manufacturer in accordance with section 9.2.

For certain circuit-breakers connected to the low voltage side of transformers, it may be necessary to specify higher values, especially in case of extra high short-circuit currents. These values will then be specified in the request for tender.

4.6 Rated operating sequence

The rated operating sequence shall be:

O - 0.3s – CO - 1 min - CO

For some circuit-breakers, for instance series capacitor by-pass switches, other operating sequences may be needed. These will then be specified in the request for tender. For circuit-breakers with operating device driven by compressed air or hydraulic the recovery time between a finished operating sequence and a new CO shall be stated by the manufacturer in the list of data in accordance with section 9.2.

4.7 Capacitive current switching

Circuit-breakers intended for switching of capacitive currents shall be of class C2 i.e. with very low probability for restrikes.

4.7.1 Rated breaking current, line at no load

Tests shall normally be performed with values in accordance with SS-EN 62271-100 § 4.107 table 9.

If the line length exceeds 300 km, the following values shall be used for the currents (will be specified in the request for tender):

<table>
<thead>
<tr>
<th>Rated Voltage [kV]</th>
<th>Breaking current [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td>245</td>
<td>250</td>
</tr>
<tr>
<td>420</td>
<td>650</td>
</tr>
</tbody>
</table>

Note: In accordance with SS-EN 62271-100 § 6.111.7 the test voltage at a single-phase test shall just before opening not be less than \( U_r / \sqrt{3} \times k_c \) where \( k_c \) is 1.4 for applications in solidly earthed networks.
4.7.2 Rated breaking current, cable at no load
Switching of cables at no load shall be tested. The tests shall be performed with values in accordance with SS-EN 62271-100 § 4.107 table 9 or a higher value of the current if applicable.

4.7.3 Switching of capacitors
The tests of capacitor breakers shall verify the capacity to switch both single and back-to-back capacitor banks. Tests shall be performed with values in accordance with SS-EN 62271-100 § 4.107 table 9 or a higher value of current if applicable. Values for the closing current can be determined with help of SS-EN 62271-100 Annex H.

The rated inrush current shall be 20 kA peak with a frequency of 4.25 kHz. Higher values can be needed in specific cases, for instance at by-pass breakers for series capacitors. See SS-EN 62271-109. The inrush current may be reduced with help of a reactor or with point-on-wave closing. If a reduction of the inrush current is carried by means of controlled point-on-wave switching, the circuit-breaker shall be dimensioned for values without any inrush current reduction.

Specific requirements on the circuit-breaker at point-on-wave closing and the corresponding test are explained in appendix 2.

4.8 Inductive current switching
Testing of circuit-breakers that are used to shunt reactor currents shall be carried out in accordance with SS-EN 62271-110.

Grid disturbances and voltage dips when switching shunt reactors and transformers can be reduced by point-on-wave controllers. Point-on-wave controllers shall be installed for all reactors, power transformers and capacitor banks. For more information see TR02-03-1, subparagraph Brytarsynkroniseringsdon.

For information on power quality requirements see documents TR06. Specific requirements on circuit-breakers with point-on-wave controllers are specified in appendix 2.

4.9 Break time
The rated break time shall not exceed 45 ms.

4.10 Mechanical capability
Circuit-breakers shall be of mechanical class M1 (2000 operating sequences) unless specified otherwise. Circuit-breakers used for switching shunt reactors and capacitor banks, as well as all disconnecting circuit-breakers, shall be of mechanical class M2 (10 000 operating sequences).
4.11 Electrical capability
Circuit-breakers shall be of class E1.

4.12 Tightness
Circuit-breakers containing fluorinated greenhouse gases shall not have a leak rate exceeding 0.5 % per year.

5 Circuit-breaker design

5.1 General
For environmental reasons, circuit-breakers containing fluorinated greenhouse gases may only be applied if there are no acceptable alternatives available.

Reaction forces at operation and permissible oscillations in the supporting structure shall be stated for dimensioning of the foundation and the supporting frame.

5.2 Indications
The circuit-breaker’s position shall be indicated mechanically at the breaker’s poles, linkages or operating mechanism. The position indicator shall be easy to read during operation.

As indication of position, the circuit-breaker’s end positions shall be indicated. For labelling see section 7.1.

5.3 Gas and gas-monitoring
Gas weights shall be reported for the complete circuit-breaker. For all gases the first filling shall be included in the circuit-breaker delivery.

Circuit-breakers containing gas shall be monitored for low density level by means of density meters with a closing contact function at two levels (filling, blocking). The gas density shall be indicated on a gauge.

It shall be possible to install and maintain gas-filled circuit-breakers in such a way that the risk of release of gas(es) to the atmosphere is minimized.

Circuit-breakers containing gas shall be designed so that topping up of gas can be performed in a safe way for the personnel with the breaker in operation.

Equipment containing fluorinated greenhouse gases shall be labelled according to EU-regulations.
5.4 Rating plates
Rating plates shall have text written in Swedish and shall be positioned outside. Rating plates can be placed separately on the circuit-breaker and operating mechanism or be combined where the two form one unit.

The highest tested values of the circuit-breaker regarding rated current and rated short-circuit breaking current shall be stated on the rating plate even if a lower value has been indicated in the request for tender.

Besides the mandatory data, the rated pressure for gas and liquid shall be stated at breaker and operating mechanism plates.

On the operating mechanism the voltage and frequency for the circuits in the mechanism (control and auxiliary circuits) shall be stated.

5.5 Protection against corrosion
External parts shall be made of a corrosion resistant material. Steel shall be stainless or hot-dip galvanized (SS-EN ISO 1461). Machined surfaces may be protected in another permanent way.

Internal parts are considered satisfactory protected if they are painted or coated with grease.

Circuit-breaker parts subjected to crevice corrosion shall have a reinforced corrosion protection.

For circuit-breakers installed in a corrosive atmosphere reinforced corrosion protection may be necessary. This shall then be stated in the request for tender.

Pre-treatment and surface protection of steel support structures shall meet the requirements given in TR01-01, clause T.4.3.1.

5.6 Insulators
All circuit-breakers and disconnecting circuit-breakers shall be equipped with composite insulators. Breaking chambers should be designed in such a way that damage on the insulator as a result of an inner over-pressure is avoided.

Composite insulators shall be of grey colour. Composite insulators shall be designed and tested in accordance with applicable standards and SS-EN 61462. The outer insulation material of composite insulators shall be made of silicon rubber. In cases when the insulator tube is reinforced with glass fibre residue products from the SF6-gas may damage the glass fibre. In such cases the inside of the tube shall be equipped with a protective layer or must otherwise be protected from damage from any SF6-gas residue.
Composite insulators with an integrated optic fibre shall be designed and tested according to the same standards as applies to regular composite insulators. The optic fibre must not have any negative impact on the isolating properties or any other properties of the insulator. All testing of the circuit-breaker shall be carried out with the optical fibre fitted in the same manner as in the finished product. The function of the optical fibre shall be verified after every test that may influence the fibre optical properties.

In a normally polluted environment a creepage distance of Site Pollution Severity (SPS) class b is required and for polluted environments class d is required. Classes are specified in IEC 60815-1. Areas near (approx. 30 km) the coast line in western Sweden as well as the valley along Götaälven river up to lake Vänern are considered to be a polluted environment. For some exposed locations an increased creepage distance may be required. This additional request shall then be specified in the request for tender.

Breaking chamber insulators on disconnecting circuit-breakers shall have an extended creepage distance according to SPS class d.

The specified creepage distances are based on the relationship between creepage distance and pollution level as shown in the figure 1 of the standard IEC 60815-3.

The required creepage distances for vertical insulators and breaking chamber insulators without grading capacitors in normal and polluted environments are specified in the table below:

<table>
<thead>
<tr>
<th>Rated voltage (kV)</th>
<th>Min. creepage distance (mm)</th>
<th>Polluted environment (class d)</th>
<th>Normal environment (class b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>245</td>
<td>6120</td>
<td>3920</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>10500</td>
<td>6720</td>
<td></td>
</tr>
</tbody>
</table>

1) According to IEC 60815-1

The required creepage distances for horizontal breaking chambers with grading capacitors or switching resistors are listed in the table below:

<table>
<thead>
<tr>
<th>Rated voltage (kV)</th>
<th>Min. creepage distance (mm)</th>
<th>Polluted environment (class e)</th>
<th>Normal environment (class c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>245</td>
<td>7590</td>
<td>4900</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>13020</td>
<td>8400</td>
<td></td>
</tr>
</tbody>
</table>

1) Based on SPS class e, 53.7 mm/kV, and SPS class c, 34.7 mm/kV (phase/earth) respectively.
5.7 HV Terminals

Circuit-breakers with one interrupter chamber per pole shall be possible to connect in two opposite directions.

The H.V. terminals shall consist of a plate. If the connection plate has a thickness of less than the required thickness “e” from Appendix 1 the suitability of the plate shall be verified through a temperature-rise test. The high voltage terminal shall be designed as one plate without additional parts. Dimensions of the terminals are shown in Appendix 1.

Terminals of copper or copper alloy shall be tin-plated with a layer of minimum 50 μm or alternatively silver-plated with a layer of minimum 20 μm. Any copper alloy sensitive to stress corrosion shall not be used.

Terminals made of aluminium or aluminium alloy shall not be surface treated. An aluminium alloy sensitive to stress corrosion, layer corrosion or intercrystalline corrosion shall not be used. Terminal plate of aluminium or aluminium alloy shall have a hardness of min H-hardness 75.

Terminal plates are selected on the basis of rated current for the circuit-breaker as follows:

<table>
<thead>
<tr>
<th>Rated current of circuit-breaker (A)</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 - 3150</td>
<td>9 - 125</td>
</tr>
<tr>
<td>4000</td>
<td>12 - 165 *)</td>
</tr>
</tbody>
</table>

*) Terminal plate 9 - 125 may be chosen if the manufacturer by temperature-rise test can show that the permitted rise of temperature will not be exceeded at loads up to 4000 A.

5.8 Pole arrangement

The following pole distance shall be used unless otherwise is specified:

<table>
<thead>
<tr>
<th>Rated voltage (kV)</th>
<th>Distance (c/c) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>245</td>
<td>3500</td>
</tr>
<tr>
<td>420</td>
<td>5500</td>
</tr>
</tbody>
</table>

In cases when the steel support is included in the circuit-breaker delivery the support height should be selected such that the distance from ground surface level to the lowest part of the insulating material of the insulator is min. 2500 mm.

The distance from ground surface level to the lowest part of the breaking chamber shall be minimum 7000 mm for 420 kV circuit-breakers. The distance from ground...
surface level to the lowest edge of the upper HV terminal shall be minimum 5600 mm for 245 kV circuit-breakers.

In substations where large amounts of snow can be expected or due to other constructional requirements the previously mentioned distances may have to be increased to a value that will be specified in the request for tender.

5.9 **Earthing.**

The earthing terminal shall be designed for cable lugs with two holes.

5.10 **Condition check**

It shall be possible to perform a condition check on a circuit-breaker on-line by carrying out a small number of OC-operations. The condition check shall at least include the measurement of operating times, contact travel, contact speed, as well as coil and motor currents.

The manufacturer shall propose and describe a complete condition check method. For this purpose, auxiliary position transducers and fixed or temporary movement transducers may be used. It shall be possible to connect the measurement equipment to the standard function testing equipment used.

The circuit-breaker documentation shall include a detailed description of the condition check method. The description shall include interface and details of any adjustments. The factory routine tests should include the function of the condition checking equipment. The routine test protocols shall, besides the conventional tests results according to the IEC, include the results from the condition checking equipment. Nominal values and permitted tolerances shall be given for both a new and aged circuit-breaker.

5.11 **Special requirements for disconnecting circuit-breakers**

Disconnecting circuit-breakers shall be designed and tested in accordance with SS-EN 62271-108 and SS-EN 62271-102.

Disconnecting circuit-breakers shall not have grading capacitors or resistors in parallel with the breaking chamber.

Disconnecting circuit-breakers shall be equipped with composite insulators.

The creepage distance across the open pole shall, regardless of pollution level, fulfil the requirements for insulators in a polluted environment (class d) according to §5.6.
There are severe requirements on reliability for disconnecting circuit-breakers including the interlocking device and the position indicators. For information on testing see SS-EN 62271-102 and SS-EN 62271-108.

The combined test according to SS-EN 62271-108, §6.114 shall preferably be carried out in one sequence according to the test procedure described in figure 4 of the abovementioned standard. However, the test procedure according to figure 3 where the test is carried out in two separate sequences is also acceptable.

For disconnecting circuit-breakers local electrical operation of the operating mechanism and the blocking device for closing or opening is not allowed.

5.11.1 General requirement for interlocking and blocking system
It shall be possible to electrically control the blocking device remotely.

It shall be possible to mechanically lock the circuit-breaker in its OPEN position (see sub-clause 5.11.2).

When the blocking system is activated, electrical operation of the breaker shall be prevented by disconnecting all closing circuits.

It shall, furthermore, be possible to mechanically operate the blocking device locally. The motor circuit, or its equivalent, shall be automatically disconnected before local operation is made possible.

The blocked position shall be clearly indicated and visible from outside the control cubicle and signed “BLOCKERAD” with white letters on a green background. See also sub-clause 7.5.

It shall be possible to lock the blocking device with a padlock according to the user’s standard (see sub-clause 6.1.1). (Note that, according to Swedish Electric Safety Regulations, ESA, the disconnecting circuit-breaker is not blocked until the control voltage to the blocking device is disconnected and a padlock with sign has been fitted.)

In cases when an earthing switch is integrated, additional requirements may be applicable.

5.11.2 Mechanical blocking of closing operation
It shall be possible to mechanically lock the circuit-breaker in its OPEN position by a reliable mechanical blocking of the breaker’s power kinematic chain. The blocking device shall be able to withstand the forces released by the operation of a blocked breaker. In addition to the tests of the kinematic chain specified in SS-EN 62271-102 five attempts to operate a blocked breaker shall be made as a type test with maximum mechanical loading.
5.11.3 Design
The same requirements as for circuit-breaker operating mechanism apply to the blocking device and its peripherals regarding the design and performance.

The blocking device shall have a rating plate with minimum the following data stated: manufacturer, type identification, serial number and year of manufacturing.

At least two auxiliary closing contacts which can indicate the blocked position shall be available.

5.11.4 Power-frequency voltage test of open pole at reduced gas pressure
For gas filled disconnecting circuit-breakers a type test shall be performed with power-frequency voltage stress across open pole. The gas density in the disconnecting circuit-breaker shall be 0.1 MPa abs at 20 °C (corresponding to atmospheric pressure), the power frequency voltage shall be \( \frac{U_r}{\sqrt{3}} \) where \( U_r \) is the rated voltage, and the voltage shall be applied for 1 h. No voltage collapse shall occur.

5.12 Maintenance
The manufacturer shall state the need for maintenance as a function of several parameters. The parameters are: time, rated operation current, fault currents, number of operations and environment. Lifetime, intervals of overhaul, needed auxiliary devices, spare parts and needed time for overhaul shall also be specified.

Standard materials shall be available in Swedish specialist shops.

6 Design of operating device

6.1 Mechanical design

6.1.1 General
The vital parts shall be easily accessible for inspection and service.

The enclosure shall be easy to dismantle and shall have at least one easy-to-open door, which in outdoor application shall be lockable with a padlock which shackle has a diameter between 5 - 6 mm. Opening and closing of the door shall be possible by a single permanently attached hand-grip which is easily accessible.
6.1.2 Degrees of protection
The operating mechanism shall have an enclosure with a degree of protection of at least IP54 in accordance with SS-EN 60529. For indoor installations the degree of protection shall be at least IP51.

The enclosure for the operating mechanism shall be ventilated and the ventilation openings shall be covered with a densely meshed wire netting or similar.

6.1.3 Earthing
The metal enclosure shall be provided with an outer terminal for protective earthing.

Enclosure made of insulating material shall be provided with a similar terminal to which all separate metal internal parts shall be connected.

On the inside of the enclosure there shall be a connection for protective grounding of cable sheaths.

6.1.4 Device for slow close and open operation
Any device for slow closing and opening operation shall be of self-restricting design. The device shall have sufficient mechanic strength for safe operation.

6.2 Electrical design
6.2.1 General
Control and motor circuits shall, if nothing else is specified, be designed for DC, 110 V or 220 V. Heating circuits shall be designed for 230 V, 50 Hz.

Live part near device for service shall be protected against unintentional contact.

Auxiliary contacts shall be easily accessible for connection, inspection and adjustment.

Components shall be provided with special markings for identification on electrical circuit diagrams. Terminals shall be marked clearly and durable.

Connecting cables inside the operating mechanism shall have a minimum cross section of 1.5 mm² and be marked clearly and durably at both ends.

Contact parts and screws shall be corrosion resistant.

6.2.2 Function
Circuit-breakers shall be designed for electrical closing (TILL) and opening (FRÅN) by remote control. Local operation is not permitted for either opening or closing.

The electrical connections shall be so arranged that started operations are completed irrespective of the duration of the operating impulse. Started operation shall be
completed even if a reverse impulse is given. An impulse with a duration > 50 ms shall start the operation. Relays shall be designed for continuous connection.

Motor circuit shall be designed for plus and minus operation from motor relays, protection devices and possible contactor.

6.2.3 Alarms
Gas-filled circuit-breakers shall have an alarm for low gas density, 2 levels in accordance to sub-clause 5.3.

Auxiliary relay shall by a closing contact, give alarm at:

- No motor voltage
- Motor protection trip
- Loss of anti-corrosion heater (only by current sensing alarm)
- Any additional heater (alarm function shall be verified by low temperature test)
- Operating voltage turned-off

From motor spring type mechanism:

- Spring not fully charged
- Alarm after motor protection trip

From compressed air type operating mechanism:

- High pressure
- Not full pressure
- Long operating time for internal compressor

From hydraulic type operating mechanism:

- High pressure
- Not full pressure in high pressure system
- Long operating time for hydraulic pump

Monitoring of any additional functions in the operating device shall be connected to one of the existing alarms above.

6.2.4 Auxiliary contacts
Auxiliary contacts shall synchronously follow the breaker's contacts movement and accurately reflect its open and closed positions.

The following number of contacts shall be provided:
- For anti-pumping relay:
  - One closed contact at closed circuit-breaker

- For indication of breaker position:
  - Two closed contacts at closed circuit-breaker
  - Two closed contacts at open circuit-breaker

- For relay protection etc.:
  - Two closed contacts at closed circuit-breaker
  - Two closed contacts at open circuit-breaker

- If there are any auxiliary contacts for condition control:
  - One closed contact at closed circuit-breaker
  - One closed contact at open circuit-breaker

Additional contacts needed for control circuits in electric counters and for the construction shall be provided if necessary.

Data for auxiliary contacts shall be adapted to actual loads. According to SS-EN 62271-1 the break and make current shall be minimum 2 A at 220 V dc with a current time constant of at least 20 ms.

6.2.5 Motor
Motor shall be protected against switching overvoltages caused by the operating mechanism itself. The amplitude of the voltage must not exceed 50 % of the rms value of the test voltage.

Motor circuits shall be galvanized separated from the control circuits.

6.2.6 Motor protection and motor protection switch
The operating device shall be provided with a motor protection or similar equipment in order to prevent damages on the components.

For safety reasons it shall be possible to open the motor circuits. Motor protective circuit-breakers shall have two-pole contact function and manual switching shall be possible.

If manual switching is not possible, a separate two-pole switch shall be used. This switch shall have necessary making and breaking capacities for a fully braked motor.
6.2.7  Fuse
Short circuit protection in the operating mechanism is not required. Feeders are fused in the fuse panel. The manufacturer shall state the minimum fuse possible to use and the maximum permissible.

6.2.8  Contactor
Contactor shall be chosen with an operation frequency class of at least 0.3 and for a minimum of 1 million operating cycles.

6.2.9  Switch for operating voltage
For safety reason when working in the operating mechanism, it shall be possible to open all operating circuits by a switch. The switch shall have the positions TILL (ON) and FRÅN (OFF) and have contacts for breaking plus and minus.

Signal when operating voltage is turned-off shall give alarm in accordance to sub-clause 6.2.3; see also TR02-08-02.

6.2.10 Operating coils
There shall be two independent coils for closing and two independent coils for opening. Coil circuits ought to have a maximum rating of 350 W and at normal operation resist a lasting incoming operation impulse.

6.2.11 Anti-pumping relay
An anti-pumping relay shall be connected so that unintended closing operations are prevented in the event of lasting closing impulse after a CO operating sequence. The anti-pumping function shall be independent of other protection devices.

6.2.12 Heating
The operating mechanism shall be equipped with continuous basic heating to ensure ventilation. If additional heating is necessary for reliable operation it shall be governed by a thermostat. Low heating power is preferred. This can for example be achieved by insulation of the enclosure. Power requirement and set values shall be stated.

Heaters shall be electrically and thermally protected from unintended contact. Heaters shall be easily replaceable.

Heating equipment shall not cause icing of the linkage system or heating points resulting in accelerated ageing of any component.

Basic heating and additional heating shall be supervised by an alarm device. Not more than two heaters shall be controlled by each alarm circuit. If there are more than two alarm circuits, every circuit shall be locally indicated and collected alarm shall be given for remote indication.
For safety reasons, when working in the operating mechanism, it shall be possible to open all phases in the heating circuits with a safety switch.

6.2.13 Terminal blocks
Cables coming from outside shall be connected to one and the same side of the terminal blocks. Cables coming from inside shall be connected to the other side of the blocks. It is not allowed to connect more than two cables to each terminal block.

The number of terminal blocks is chosen so that each cable coming from outside can be connected to own terminal block. For test purpose there shall be at least five terminal blocks of which two shall be connected and marked + and -, respectively. There shall also be five extra terminal blocks installed.

Each terminal block shall have a clearly visible label and be located for easy access. Terminal blocks shall be disconnectable. Disconnection shall only be possible by using tools. The disconnection device shall be so designed that unintended opening of circuits as a result of vibrations etc. shall be prevented. Disconnection shall not be directed upwards.

Terminal blocks shall be designed for connection of single stranded conductors with cross sectional areas of 1 - 6 mm² and shall have screw terminals with test point for the connection of 4 mm diameter test probes (banana plugs).

Terminal blocks intended for motor feeder shall have the possibility of connecting cables with a cross section up to 16 mm². If these terminal blocks are not disconnectable they shall be connected in series with terminal blocks of 10 mm². Terminal blocks for internal circuits may be chosen by the manufacturer.

6.2.14 Counter for operating sequences
The number of operating sequences CO shall be registered with a counter for at least 9999 operating sequences. It shall not be possible to reset the counter. The functionality of the counter shall not be affect by vibrations.

6.3 Specific requirements on motor-operated spring mechanism

6.3.1 Manual charging of closing spring
A device for manual charging of the closing spring shall be provided. Portable tools shall have a secure and protected place for storing. At operation, tools shall automatically be released at motor start or the motor circuits shall be disconnected plus and minus.
6.3.2 Starting sequence for single pole operated breakers
Spring charging in a single pole operated breaker shall be carried out in sequence for the three poles so that only one spring mechanism is charged at a time. All springs shall be loaded within one minute in accordance with rated operating sequence.

6.3.3 Indication of spring-charging
Charged and uncharged closing spring shall have correct mechanical indication. The term “uncharged spring” is defined as the condition when the spring charging motor automatically starts. Indication of the spring charging status shall be supplemented with Swedish text in accordance with sub-clause 7.6.

6.3.4 Block for release of charged closing spring
A mechanical block shall be installed in order to prevent a release of a charged closing spring at closed circuit-breaker.

6.3.5 End limit switches
In addition to the necessary switches given by the design, the following end limit switches shall be provided:

- Four closed at charged closing spring, open in intermediate position and in position uncharged of which two are for control of closing coil, one for alarm and one for line protection and automatic network reset.

- One closed and one open at charged closing spring as spare.

The performance of the end limit switches shall be chosen so that full opening and closing capacity is obtained in the circuit they belong to. However, the breaking and making current for auxiliary contacts shall, in accordance with SS-EN 62271-1, be at least 2 A at 220 V dc with a current time constant of at least 20 ms.

6.4 Specific requirements on compressed air operated mechanism

6.4.1 Pneumatic equipment
Components shall be provided with durable labelling for identification on pneumatic diagrams.

Feeding tubes in a system for a single circuit-breaker or common for many breakers into an air pressure vessel shall at the entrance be equipped with a hand-controlled two-way valve and after that a filter and possibly a reducing device and a non-return valve.

It shall be possible to reassemble pipe joints.
6.4.2 Equipment for control and supervision

Control and supervisory devices shall be connected to the pressure vessel via a filter.

There shall be a pressure gauge for measuring the pressure in the pressure vessel. The pressure gauge shall comply with applicable Swedish Standard, SMS, and be easy to read. The pressure gauge shall be of accuracy class 1.0 and have a centric scale. The measuring range shall be 50-67% of the scale. The maximum permissible operating pressure shall be indicated with a red line on the scale. The pressure gauge shall be fitted with or connected to a damping device.

For control of the pressure gauge there shall be a flange at the pressure gauge for connection of a control gauge. The flange shall comply with SMS 1645 and SMS 1647 respectively. The flange shall be easily accessible with a free spacing of at least 200 m.

There shall be at least the following contacts at pressure supervised devices (except for contacts for operational and alarm function):

- Two contacts closed at pressure < rated pressure for control of motor and/or magnetic valve and for a time delayed alarm.
- One contact closed at pressure > rated pressure for control of any magnetic valve for relief of unpermitted high pressure.
- Two closed contacts at a pressure > the lowest pressure that permits the function CO to be completed with retaining guaranteed performance for the breaker. Designation TL.
- One closed contact at a pressure > the lowest pressure that permits the function O to be completed with retaining guaranteed performance for the breaker. Designation UL.

The contact performance shall be chosen so that full opening and closing abilities are obtained in their circuits. Performance data shall be stated. The pressure levels shall be easy to set, stable and shall give good functional margins.

Settings and tolerances shall be stated.

The compressor shall be equipped with a counter showing operation time and a device for alarm of abnormal long operation time defined as twice the normal operation time.

6.4.3 Pressure evacuation

Discharging of air and possible condensation in pressure vessels is performed by hand operated two-way needle valves. If the vessel is accessible during operation, the needle valve shall be mounted on the vessel. The design shall be able to withstand the effects of freezing of the condensate.
6.4.4  Pressure relief
Pressure vessel and every pressurized part which can be separated shall be relieved from impermissible high working pressure by a safety valve. The pressure relief by the safety valve shall be limited to a level which ensure opening of the circuit-breaker. The safety valve for an outdoor located circuit-breaker shall be placed within the enclosure of the operating mechanism. The exhaust shall be placed on the back-side of the enclosure and directed so that personal injury caused by pressure relief is prevented.

6.5  Specific requirements on hydraulic operated mechanism

6.5.1  Hydraulic equipment
Permitted limits for the quality and degree of contamination for the hydraulic oil shall be stated.

Quick filling and draining of oil in the hydraulic system shall be possible by a hand operated two-way valve.

For condition monitoring, there shall be a diagram stating the lowest pressure at which the operating mechanism can be operated within the entire temperature range.

The operating mechanism shall be equipped with a motor driven pump. The hydraulic pump shall be equipped with an operation time counter. Abnormally long pump motor operating time motor shall be alarmed at twice the operating time after a normal operating sequence. The pump motor operation shall automatically be limited after five times the normal operating time. Manual pressure increase shall be possible with a hand driven pump.

In the sucking pipe to the hydraulic pump, a filter shall be installed which shall be easily accessible for internal inspection. When changing the filter, it shall be possible to close the pumping circuit with a hand driven two-way valve.

Directly after the pump, a non-return valve shall be placed. A non-return valve shall not be placed between accumulator and safety valve.

Gas accumulator shall be filled with nitrogen or equivalent suitable dry gas. The accumulator shall be equipped with a valve for gas control, filling and discharge.

An unpermitted high pressure shall be reduced with a safety valve placed in a connection to the accumulator. The connection shall not be possible to block. The pressure relief of the safety valve shall be limited to a level ensuring opening of the circuit-breaker.

It shall be possible to reassemble pipe joints.
6.5.2 Equipment for control and supervision
Contacts controlled by pressure switches shall be provided with the same adjustable functions and be as many as described above for the compressed air operated mechanism. Moreover, there shall be contacts for supervision of minimum and maximum operating pressure in the low pressure system.

Each pressure system shall be equipped with a pressure gauge. For inspection of the pressure gauge there shall be a possibility for connection of a test gauge. The same requirements for design as for the compressed air system do apply.

7 Labels

7.1 Indication
Indication of the breaker's position in accordance with section 5.2 shall be:

- Closed position - I - black letter on yellow background.
- Open position - O - white letter on green background.

7.2 Switch for operating circuit
Switch for operating voltage in accordance with subsection 6.2.9 shall have the symbols “O” and “I” and a label with text: “MANÖVERSPÄNNING”

Switches placed in the operating mechanism cubicle on disconnecting circuit-breakers shall be clearly labelled to avoid any confusion regarding the different functions: circuit-breaker, earthing switch and blocking device.

7.3 Motor-protective circuit-breaker
Motor protective circuit-breaker in accordance with subsection 6.2.6 shall have the symbols “O” and “I” and a label with text: “MOTOR”

7.4 Switch for heating circuit
Switch for heating voltage in accordance with subsection 6.2.12 shall have the symbols “O” and “I” and a label with text: “VÄRME”

7.5 Locking of disconnecting circuit-breaker
The locked position of the disconnecting circuit-breaker shall, in accordance with section 5.11, be labelled “BLOCKERAD” with white letters on a green background. If a label for the unlocked position is present it shall be labelled “EJ BLOCKERAD” in black letter on a yellow background.
7.6  Spring-charging
The closing spring shall have symbols and be labelled with clarifying text: “SPÄND”
for charged spring and “OSPÄND” for uncharged spring.

8  Pressure vessel requirements

The requirements given below are applicable for the pressurized parts which are
excluded from the regulations from the National Board of Occupational Safety and
Health Ordinance (Arbetarskyddsstyrelsens tryckkärlsförordning). For conventional
pressure vessels AFS 2005:2 is applicable.

8.1  Quality system
Manufacturer designing and producing pressurized parts in electrical equipment shall
follow a quality system corresponding to SS-ISO 9001.

Subcontractors who are only manufacturers shall follow a quality system
corresponding to SS-ISO 9002 or SS-ISO 9003, depending on the extent and
complexity of manufacturing.

8.2  Acceptance of pressurized vessels
Before start of manufacturing the design drawings and control plans, showing the
intended control of material and manufacturing, shall be accepted.

8.3  Pressure vessel documentation
When a new type of circuit-breaker is to be approved the manufacturer shall present a
list of metal enclosures and other pressurized vessels used in the equipment together
with specification of their detail number/drawing number, material, pressure, require-
ment for yield strength and regulatory compliance according to applicable standards.

9  Documentation

9.1  General
Instructions, dimension drawings and diagrams, handed over at delivery of the circuit-
breaker, shall be in Swedish.

New types of disconnecting circuit-breakers shall undergo an approval process before
they can be approved for installation in the Power Grid; see TR01-19E.
9.2 Tender documentation
Together with the tender, the following documents shall be provided: List of data, dimension drawings, electrical circuit and schematic diagrams, instructions for erection, operation and maintenance, and a compilation list of all type tests. Complementary documents may be requested if needed.

9.3 Documentation together with apparatus delivery
In connection with the apparatus delivery the following documents shall be delivered electronically and in one paper copy, if nothing else has been agreed upon:

- Updated list of data containing information in accordance to Annex 3.
- Instructions for transport, storing, erection, service, testing and adjustment. These documents shall also be sent in one copy together with the delivery of the circuit-breaker.
- Instruction and values for condition control; see also sub-clause 5.10.
- Environmental information in accordance to TR13-04-01, sub-clause 4.1.
- The following information shall be sent in separate document if this is not included in the user manual: lubrication chart, list of lubricants and contact grease, list of other chemical products including gases, list of products and protective information for all listed chemical products, list of special tools and accessories for erection and maintenance and list of equipment for testing and condition control.
- Compilation that verifies that pressurized components of the circuit-breaker comply with applicable requirements according to sub-clause 8.3
- Final dimension drawings. Operating forces as well as allowed static and dynamic terminal forces shall be stated on the dimension drawings using direction arrows.
- Final electrical circuit and schematic, pneumatic, hydraulic diagrams
- Routine test certificates. These documents shall also be sent in one copy together with the delivery of the circuit-breaker.

9.4 Documentation and spares after delivery
The manufacturer shall when requested provide the client with necessary service messages and shall undertake to be able to provide spare parts for maintenance during a period of at least ten years after delivery. Improvements in design or instructions, which can be applied to the equipment supplied, shall be notified after delivery, preferably in the form of service messages. See also SS-EN 62271-1, sub-clause 10.4.1.
Appendix 1.
Terminal Plate, dimensions

Plate  Figure  Dimensions (mm):  a  b  c  d  e
9 - 125  1  9-hole  125  22,5  40  14  35
12 - 165  2  12-hole  125  22,5  40  14  35
Appendix 2.
Additional requirements for circuit-breakers used for controlled switching

1. Background
Controlled switching of circuit-breakers is a way to decrease the stresses on the network, surrounding equipment, and the circuit-breaker itself, at making and breaking operations. The applications which are considered are:

- Reduction of inrush currents and overvoltages at energisation of capacitor banks
- Reduction of inrush currents and voltage distortion at energisation of shunt reactors and power transformers
- Elimination of reignitions at de-energisation of shunt reactors

The beneficial effect of applying controlled switching depends on the properties of the circuit-breaker, the control equipment (controller), but also on the properties of the load being switched. For the circuit-breaker, the following requirements apply:

- Good accuracy of opening and closing times, also during variation of ambient temperature, control voltage, number of operating sequences, idle time, etc. The controller may be used to compensate for influence of e.g. ambient temperature and control voltage, but cannot compensate for purely statistical variations in the opening and closing times.

- Sufficiently high dielectric capability of the contact system (RDDS and RRDS). This is e.g. necessary in order to obtain short pre-arcing time at making operations.

2. General requirements on the circuit-breaker
For controlled making operations the pre-arcing time has to be short. The contact speed (and RDDS) shall be high enough to limit the maximum pre-arcing time to less than 3 ms for making operations under normal voltage conditions.

Controlled de-energisation of shunt reactors shall result in re-ignition free switching operations, in line with the requirements in SS-EN 62271-110.

3. Mechanical scatter of operating times
The following requirements on maximum deviations of the operating times due to mechanical scatter shall be fulfilled:

- Closing time: ±1 ms
- Opening time: ±1 ms

These requirements shall be verified by tests.

4. Impact of ambient temperature
The influence of variations in ambient temperature on the operating times shall be reported and verified by tests.

5. Impact of control voltage
The influence of the control voltage on the operating times shall be reported and verified by tests.

6. Impact of stored energy level
Certain types of circuit-breakers, e.g. those equipped with hydraulic operating mechanisms, may be operated within a span of varying operating energy. For such circuit-breakers the influence of variation of the operating energy on the operating times shall be reported and verified by tests.

7. Impact of idle time
The influence of idle time on the operating times shall be reported and verified by tests.

The following requirements on maximum deviations of the operating times after idle time up to 64 h shall be fulfilled:

- Closing time: ±1 ms
- Opening time: ±2 ms

8. Tests
The tests required in sub-clauses 3, 4, 5 and 6 in this appendix 2 may be performed in connection with, or in some cases be compiled from test reports from the regular mechanical and high and low temperature tests specified in SS-EN62271-100, sub-clause 6.101. The result from at least 10 closing- and opening operations in one sequence shall be submitted. As an alternative, tests may be performed according to relevant sections of IEC TR 62271-302.

The tests required in sub-clause 7, showing the impact of idle time, may e.g. be performed according to IEC TR 62271-302, sub-clause 6.101.2.8.
Appendix 3.
List of data

1. General
This appendix indicates the minimal requirements regarding the data that the manufacturer shall report on a compiled document “List of data”. Additional information may be chosen by the manufacturer.

The highest tested values of the circuit-breaker regarding rated current and rated short-circuit breaking current shall be stated on the List of data even if a lower value has been indicated in the request for tender.

2. Minimal content required in the List of data
- Name of the substation
- Supplier’s reference number
- Manufacturer
- Type designation
- Year of manufacturing
- Rated frequency (Hz)
- Rated voltage (kV)
- Rated current (A)
- Rated short-circuit breaking current (kA)
- Rated duration of short-circuit (s)
- Rated breaking current of line at no load (A)
- Rated breaking current of cable at no load (A)
- Insulation level to earth – LIWV (kV)
- Insulation level to earth – SIWV (kV)
- Insulation level to earth – PFWV, 1 minute (kV)
- Insulation level over open pole - LIWV (kV)
- Insulation level over open pole - SIWV (kV)
- Insulation level over open pole - PFWV, 1 minute (kV)
- Temperature limits (°C)
- Arc-interrupting medium (SF₆, SF₆/N₂, SF₆/CF₄)
- Gas weight 1 (kg)
- Gas weight 2 (kg)
- Closing time (ms)
- Opening time (ms)
- Operating sequence
- Svenska kraftnät’s Technical Guideline (TR01-08E rev.X)
- Standards
- Dimension drawings (with rev.-nr)
- Mechanical class
- Capacitive current switching class
- Electrical capability class
- Circuit diagrams (with rev.-nr)
- Serial number of the poles
- Insulator material and colour
- Creepage distance to earth (mm)
- Creepage distance over pole (mm)
- Type of operating mechanism (spring/hydraulic/compressed-air)
- Quantity of hydraulic oil (when applicable) (kg)
- Number of operating mechanisms for a 3-pole circuit-breaker
- Type designation of the operating mechanism
- Serial number(s) of the operating mechanism(s)
- Motor voltage (V DC)
- Control voltage (V DC)
- Heater voltage (V AC)
- Manufacturer of the blocking device
- Type designation of the blocking device
- Serial number of the blocking device
- Year of manufacturing of the blocking device