Live Tank Circuit Breakers
Buyer’s Guide - Section Explanations
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Our task is to help our customers to a more reliable power grid and sustainable society at large. This is why we always strive for the leading position in research and development. ABB has all the experience necessary for successful development of power transmission technology.

This Buyer’s Guide concerns one of our true specialty areas – high voltage circuit breakers – an area in which we are constantly striving to improve product performance that delivers real customer value. What has pushed development forward has been the capability to increase availability at our customers’ installations by supplying reliable high voltage equipment.

Development is a team effort
Our development team consists of highly qualified and experienced technicians with expert knowledge in, for example, plasma physics, materials physics, gas dynamics, mechanics and high voltage technology. We also collaborate with others with expert knowledge and skills, both at ABB and externally.

An important aspect of development work is our close dialog with customers, which enables us to find out about their experiences. Customers who demand more of our products give us the best platforms to realize new innovations.

Thought leadership
Our design work with constant improvements and simplification of our products have resulted in; 550 kV circuit breakers without grading capacitors; the Motor Drive with a servo motor system that accurately controls and monitors the contact operation and the LTB D1 and E1 circuit breakers with MSD operating mechanism that provide fast and simple installation at site.

Other mile stones:
- 80 kA with only two breaking chambers per pole
- The DCB concept that enables smarter, safer and greener substations
- Excellent earthquake performance suitable for seismic regions
- The eco-efficient CO₂ circuit breaker LTA

New technology requires careful testing.
ABB’s high power laboratory is among the world’s most modern and best equipped labs for switchgear technology, with facilities for testing circuit breakers with rated voltages of up to 1200 kV and breaking currents of up to 80 kA.
Product portfolio
Live Tank Circuit Breakers

ABB has a complete portfolio and well proven technology for high voltage circuit breakers used in a number of applications.

<table>
<thead>
<tr>
<th>Standards</th>
<th>LTB D1 72.5 – 170</th>
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<th>LTB E2 362 – 550</th>
<th>LTB E4 800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated current</td>
<td>72.5 – 170 kV</td>
<td>72.5 – 245 kV</td>
<td>362 – 550 kV</td>
<td>800 kV</td>
</tr>
<tr>
<td>Circuit-breaking capacity</td>
<td>up to 3150 A</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
</tr>
</tbody>
</table>

The circuit breakers can also be supplied for ambient temperatures down to -60 or up to +70 ºC.

<table>
<thead>
<tr>
<th>Standards</th>
<th>HPL 72.5 – 300</th>
<th>HPL 362 – 550</th>
<th>HPL 800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>IEC, IEEE</td>
<td>IEC, IEEE</td>
<td>IEC, IEEE</td>
</tr>
<tr>
<td>Rated current</td>
<td>72.5 – 300 kV</td>
<td>362 – 550 kV</td>
<td>800 kV</td>
</tr>
<tr>
<td>Circuit-breaking capacity</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
</tr>
</tbody>
</table>

*) Up to 1200 kV on request

The circuit breakers can also be supplied for ambient temperatures down to -60 or up to +70 ºC.
As a complement to the basic versions of our circuit breakers, which are primarily designed for conventional substation solutions, there is a disconnecting circuit breaker configuration with the disconnecting function integrated into the breaking chamber. A safe interlocking system, composite insulators and a motor-driven grounding switch provide personal safety.

<table>
<thead>
<tr>
<th></th>
<th>DCB LTB 72.5</th>
<th>DCB LTB 145</th>
<th>DCB HPL 170-300</th>
<th>DCB 362-550</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>IEC</td>
<td>IEC</td>
<td>IEC</td>
<td>IEC</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>72.5 kV</td>
<td>145 kV</td>
<td>170 - 300 kV</td>
<td>362 - 550 kV</td>
</tr>
<tr>
<td>Rated current</td>
<td>up to 3150 A</td>
<td>up to 3150 A</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
</tr>
<tr>
<td>Circuit-breaking capacity</td>
<td>up to 40 kA</td>
<td>up to 40 kA</td>
<td>up to 50 kA</td>
<td>up to 63 kA</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
<td>-30 – +40 ºC</td>
</tr>
</tbody>
</table>

The disconnecting circuit breakers can also be supplied for other data on request.
For more information about DCBs, please see Application Guide 1HSM 9543 23-03en
Installations with ABB Live Tank Circuit Breakers

LTB 420 E2 with current transformer IMB. Installation in Denmark.

Substation in Oman with desert climate. ABB equipment with LTB 145.

Disconnecting circuit breaker LTB DCB for 72.5 kV installed at a windfarm in Sweden.

Disconnecting circuit breaker HPL DCB for 420 kV installed in a switching station in Sweden.

Disconnecting circuit breaker LTB DCB for 145 kV with the operating mechanism Motor Drive installed at refurbishment in Norway.

1100 kV by-pass switch in series compensation installation in China.
Exceeding Customer Expectations — ABB Live Tank Circuit Breakers

ABB has over a century of experience in developing, testing and manufacturing high voltage circuit breakers. Through the years, our circuit breakers have acquired a reputation for high reliability and long life in all climates and in all parts of the world.

Our apparatus are manufactured in a workshop where we continuously are working with improvements regarding quality, work environment, environment and safety.

<table>
<thead>
<tr>
<th>Product range</th>
<th>Type</th>
<th>Maximum rated voltage (kV)</th>
<th>Maximum rated current (A)</th>
<th>Maximum rated breaking current (kA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Breaker LTB</td>
<td>LTB D1/B</td>
<td>170</td>
<td>3150</td>
<td>40</td>
</tr>
<tr>
<td>SF₆ Auto-Puffer™ interrupter design</td>
<td>LTB E1</td>
<td>245</td>
<td>4000</td>
<td>50</td>
</tr>
<tr>
<td>Spring or Motor Drive operating mechanism(s)</td>
<td>LTB E2</td>
<td>550</td>
<td>4000</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>LTB E4</td>
<td>800</td>
<td>4000</td>
<td>50</td>
</tr>
<tr>
<td>Circuit Breaker HPL</td>
<td>HPL B1</td>
<td>300</td>
<td>5000</td>
<td>80</td>
</tr>
<tr>
<td>SF₆ puffer interrupter design</td>
<td>HPL B2</td>
<td>550</td>
<td>5000</td>
<td>80</td>
</tr>
<tr>
<td>Spring operating mechanism(s)</td>
<td>HPL B4</td>
<td>800 *)</td>
<td>4000</td>
<td>80</td>
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<tr>
<td>Controlled Switching</td>
<td>Switchsync™</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Condition Monitoring</td>
<td>OLM2</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*) Up to 1200 kV on request

Other data and/or special applications not covered in this Buyer’s Guide will be quoted on request.

How to interpret the type designations

The circuit breaker type designations are for simplicity reasons not always given in full in this document. The product portfolio basically consists of three product groups:

- LTB xxxD1/B (a single-unit circuit breaker)
- LTB xxxEy (a single-, two- or four-unit circuit breaker)
- HPL xxxBy (a single-, two- or four-unit circuit breaker)

Circuit breakers of type LTB are SF₆ gas circuit breaker of self-blast design while circuits-breakers of type HPL are SF₆ puffer circuit breakers.

In the full type designation xxx indicates the rated voltage and y indicates number of series connected breaking units per pole. In this document where the circuit breakers are described in general the voltage designations as well as the number of series connected breaking units are omitted.

Other informations

For information about Compact air insulated HV switchgear solutions with Disconnecting Circuit Breaker, please see separate Application Guide.

Catalogue publication 1HSM 9543 23-03 en.

Further information about controlled switching applications and Switchsync™ controllers is found in Controlled Switching, Buyer’s Guide/Application Guide.

Catalogue publication 1HSM 9543 22-01en.

Information about the new CO₂ insulated high voltage circuit breaker LTA is found in brochure 1HSM 9543 21-06en.
Explanations

Technical specifications - General
Standard/Customer specification
There are international and national standards, as well as customer specifications. ABB High Voltage Products can meet most requirements, as long as we are aware of them. When in doubt, please enclose a copy of your specifications with the inquiry.

Tests
Type tests (design tests) and routine tests (production tests) are required by standards.

- Type tests
Type tests are performed only once on one representative test object in accordance with applicable standards and are not repeated without extra charge. The purpose of the type tests is to verify the ratings of the design.

- Routine tests
Before delivery routine tests are performed in accordance with applicable standards on each circuit breaker. The purpose of the routine tests is to verify the assembly and the function on every individual circuit breaker. Routine test certificates are sent to the user with each delivery.

Extended routine tests exceeding requirements by standards will be charged extra.
Please see special chapter Quality Control and Testing.

Rated voltage
The rated voltage is the maximum voltage (phase-phase), expressed in kV rms, of the system for which the equipment is intended. It is also known as maximum system voltage.

Rated insulation level
The combination of voltage values which characterizes the insulation of a circuit breaker with regard to its capability to withstand dielectric stresses.

The rated value given is valid for altitudes ≤1000 m above sea level. A correction factor is introduced for higher altitudes.

The definition “Across isolating distance” is only applicable for disconnectors and disconnecting circuit breakers.

Rated LIWL
The lightning impulse test is performed with a standardized wave shape 1.2/50 µs for simulation of lightning over-voltage.

The rated Lightning Impulse Withstand Level (LIWL) indicates the required withstand level phase-to-earth (phase-to-ground), between phases and across open contacts. The value is expressed in kV as a peak value.

For voltages ≥300 kV two values are stated by IEC, a LIWL voltage on one of the main terminals and power frequency voltage on the other.

Example 420 kV: 1425 (+240) kV.

Alternatively a LIWL pulse with the sum of the two voltages (1665 kV) can be applied on one terminal, while the other is grounded.

BIL (Basic Insulating Level) is an old expression but means the same as LIWL.

Rated Full Wave is often used in older ANSI/IEEE standards but means the same as LIWL.

Rated Power Frequency Withstand Voltage
This test is to show that the apparatus can withstand the power frequency over-voltages that can occur.

The Rated Power Frequency Withstand voltage indicates the required withstand voltage phase-to-earth (phase-to-ground), between phases and across open contacts. The value is expressed in kV rms.

Rated SIWL
For voltages ≥300 kV the power-frequency voltage test is partly replaced by the switching impulse test. The wave shape 250/2500 µs simulates switching over-voltage.

The rated Switching Impulse Withstand Level (SIWL) indicates the required withstand level phase-to-earth (phase-to-ground), between phases and across open contacts. The value is expressed in kV as a peak value. The switching impulse is required only for voltages ≥300 kV. Two values are stated by IEC, a SIWL voltage on one of the main terminals and power frequency voltage on the other.

Example 420 kV: 900 (+345) kV.

Alternatively a SIWL pulse with the sum of the two voltages (1245 kV) can be applied on one terminal, while the other is grounded.
**Rated Chopped Wave Impulse Withstand voltage**

**Phase-to-earth and Across open gap**
The rated chopped wave impulse withstand level at 2 µs and 3 µs respectively, indicates the required withstand level phase-to-earth (phase-to-ground) and across open contacts.

The chopped wave impulse is only referred to in IEEE standards and hence, not applicable for IEC.

**Rated frequency**
The rated (power) frequency is the nominal frequency of the system expressed in Hz, which the circuit breaker is designed to operate in.

Standard frequencies are 50 Hz and 60 Hz.

Other frequencies, such as 16 2/3 Hz and 25 Hz might be applicable for some railway applications.

**Rated normal current**
The rated normal current (sometimes referred to as rated current, nominal current or rated continuous current) is the maximum continuous current the equipment is allowed to carry. The current is expressed in A rms.

The rated normal current is based on a maximum ambient temperature of +40 °C. At higher temperatures derating of the normal current might be necessary.

**Rated short-time withstand current**
The rated short-time withstand current is the maximum current (expressed in kA rms) which the equipment shall be able to carry in closed position for a specified time duration. The rated short-time withstand current is equal to the rated short-circuit breaking current.

Standard values for duration are 1 or 3 s.

**Rated peak withstand current**
The peak withstand current is the peak value of the first major loop (expressed in kA) during a short-time withstand current that the equipment shall be able to carry. The peak value is related to the rms value, frequency and time constant (τ). Specified values are:

- 2.5 x rated short-time withstand current at 50 Hz at τ = 45 ms
- 2.6 x rated short-time withstand current at 60 Hz at τ = 45 ms
- 2.7 x rated short-time withstand current at 50/60 Hz at τ > 45 ms

**Rated short-circuit breaking current**
The rated short-circuit (breaking) current is the maximum symmetrical short-circuit current in kA rms, which a circuit breaker shall be capable of breaking.

Two values are related to the rated short-circuit current:

- The rms value of the AC component
- The percentage DC component (depending on the minimum opening time of the circuit breaker and the time constant τ)

**Rated short-circuit making current**
The rated short-circuit making current is the maximum peak current the circuit breaker shall be able to close and latch against. This is also referred to in IEEE as closing and latching capability.

Rated short-circuit making current is equal to Rated peak withstand current.

The peak value is related to the rms value of the rated short-circuit breaking current, frequency and time constant (τ). Specified values are:

- 2.5 x rated short-time withstand current at 50 Hz at τ = 45 ms
- 2.6 x rated short-time withstand current at 60 Hz at τ = 45 ms
- 2.7 x rated short-time withstand current at 50/60 Hz at τ > 45 ms
Explanations

System and Switching Conditions

Earthing of the network
The earthing of the network may vary with region and rated voltage.

For higher rated voltages, networks tend to have effectively earthed neutral. For lower rated voltages, networks usually have non-effectively earthed neutral (isolated or resonant earthed).

The type of earthing is an important parameter for defining the transient recovery voltage

First-pole-to-clear-factor
The first-pole-to-clear-factor ($k_{pp}$) is depending on the earthing of the network. The first-pole-to-clear-factor is used for calculating the transient recovery voltage for three-phase faults.

In general the following cases apply:

- $k_{pp} = 1.3$ corresponds to three-phase faults in systems with an effectively earthed neutral.
- $k_{pp} = 1.5$ corresponds to three-phase faults in isolated systems or resonant earthed systems.
- $k_{pp} = 1.0$ corresponds to special cases, e.g. two-phase railway systems, short-line fault.

A special case is when there is a three-phase fault without involving earth. This case corresponds to $k_{pp} = 1.5$. This case is covered by the IEEE standards.

Rated Transient Recovery Voltage
The rated transient recovery voltage (TRV) is the peak transient voltage (expressed in kV) that corresponds to the first-pole-to-clear when interrupting a three-phase fault at rated short-circuit current.

The rated transient recovery voltage ($u_c$) is calculated as follows (based on IEC):

$$u_c = \frac{U_i \times k_{pp} \times \sqrt{2} \times k_a}{\sqrt{3}}$$

Where:

- $U_i$ Rated voltage (kV)
- $k_{pp}$ first-pole-to-clear-factor (out-of-phase) or out-of-phase voltage factor
- $k_a$ Amplitude factor (According to IEC: 1.25)

Example:
At 145 kV with $k_{pp} = 1.5$, the rated transient recovery voltage will be 249 kV

Rated out-of-phase making and breaking current
The rated out-of-phase breaking current is the maximum out-of-phase breaking current the circuit breaker shall be capable of breaking.

The standard value of the rated out-of-phase breaking current is 25% of the rated short-circuit breaking current.

Out-of-phase
The power frequency recovery voltage (rms) for out-of-phase conditions can be calculated as:

$$u = \frac{U_i \times k_{pp}}{\sqrt{3}}$$

The corresponding transient recovery voltage ($u_c$) can be calculated as:

$$u_c = \frac{U_i \times k_{pp} \times \sqrt{2} \times k_a}{\sqrt{3}}$$

Where:

- $U_i$ Rated voltage (kV)
- $k_{pp}$ first-pole-to-clear-factor (out-of-phase) or out-of-phase voltage factor
- $k_a$ Amplitude factor (According to IEC: 1.25)

Standardized values for the out-of-phase voltage factors are:

- 2.0 for systems with effectively earthed neutral
- 2.5 for systems with non-effectively earthed neutral

Example:
At 245 kV with $k_{pp} = 2.0$, the out-of-phase transient recovery voltage will be 500 kV

The applied voltage before making is not affected by the earthing of the system. The maximum applied voltage during out-of-phase conditions is always 2.0 times the single-phase voltage.

Rated surge impedance and other short-line fault characteristics
When a short-circuit occurs on an overhead line not far from a circuit breaker, traveling waves will generate a very steep first part of the transient recovery voltage. The Rate of Rise of Recovery Voltage, RRRV is depending on the short-circuit current and the surge impedance.

The surge impedance may vary depending on e.g. type of conductors.

Example:
In standards IEC and IEEE, the surge impedance has been standardized to a value of 450 Ω.

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Other characteristics for the short-line fault are the peak factor and the RRRV factor. These have been standardized to the following values:

- Peak factor: 1.6
- RRRV factor: 0.2 (kV/µs)/kA for 50 Hz
  0.24 (kV/µs)/kA for 60 Hz

**Capacitive voltage factor**

The capacitive voltage factor is used for defining the single-phase recovery voltage for different capacitive switching applications. The factor is depending on the following:

**Application**
- No-load line switching
- No-load cable switching
- Capacitor bank switching

**Earthing of the network**
- Earthed neutral
- Non-effectively earthed neutral (isolated or resonant earthed)

Standard values for capacitive voltage factors for normal service conditions are as follows:

**No-load line switching:**
- 1.2 (effectively earthed neutral)
- 1.4 (non-effectively earthed neutral)

**No-load cable switching:**
- 1.0 (screened cables in systems with solidly earthed neutral)
- 1.2 (belted cables in systems with effectively earthed neutral)
- 1.4 (in systems with non-effectively earthed neutral)

**Capacitor bank switching:**
- 1.0 (capacitor bank with earthed neutral in systems with solidly earthed neutral)
- 1.4 (capacitor bank with non-effectively earthed neutral)

When different capacitive voltage factors apply from different applications, the highest value should be referred to.

The voltage factor can be used to calculate the single-phase recovery voltage peak:

\[ u_r = \frac{U_r \times k_c \times 2 \times \sqrt{2}}{\sqrt{3}} \]

Where:
- \( U_r \) Rated voltage
- \( k_c \) Capacitive voltage factor

**Example:**

What is the peak recovery voltage for a 245 kV breaker when switching a no-load line with earthed neutral?

The voltage factor is 1.2 due to earthed neutral system.

The peak recovery voltage is:

\[ u_r = \frac{245 \times 1.2 \times 2 \times \sqrt{2}}{\sqrt{3}} = 480 \text{ kV} \]

**Capacitive switching class**

There are two different capacitive switching classes:

- Class C1: Circuit breaker with low probability of restrike during capacitive switching.
- Class C2: Circuit breaker with very low probability of restrike during capacitive switching.

A circuit breaker intended for Class C2 can of course also be used for Class C1.

**Rated capacitive inrush current and inrush frequency**

The rated capacitive inrush current (peak value) is only applicable for circuit breakers intended for switching of (mainly back-to-back) capacitor banks.

The inrush current is characterized by a very high inrush current and inrush frequency.

Values may vary due to different configurations of capacitor banks, current limiting inductance etc.

Standardized value of inrush current is 20 kA (peak value) and with an inrush current frequency of 4.25 kHz.

**Time constant**

The time constant of the system is equal to the ratio between inductance and resistance in the network (L/R) and is expressed in ms. Standard value is 45 ms. The time constant will affect the required DC component.

There is a relationship between the time constant and the X/R-ratio.

If a required X/R-ratio has been given, the time constant in ms can easily be calculated by dividing the X/R-ratio with \((2 \times \pi \times f)\), where \( f \) is the rated frequency.

**Example:**

\( X/R = 14 \) corresponds to a time constant of 45 ms at 50 Hz

\( X/R = 17 \) corresponds to a time constant of 45 ms at 60 Hz
Explanations

Ambient Conditions

Minimum ambient temperature
The minimum ambient (air) temperature specifies the lowest temperature at which the circuit breaker shall be able to operate, at specified ratings.

Important standard values are -30 °C and -40 °C.

The minimum ambient temperature affects the choice of gas pressure and/or gas mixture.

Maximum ambient temperature
The maximum ambient (air) temperature specifies the highest temperature at which the circuit breaker shall be able to operate, at specified ratings.

The maximum ambient temperature can affect the continuous current carrying capability.

Standard value is +40 °C.

Altitude
The external dielectric strength becomes reduced at higher altitudes due to the lower density of air. Standard dielectric type tests are valid for installations up to 1000 masl. For verification of the suitability of installation at higher altitudes the test voltages has to be corrected.

Correction factor according to standard has to be used for external insulation. (IEC 62271-1)

Creepage distance
The creepage distance is defined as the shortest distance along the surface of an insulator between two conductive parts.

The required creepage distance is specified by the user in:

- mm (total creepage distance)
- mm/kV (creepage distance in relation to the phase to ground voltage).

NOTE!
Creepage distance voltage used to be phase to phase voltage. To avoid confusion check which voltage reference that is used.

Pollution level
Environmental conditions, with respect to pollution, are sometimes categorized in pollution levels. The pollution levels are described in IEC 60815. During 2008 the former levels I, II, III and IV were replaced with the five levels a, b, c, d, and e.

There is a relation between each pollution level and a corresponding minimum nominal specific creepage distance.

Since 2008 IEC 60815 states that the phase - ground voltage shall be used for description of creepage distances instead of phase - phase voltage as in the old versions of the standard.

As a reference the old values are also given below.

<table>
<thead>
<tr>
<th>Pollution level</th>
<th>Creepage distance (Phase - Ground voltage) mm/kV</th>
<th>Creepage distance (Old) Phase - Phase voltage mm/kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>a - Very light</td>
<td>22.0</td>
<td>-</td>
</tr>
<tr>
<td>b - Light</td>
<td>27.8</td>
<td>(16)</td>
</tr>
<tr>
<td>c - Medium</td>
<td>34.7</td>
<td>(20)</td>
</tr>
<tr>
<td>d - Heavy</td>
<td>43.3</td>
<td>(25)</td>
</tr>
<tr>
<td>e - Very Heavy</td>
<td>53.7</td>
<td>(31)</td>
</tr>
</tbody>
</table>

Ice class
If applicable, outdoor switchgear may be assigned to withstand a specified ice coating. Three classes exist in IEC:

- 1 mm of ice coating
- 10 mm of ice coating
- 20 mm of ice coating

Wind load
The specified wind loads for circuit breakers intended for outdoor normal conditions are based on a wind speed of 34 m/s, (IEC).
Design

Single- or three-pole operation
For single-pole operation (1-pole operation), each individual pole of the circuit breaker is operated by its own operating mechanism. This makes single-phase as well as three-phase auto-reclosing possible.

For three-pole operation, (ganged operation) all three poles are operated by a common operating mechanism. The three poles are mechanically linked together for three-phase auto-reclosing.

(Two-pole operation applies only for special applications, i.e. railway systems.)

Trip-free circuit breaker
A circuit breaker which can perform a complete opening operation, even if the trip command is activated during a closing operation and with the closing command maintained.

NOTE! To ensure proper breaking of the current that may be established, it may be necessary that the contacts momentarily reach the closed position.

Fixed trip
A circuit breaker that cannot be released except when it is in the closed position.

Pre-Insertion Resistors (PIR)
Pre-insertion resistors (closing resistors) are used to limit over-voltages in the network during switching operations. The pre-insertion resistors are only used during closing and consist of resistor blocks that are connected in parallel with the breaking chamber.

The resistor blocks will close the circuit approximately 8-12 ms before the arcing contacts.

Pre-insertion resistors are mainly used at higher system voltages (>362 kV).

For several applications, controlled switching using Switch-sync™ is preferred.

Rated operating sequence
The rated operating sequence (also known as standard operating duty or standard duty cycle) is the specified operating sequence, which the circuit breaker shall be able to perform at specified ratings.

There are two main alternatives:

a) O - t - CO - t' - CO

Where:

<table>
<thead>
<tr>
<th>t</th>
<th>0.3 s for circuit breakers intended for rapid auto-reclosing</th>
</tr>
</thead>
<tbody>
<tr>
<td>t'</td>
<td>3 min for circuit breakers not intended for rapid auto-reclosing</td>
</tr>
</tbody>
</table>

b) CO - t'' - CO

Where:

| t''   | 15 s for circuit breakers not intended for rapid auto-reclosing |

Mechanical endurance class
There are two different mechanical endurance classes:

Class M1: Circuit breaker with normal mechanical endurance (2,000 operations).

Class M2: Frequently operated circuit-breaker for special service requirements (10,000 operations).

A circuit breaker intended for Class M2 can of course also be used for Class M1.

Terminal load
The conductors connected to the circuit breaker terminals, as well as ice and wind loads, cause the resultant static terminal loads.

Standard values for static terminal loads are given by the standards.

The rated static terminal loads of the equipment are normally verified by load calculations.
Explanations

**Design**

**Pressure**
Gas pressures can be expressed in several units, such as MPa, bar, P.s.i etc.

\[ 1 \text{ MPa} = 10^6 \text{ Pa} = 10 \text{ bar} = 145 \text{ P.s.i} \]

**Rated filling pressure**
The rated filling pressure is given at the reference temperature of +20 °C and may be expressed in relative or absolute terms. The rated filling pressure is the pressure to which the circuit breaker is filled before being put into service.

**Alarm pressure**
The alarm pressure is given at the reference temperature of +20 °C and may be expressed in relative or absolute terms. The alarm pressure is the pressure at which a monitoring (alarm) signal indicates that replenishment is necessary in a relatively short time.

**Minimum pressure**
*(Lock out, interlocking or blocking pressure)*
The minimum pressure is given at the reference temperature of +20 °C and may be expressed in relative or absolute terms. The minimum pressure is the pressure at which the circuit breaker becomes interlocked for further operation and when replenishment is necessary.

All type tests, except mechanical endurance test, are performed at this pressure.

**Maximum pressure**
The maximum pressure is given at the reference temperature of +20 °C and may be expressed in relative or absolute terms. The maximum pressure is the pressure at which the circuit breaker is carrying its normal current at maximum ambient temperature.

**Grading capacitors**
Grading capacitors are sometimes used on circuit breakers of multi-break design (two or more identical making/breaking units connected in series) to obtain uniform distribution of the voltage stresses across the open gaps.

The grading capacitor is connected in parallel with each and every making/breaking unit and has a standard value of 1600 pF/capacitor.

The total capacitance across one open pole is calculated as follows: 

\[ C_{\text{tot}} = \frac{C_{\text{g}}}{n} \]

Where:

- \( C_{\text{g}} \) is the capacitance of each grading capacitor.
- \( n \) is the number of making/breaking units connected in series

**Parallel capacitor**
Parallel capacitors are used to modify the line-side transient recovery voltage during short-line fault conditions. Use of a parallel capacitor may result in a higher short-circuit breaking capacity.
Time Quantities

Opening time
The opening time is the interval of time from energizing of the opening release (e.g. opening coil) for a circuit breaker being in closed position and the instant when the (arcing) contacts have separated in all poles.

Closing time
The closing time is the interval of time from energizing of the closing release (e.g. closing coil) for a circuit breaker being in open position and the instant when the (arcing) contacts touch in all poles.

Rated break time
The rated (maximum) break time (interrupting time) is the time interval between energizing the trip circuit and when the arc is extinguished in all poles.
The break time is expressed in ms or cycles
(20 ms = 1 cycle at 50 Hz).
In IEC, the break-time is based on the results of the terminal fault test duties with symmetrical current.
Compensation is made for single-phase testing and for reduced control voltages.

Dead time
The dead time (during auto-reclosing) is the interval of time between final arc extinction in all poles in the opening operation and the first re-establishment of current in any pole in the subsequent closing operation.
IEC and ANSI/IEEE specify a dead time of 300 ms.

Arcing time
Interval of time between the instant of the first initiation of an arc and the instant of final arc extinction in all poles.

Pre-arcing time
Interval of time between the initiation of current flow in the first pole during a closing operation and the instant when the contacts touch in all poles for three-phase conditions and the instant when the contacts touch in the arcing pole for single-phase conditions.

Reclosing time
The reclosing time is the interval of time between the energizing of the opening release (e.g. opening coil) and the instant when the contacts touch in all poles during a reclosing cycle.
If the differences in operating times (closing and opening time respectively) between poles are small and can be neglected, the following approximative formula can be applied:
Reclosing time = Opening time + Arcing time + Dead time + Pre-arcing time

Close-Open time
The close-open time is the interval of time between the instant of contact touch in the first pole during a closing operation and the instant when the (arcing) contacts have separated in all poles during the following opening operation.
The opening release (e.g. opening coil) shall have been energized at the instant when the contacts touch during closing (CO-operation without any intentional time delay; pre-tripped CO-operation).
NOTE: The close-open time is not equal to Closing time + Opening time.

Open-Close time
The open-close time (during auto-reclosing) is the interval of time between the instant of contact separation in all poles and the instant when the contacts touch in the first pole in the subsequent closing operation.
If the differences in operating times (closing and opening time respectively) between poles are small and can be neglected, the following approximative formula can be applied:
Open-Close time = Arcing time + Dead time + Pre-arcing time

Make time
Interval of time between energizing the closing circuit, the circuit breaker being in the open position, and the instant when the current begins to flow in the first pole.

Make-Break time
The make-break time is the interval of time between the initiation of current flow in the first pole during a closing operation and the end of the arcing time during the subsequent opening operation.
The make-break time is based on an operation where the opening release (e.g. opening coil) shall have been energized at the instant when the contacts touch during closing (CO-operation without any intentional time delay also known as a pre-tripped CO-operation).
If the differences in operating times (closing and opening time respectively) between poles are small and can be neglected, the following approximative formula can be applied:
Make-break time = Pre-arcing time + Close-open time + Arcing time
Explanations

Time definitions according to IEC

Closed position

Open position

Contact movement

Opening operation

Opening time

Arcing time

Break time

Final arc extinction in all poles

Separation arcing contacts in all poles

Energizing of opening release

Separation arcing contacts in first pole

Closed position

Contact movement

Open position

Make time

Closing operation

Closing time

Pre-arcing time

Contact touch in all poles

Energizing of closing circuit

Start of current flow in first pole
Operation and Control
Operating Mechanism - Control Cubicle

Control voltage
Control voltage is a DC supply used for the control circuits such as: Close circuit and trip circuits etc.

Common rated control voltages:
- 110, 125, 220 or 240 V DC
- (Less common rated control voltages: 250, 60 or 48 V DC)

The operating mechanism, including the control circuit, is designed for a rated control voltage but must additionally have operational capability throughout a specific voltage range to accommodate variations in supply voltage. The following required voltage ranges are required according to IEC:

- Minimum voltage (auxiliary equipment): 85% of rated voltage
- Maximum voltage (auxiliary equipment): 110% of rated voltage
- Minimum voltage (close circuit): 85% of rated voltage
- Maximum voltage (close circuit): 110% of rated voltage
- Minimum voltage (trip circuit): 70% of rated voltage
- Maximum voltage (trip circuit): 110% of rated voltage

Heating voltage / AC Auxiliary voltage
AC Auxiliary voltage is an AC single-phase (phase – neutral) supply used for Heaters, Socket outlet and Lighting etc. when used. Normal values:
- 110 - 127 V AC
- 220 - 254 V AC

Motor voltage
Motor voltage is a DC supply or an AC single-phase (phase – neutral) supply for the spring charging motor.

Common rated motor voltages:
- 110, 125, 220 and 240 V DC
- 115, 120, 127, 230 and 240 V AC

The motor and the motor circuit are designed for a rated voltage but must additionally have operational capability throughout a specific voltage range to accommodate variations in supply voltage. The following required voltage range is required according to IEC:

- Minimum voltage for motor circuit: 85% of rated voltage
- Maximum voltage for motor circuit: 110% of rated voltage

Closing spring charge motor
The closing spring charging motor charges the closing spring after every closing operation.

Motor contactor
Motor contactor is controlled by the limit switch and starts / stops the closing spring charging motor.
(N.A. for FSA operating mechanism)

Limit switch
The limit switch is monitoring the closing spring charging status.

For operating mechanism BLK and FSA1 it can be of inductive or mechanical type.

For operating mechanism BLG and MSD only mechanical type.

Auxiliary contacts
Auxiliary contacts are contacts that show the circuit breaker position.

At least one contact is used in each control circuit (trip / close) to control the coil supply. Contacts not used in control circuits, are normally connected to terminals for customer use.

Normal spare contact quantities for customer use:
- FSA: 7 NO + 7 NC
- BLK: 8 NO + 8 NC
- BLG: 9 NO + 9 NC
- MSD: 9 NO + 9 NC

NO = Normally open, NC = Normally closed

Impulse contact / Wiping contact
A contact that gives an short impulse during contact movement.

Local / Remote / Disconnected selector switch
The local / remote / disconnected selector switch is used to switch between remote operating and local operating (via the open / close switch). It also has a disconnected position where operation is not possible. However a protection trip bypass can be supplied that makes it possible to trip the circuit breaker remotely even in disconnected position.

As an alternative a Local / Remote switch without disconnecting possibility can be provided.
Operation and Control
Operating Mechanism - Control Cubicle

NC-contact
NC-contact (normally closed contact) is a closed contact when device is not energized or in the drawn situation, according to circuit diagram. Could also be called: Break contact or b-contact.

NO-contact
NO-contact (normally open contact) is an open contact in the same situation. Could also be called: Make contact or a-contact.

NOC-contact
NOC-contact (normally open-closed contact) is a closed contact that opens and an open contact that closes with a common backside when changing position. Could also be called: Change-over contact.

Trip / Close switch
The trip / close switch is used for control operations, when the local / remote (/ disconnected) switch is in local position.

Counter
The counter is a non-resettable electromechanical counter that counts every close operation. (FSA has a mechanical counter)

Anti-pumping relay
The anti-pumping relay is a device that makes sure that there can be only one closing operation for each closing order.

MCB – Miniature Circuit Breaker
The MCB (Miniature Circuit Breaker) is a small automatic breaker that can be manually controlled or automatically tripped due to over-current.

The over-current is either thermal (type K) or peak value (type B). 1NO + 1NC auxiliary contacts, that shows MCB position, can be included.

The MCB is normally used for AC auxiliary circuit (and motor circuit for operating mechanism type BLK)

Direct On Line Motor Starter
Direct On Line Motor Starter is a motor protection and manual control unit. This could also be an MCB (thermal controlled type). This unit trips the motor supply when motor overload occurs or when the Direct On Line Motor Starter is manually operated.

Operating coils
Close and trip coils in operating mechanisms BLK, BLG and MSD have relatively low power consumption, normally 200 W, due to a very good latch design.

One close and two trip coils are supplied as standard.

Additional close coils can be supplied as option. Also the second trip coil can be of the double type and additional trip circuit can be used.

Hand / Motor switch
The hand / motor switch disconnects the motor circuit during hand cranking.

The hand / motor switch, either manual or automatic, has the following functions:
– Motor position; connects the motor to the power supply.
– Hand position; short-circuits the motor and is used as a generator brake.

(N.A. for FSA and MSD operating mechanism)

Heaters, Thermostat, Humidity controller
Every operating mechanism has a continuous connected anti-condensation heater of 70 W.

In addition to that, one or more controlled heaters are fitted, depending on ambient temperature or humidity. These are controlled by a thermostat, or as an option, a humidity controller (a moisture detector controller).

Density switch
The density switch is a device that measures the ambient temperature compensated gas pressure, inside the circuit breaker. Therefore, alarm signal and blocking function are activated only if the pressure drops due to leakage.

The density switch includes normally: a scale display, one contact indicating the alarm pressure and two contacts controlling the gas-supervision interlocking relays at the blocking level.
Operation and control - ABB options

Gas supervision
- **Fail-safe**
  Normally a switch with contacts closing at low gas-pressure is used.

A fail-safe option can be supplied where contacts are opening at low gas-pressure, so the gas supervision interlocking relays are energized until the blocking occurs.

- **Trip at low SF₆**
  Another option is trip at low SF₆-pressure. This option gives a trip order via the gas supervision interlocking relays at the same time blocking occurs.
  Most type tests are carried out at this blocking pressure.

Panel light
Panel light can as an option be fitted on the control panel.

The panel lamp is automatically switched on when the panel door is opened.

Socket outlet
Socket outlet can be fitted inside the cubicle.

Normal designs are:
- Schucko – Commonly used in Northern Europe
- (CEE 7/7) Round 2-pole socket with earth-bars on side.
- CEE 7/4 – French/Belgium std. with round 2-pole plug with inverted earth-pole.
- Hubbel – American standard.
- Crabtree – British standard.
- GPO – Australia

TCS – Trip Circuit Supervision
TCS – Trip Circuit Supervision is mainly used to check the connection between the protection trip relay (control room) and the operating mechanism and secondly the trip coil(s) inside the operating mechanism(s).

The TCS is a device that can be fitted in parallel with the protection trip relay(s) and sends a low (< 50 mA) testing current through the trip circuit(s).

To be able to monitor the trip circuits when the circuit breaker is in open position (when the auxiliary contact in the trip circuit is open), there is a parallel wiring to this contact. There are two normal ways to do this:

1. A resistor in parallel with this contact, with resistance value given by the supplier of the TCS device.
2. A NC-contact of the auxiliary contact in parallel with the original NO-contact. This requires either 2 outputs from the TCS-device or two parallel TCS-devices.

An example of TCS device is SPER from ABB ATCF.

Resistor values for SPER, according to 1. above:
- 220 V dc. 33 kΩ
- 110 V dc. 22 kΩ
- 60 V dc. 5.6 kΩ
- 48 V dc. 1.2 kΩ

Protective trip
The protective trip in the trip circuits is a direct line, by-passing the Local / Remote selector switch.

Note! Used only when protective tripping should override the selector switch.

Position indicating lamps
As an option we can supply green/red-indicating LED-lamps connected to the auxiliary switch for circuit breaker position indication inside the cubicle.
Explanations

Operation and control - ABB options

**Key-interlock**

**Provision** for key-interlock is mechanical (and electrical) interlocking device, which interlocks the closing function, with a bracket suitable for installing the following brands: Castell, Kirk and Fortress.

**Emergency trip, manual trip push-button**

Manual mechanical trip push-button can on request be fitted on the inside or the outside of the operating mechanism. (Only inside for FSA)

**Note! Mechanical trip overrides SF₆-blocking**

**69-device**

An interlocking device, according to device No. 69 in the ANSI standard, that requires a resetting after each manual tripping before closing of the circuit breaker can be done. (N.A. for FSA operating mechanism)

**Spring charge supervision**

As an option a relay can be fitted to give an alarm when one or more of the errors / events below occurs:

1. Loss of motor voltage.
2. The direct on line motor starter is tripped manually.
3. The direct on line motor starter is tripped due to over-current.
4. An electrical error prevents spring charging.
5. A mechanical error prevents spring charging.

The relay can be an auxiliary relay or with a time delay relay depending on alarm delaying possibility in the bay control unit. The alarm delay must be at least as long as the spring charging time, normally 15 s.

**Voltage supervision**

The circuits can be equipped with voltage supervision relay(s).

This could be a zero-voltage relay (a standard auxiliary relay -not adjustable) or voltage supervision relays (with adjustable setting for voltage and hysteresis).

**Heater supervision**

The heating circuit can be equipped with a current supervision relay (with adjustable setting for current and hysteresis) or an indicating lamp in series with the continuously connected heater.

**Capacitor tripping**

Trip circuits can be equipped with capacitor tripping devices. Used to automatically trip the circuit breaker at loss of, or at low operating voltage.

The capacitor tripping device is always used together with a voltage supervision relay (adjustable setting for voltage and hysteresis) that controls the tripping voltage level (one capacitor device / trip coil is required).

**0-voltage trip coil**

The operating mechanisms can be equipped with 0-voltage Trip coil. It is used to automatically trip the circuit breaker at loss of, or low operating voltage.

The 0-voltage Trip coil is always used together with a voltage supervision relay (adjustable setting for voltage and hysteresis) that controls the tripping voltage level.

**Fuses**

Fuses can be fitted in every circuit on request.

Normal types:

- MCB – Miniature Circuit Breaker
- Red spot – Fuses (Links)
- UK 10,3-HESI – Fuses (Links)

Note! The trip and close circuits should preferably not include fuses.

**Phase discrepancy**

Phase discrepancy (Pole discordance) is a device that could be used on single pole operated circuit breakers, that uses auxiliary contacts to indicate that all phases are in the same position. When the poles are in different positions a time relay starts, and after a pre-set time, a trip order and alarm signal is normally initiated.
Seismic conditions

Seismic stress
There are many zones in the world where earthquakes may occur, and where circuit breakers should be designed to withstand the corresponding stresses. When an earthquake occurs, the acceleration and amplitude of the motion of the ground will vary in a statistical manner. The stress conditions are normally most severe in the horizontal direction. The type of soil (sand, clay, rock, etc) has a strong influence on the actual local severity of an earthquake and the damage it may inflict.

For technical purposes earthquake stresses are normally defined by the maximum value of the horizontal acceleration. IEC has standardized three values of maximum horizontal acceleration 2, 3, and 5 m/s², corresponding to 0.2, 0.3, and 0.5 g. IEEE, which is more relevant (more severe) has corresponding standardized values, 0.25 g and 0.5 g respectively for moderate and heavy seismic action.

Resulting stress on circuit breakers
When a HV circuit breaker is subjected to an earthquake, the motion of the ground will induce oscillations in the circuit breaker with corresponding mechanical stress. The mechanical stress will normally be most severe at the lower end of the support column.

The circuit breaker will have one or more natural oscillation frequencies, eigenfrequencies, where the predominant one is typically a few Hz. Since the frequency of typical earthquake oscillations is also of the order of a few Hz, the actual stress on the breaker may be amplified due to mechanical resonance. The degree of amplification depends on the eigenfrequency (natural oscillation frequency) and damping of the circuit breaker, and may be deduced from response spectra, published e.g. by IEC.

Earthquake dampers
An earthquake damper will increase the damping of the natural oscillation of the circuit breaker. In this way the amplification of earthquake stresses due to resonance is significantly decreased, and the maximum mechanical stress on the circuit breaker significantly reduced.

Verification of seismic capability
The seismic capability of a circuit breaker may be verified by a direct test, where a complete circuit breaker, or pole, is subjected to simulated earthquake stress on a shaker table.

Alternatively, the mechanical stresses can be determined by calculations. The most reliable calculations are based on a snap-back test. In this test a force is applied on the top of the circuit breaker pole. When the force is suddenly released the pole will oscillate and the eigenfrequencies and the damping can be measured.
Design features Puffer interrupters

1. Upper current carrier
2. Stationary arcing contact
3. Moving arcing contact
4. Puffer volume
5. Lower current carrier
6. Nozzle
7. Stationary main contact
8. Moving main contact
9. Puffer cylinder
10. Refill valve
11. Stationary piston
In its normal position, the circuit breaker contacts are closed and current is conducted from the upper current collector to the lower current collector via the main contacts, the puffer cylinder and the sliding contact system in between the puffer cylinder and the lower current collector.

At opening, the moving parts of the main and arcing contacts, as well as the puffer cylinder and nozzle, are pulled towards the open position. Note that the moving contacts, nozzle and puffer cylinder form one moving assembly.

As the moving assembly is drawn towards the open position, the refill valve is forced to close. The movement of the puffer cylinder versus the stationary piston now starts creating a compression of the SF$_6$ gas inside the puffer cylinder. Due to the contact overlap this gas compression starts before any contacts separate. After some further movement of the moving assembly the main contacts separate which results in a commutation of the current into the arcing contact path, which is still engaged. The much longer contact penetration of the arcing contact system versus the main contact system will ensure that any arc established will be trapped in between the arcing contacts and within the surrounding nozzle.

When the arcing contacts separate after some further contact travel an arc is drawn between the moving and stationary arcing contacts. As the arc flows it will also to some degree block the flow of SF$_6$ gas through the nozzle. Thus the gas pressure in the puffer volume continues to increase.

When the current waveform approaches a current zero, the arc becomes relatively weak and the pressurized SF$_6$ gas inside the puffer cylinder flows through the nozzle and cools the contact gap which reduces the electrical conductivity such that the arc is extinguished. The low electrical conductivity then prevents the current to continue.

When the current is blocked the recovery voltage starts rising across the contacts. At this time the circuit breaker contacts must have reached a contact distance long enough to create a voltage withstand that all the time exceeds the recovery voltage.

In the fully open contact position there is sufficient distance between the stationary and moving contacts to withstand rated dielectric levels.

On closing, the refill valve opens so that SF$_6$ gas can be drawn into the puffer volume making the circuit breaker ready for the next opening operation.

Note that the SF$_6$ gas pressure required for interruption is built up by mechanical means. Therefore circuit breakers using puffer interrupters require trip mechanisms with sufficient energy to overcome the pressure build up in the puffer volume required to interrupt rated short-circuit current while at the same time maintaining the contact speed required to withstand recovery voltage.
Design features Auto-Puffer™ interrupters

1. Upper current carrier
2. Stationary arcing contact
3. Moving arcing contact
4. Auto-Puffer™ volume
5. Puffer volume
6. Refill valve
7. Stationary piston
8. Nozzle
9. Stationary main contact
10. Moving main contact
11. Auto-Puffer™ valve
12. Puffer cylinder
13. Over-pressure relief valve
14. Lower current carrier
High current interruption
When interrupting high currents (e.g. rated short-circuit current), Auto-Puffer™ interrupters show the advantage they were designed to provide.

At opening, the operation of an Auto-Puffer™ interrupting a high current begins the same way as for a puffer interrupter. It is not until after the arcing period begins that a difference in the operation principle is seen between the high and low current interrupting modes.

When the arcing contacts separate, an arc is drawn between the moving and stationary arcing contacts. As the arc flows, it to some degree blocks the flow of SF₆ gas through the nozzle. Due to the high temperature of the arc it radiates a lot of heat and begins to heat the SF₆ gas in the arc quenching zone. Thus, the pressure inside the Auto-Puffer™ and puffer volumes increases due to the rise in temperature as well as due to the compression of gas between the puffer cylinder and the stationary piston.

Gas pressure inside the Auto-Puffer™ volume continues to increase and a certain pressure it is high enough to force the Auto-Puffer™ valve to the closed position.

All SF₆ gas required for interruption is now trapped in the fixed Auto-Puffer™ volume and any further increase in gas pressure in that volume is due solely to heating from the arc.

At about the same time, the gas pressure in the puffer volume reaches a level high enough to open the overpressure relief valve in the puffer piston. Since the gas in the puffer volume then escapes through the overpressure valve, there is no need for a high operating energy to overcome the compression of SF₆ gas while at the same time maintaining the contact speed necessary to create contact distance for withstanding the recovery voltage.

When the current waveform approaches zero, the arc becomes relatively weak. At this point, the pressurized SF₆ gas returns from the Auto-Puffer™ volume and flows through the nozzle and extinguishes the arc.

At closing, the refill valve opens such that gas can be drawn into the puffer and Auto-Puffer™ volumes.

Low current interruption
When interrupting low currents, Auto-Puffer™ interrupters act very much in the same way as puffer interrupters. There is not sufficient gas pressure generated by the heat of the arc to force the Auto-Puffer™ valve to close. Therefore the fixed Auto-Puffer™ volume and puffer volume form one large common puffer volume. In such a case, the SF₆ gas pressure required for interruption is built up by mechanical means only as in a puffer interrupter.

Unlike a puffer interrupter, however, Auto-Puffers™ need only mechanically generated pressure build-up sufficient to interrupt a portion of the rated short-circuit current (i.e. 20% to 30% of the rated short-circuit current).

In the open position, there is sufficient distance between the stationary and moving contacts to withstand rated dielectric levels.

Because interruption of low currents requires only moderate build-up of SF₆ gas pressure which is generated by mechanical means and since high current interruption uses heating from the arc to generate necessary gas pressure in a fixed volume, Auto-Puffer™ interrupters require far less operating energy than puffer interrupters (i.e. about 50% less).
Quality control and testing

Quality
ABB High Voltage Products in Ludvika has an advanced quality management system for development, design, manufacturing, testing, sales and after sales service as well as for environmental standards, and is certified by Bureau Veritas Certification for ISO 9001 and ISO 14001.

Testing resources
ABB has the facilities for carrying out development tests, type tests and routine tests on the circuit breakers. The laboratories for testing are located in Ludvika close to the factories and the offices for development, design and planning.

With these testing resources ABB is in the forefront in developing new and safe products for the 21st century.

Type tests
The High Power Laboratory is owned by ABB and has facilities for high power tests, temperature rise tests and mechanical tests. It is also accredited by SWEDAC (Swedish Board for Technical Accreditation).

In the STRI AB laboratory, mainly high voltage tests, environmental and special long time duration tests are carried out.

In both laboratories tests in accordance with the requirements stipulated in the international standards IEEE and IEC can be performed. It is also possible to carry out special tests specified by our customers.

The High Power Laboratory as well as STRI has status of independent laboratory and both are members of SATS (Scandinavian Association for Testing of Electric Power Equipment), which in turn is a member of STL (Short Circuit Testing Liaison).

STL provides a forum for international collaboration between testing organizations.

Routine tests
The routine tests are part of the process of producing the circuit breakers and are always performed with the same test procedures, irrespective whether or not the tests are witnessed by the client’s representative.

The circuit breaker pole or poles are tested together with the corresponding operating mechanism.

For single-pole operated circuit breakers type HPL B and LTB E, the routine tests are always individually performed for each pole.

Circuit breakers type LTB D and three-pole operated circuit breakers type HPL and LTB E are always routine tested as complete three-phase units.

In general, the routine tests are performed according to IEC or ANSI/IEEE standards.

The main routine tests steps with respect to IEC, IEEE and ABB standards are summarized in the table below.

The entire routine tests for each circuit breaker is documented in a detailed routine test report, generated by the computerized testing system. After verification by the ABB certified test supervisor, this report is provided to the customer as part of the order documentation.

<table>
<thead>
<tr>
<th>Description</th>
<th>IEC</th>
<th>IEEE</th>
<th>ABB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nameplate and design check</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Resistance measurement (Components in auxiliary and control circuits)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Function check of auxiliary and control circuits</td>
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<tr>
<td>Mechanical operating test</td>
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<tr>
<td>Resistance measurement (Main circuit)</td>
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<td>X</td>
</tr>
<tr>
<td>Dielectric test (Auxiliary and control circuit)</td>
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<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Overpressure test</td>
<td>N/A</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Dielectric test (Main circuit)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tightness test</td>
<td>X</td>
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</tbody>
</table>
Processes and support

The circuit breaker organization is process-oriented with focus on deliveries to customers. The process is continuously optimized with respect to time and quality.

Sales and Order handling
In order to assure that the deliveries fulfill the requirements in the Purchase Order (P.O.) special attention is focused on:

- Assuring the hand over of the P.O. from the Sales to the Order department.
- Order clarification, assuring the particular tasks of order, order design, purchasing and production departments.
- Possible order modifications.

The tools to monitor the orders are continuously improved in order to give our customers the best possible service.

Supply management and Purchasing
The circuit breaker unit has well defined processes for selection and approval of suppliers.

Special attention is addressed to audits at the suppliers plant, the manufacturing, Inspection and Test Plan (ITP) and the On Time Delivery (OTD) monitoring.

The suppliers are evaluated continuously with respect to quality and ODT.

Production and Assembly
All employees are trained and certified with respect to their responsibilities.

Inspections and test plans together with inspection records and control cards have been prepared for all circuit breakers in order to assure that all activities and the assembly are performed according to the specification.

Service and Spares
The circuit breaker unit takes care of the customer’s requirements with respect to service and spare parts. Certified traveling service engineers are available at the plant in Ludvika. Also, in order to be able to assist our customers as fast as possible, local service centers are established in several parts of the world.

In case of emergencies a 24-hour telephone support is available (ph.: +46 70 3505350).

By calling this number customers will get in touch with one of our representatives for immediate consultation and action planning.

Research and Development
The R&D process is utilizing a project management model with well-defined gates in order to assure that all customer requirements and technical issues are addressed.
Inquiry data
Live tank circuit breaker

As a minimum the following information is required and can preferably be copied and sent along with your inquiry.

<table>
<thead>
<tr>
<th>PROJECT DATA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>End customer</td>
<td></td>
</tr>
<tr>
<td>Name of project</td>
<td></td>
</tr>
<tr>
<td>Standard / Customer specification</td>
<td></td>
</tr>
<tr>
<td>Number of circuit breakers</td>
<td></td>
</tr>
<tr>
<td>Delivery time</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td></td>
</tr>
<tr>
<td>Transformer</td>
<td></td>
</tr>
<tr>
<td>Reactor banks</td>
<td></td>
</tr>
<tr>
<td>Capacitor banks</td>
<td></td>
</tr>
<tr>
<td>Other service duty</td>
<td></td>
</tr>
<tr>
<td>Number of operations per year</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYSTEM PARAMETERS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td></td>
</tr>
<tr>
<td>Rated frequency</td>
<td></td>
</tr>
<tr>
<td>Rated normal current</td>
<td></td>
</tr>
<tr>
<td>Maximum breaking current</td>
<td></td>
</tr>
<tr>
<td>LiWL (Lightning impulse 1.2/50 μs)</td>
<td></td>
</tr>
<tr>
<td>SiWL (Switching impulse 25/2500 μs, for $U_{\text{in}} \geq 300$ kV)</td>
<td></td>
</tr>
<tr>
<td>Power frequency withstand voltage</td>
<td></td>
</tr>
<tr>
<td>Grounded / Ungrounded neutral</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AMBIENT CONDITIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature (max - min)</td>
<td></td>
</tr>
<tr>
<td>Altitude (m.a.s.l.)</td>
<td></td>
</tr>
<tr>
<td>Earthquake withstand requirements</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BASIC MECHANICAL PARAMETERS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-pole / Single-pole operation</td>
<td></td>
</tr>
<tr>
<td>Preinsertion resistors (PIR) for line circuit breakers</td>
<td></td>
</tr>
<tr>
<td>Type of high voltage terminal (IEC/NEMA/DIN)</td>
<td></td>
</tr>
<tr>
<td>Insulator material (porcelain or composite)</td>
<td></td>
</tr>
<tr>
<td>Insulator color</td>
<td></td>
</tr>
<tr>
<td>(Porcelain: brown or gray)</td>
<td></td>
</tr>
<tr>
<td>(Composite: only gray)</td>
<td></td>
</tr>
<tr>
<td>Minimum creepage distance mm or mm/kV</td>
<td></td>
</tr>
<tr>
<td>Phase distance (center-to-center)</td>
<td></td>
</tr>
<tr>
<td>Support structure (height)</td>
<td></td>
</tr>
</tbody>
</table>
As a minimum the following information is required and can preferably be copied and sent along with your inquiry.

<table>
<thead>
<tr>
<th>OPTIONAL MECHANICAL PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bursting discs</td>
</tr>
<tr>
<td>Bracket for CT</td>
</tr>
<tr>
<td>Primary connections CB – CT</td>
</tr>
<tr>
<td>Manual trip</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DATA FOR OPERATING MECHANISM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control voltage (Coils and relays)</td>
</tr>
<tr>
<td>Motor voltage</td>
</tr>
<tr>
<td>AC-voltage (heaters, etc.)</td>
</tr>
<tr>
<td>Number of free auxiliary contacts</td>
</tr>
<tr>
<td>Special requirements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACCESSORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF₆ gas for pressurizing</td>
</tr>
<tr>
<td>Gas filling equipment</td>
</tr>
<tr>
<td>Controlled Switching (Switchsync™)</td>
</tr>
<tr>
<td>Condition monitoring (OLM)</td>
</tr>
<tr>
<td>Test equipment</td>
</tr>
<tr>
<td>- SA10</td>
</tr>
<tr>
<td>- Programma</td>
</tr>
<tr>
<td>Tools</td>
</tr>
<tr>
<td>Spare parts</td>
</tr>
</tbody>
</table>

NOTE! For information regarding the parameters asked for see chapter “Explanation”.

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