Live Tank Circuit Breakers
Buyer’s Guide -
Section Optional for special applications
# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>3</td>
</tr>
<tr>
<td>Optional for special applications:</td>
<td></td>
</tr>
<tr>
<td>Composite Insulators</td>
<td>8</td>
</tr>
<tr>
<td>Controlled Switching</td>
<td>10</td>
</tr>
<tr>
<td>On-line Monitoring System</td>
<td>16</td>
</tr>
<tr>
<td>Cable entry kits - Roxtec</td>
<td>19</td>
</tr>
<tr>
<td>Seismic withstand capability</td>
<td>20</td>
</tr>
<tr>
<td>Others:</td>
<td></td>
</tr>
<tr>
<td>Quality control and testing</td>
<td>22</td>
</tr>
<tr>
<td>Inquiry data</td>
<td>24</td>
</tr>
</tbody>
</table>
ABB is the supplier of cutting edge technology

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>
<th>LTB E1 72.5 – 245</th>
<th>LTB E2 362 – 550</th>
<th>LTB E4 800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</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>Rated current</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>Circuit-breaking capacity</td>
<td>up to 40 kA</td>
<td>up to 50 kA</td>
<td>up to 50 kA</td>
<td>up to 50 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 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>72.5 – 300 kV</td>
<td>362 – 550 kV</td>
<td>800 kV *</td>
</tr>
<tr>
<td>Rated current</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
<td>up to 4000 A</td>
</tr>
<tr>
<td>Circuit-breaking capacity</td>
<td>up to 80 kA</td>
<td>up to 80 kA</td>
<td>up to 80 kA</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.
Product portfolio
Disconnecting Circuit Breakers

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>Standards</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>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 50 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 1HSN 9543 23-03en
Installations with ABB Live Tank Circuit Breakers

- LTB 420 E2 with current transformer IMB. Installation in Denmark.
- Disconnecting circuit breaker LTB DCB for 72.5 kV installed at a windfarm in Sweden.
- Substation in Oman with desert climate. ABB equipment with LTB 145.
- 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.
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></td>
<td>LTB E1</td>
<td>245</td>
<td>4000</td>
<td>50</td>
</tr>
<tr>
<td></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></td>
<td>HPL B2</td>
<td>550</td>
<td>5000</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>HPL B4</td>
<td>800</td>
<td>4000</td>
<td>80</td>
</tr>
<tr>
<td>Controlled Switching</td>
<td>Switchsync™</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition Monitoring</td>
<td>OLM2</td>
<td></td>
<td></td>
<td></td>
</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
ABB has developed a full range of high voltage equipment including surge arresters, instrument transformers and circuit breakers with high performance and robust composite insulation as an alternative to porcelain. Use of composite insulators provides new possibilities for substation designers to improve safety and availability.

**General**
Composite insulators with silicone rubber sheds (SIR) offer many advantages over traditional porcelain insulators:

**Improved safety**
- Lower transport and handling risk
- Lower in-service risks
- Low risk for damages by vandalism

**Low weight**
- Easier handling
- Reduced foundation loads
- Excellent seismic withstand

**Hydrophobic**
- Less maintenance
- Suppressed leakage currents

**Demands on composite insulator**
Demands on insulators used for gas insulated live tank circuit breakers are high with respect to mechanical loads as well as electrical stresses. The insulator shall also withstand the decomposed SF$_6$ gas and the heat developed during current interruption.

**ABB manufacturing techniques**
The supporting part of the insulator consists of a cross-laminated fiberglass reinforced epoxy tube, joined to metal end flanges. The glass fibers on the inner surface of the hollow insulator are protected against the influence of the SF$_6$ decomposition products by a liner of epoxy, reinforced with polyester fibers.

The patented helical extrusion moulded silicone rubber insulator without joints (chemical bonds between spirals) is attached to the tube by the spiral winding process, developed by ABB. It minimizes electrical field concentrations and reduces build up of contamination.

**Color**
The insulators for the circuit breakers are delivered in light gray color.

**Applications**
Composite insulators are used for the following types of ABB live tank circuit breakers:
- LTB 72.5 – 800 kV
- HPL 72.5 – 800 kV

**Completed tests performed**

<table>
<thead>
<tr>
<th>On insulator</th>
<th>On circuit breaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerated ageing test (1,000 h)</td>
<td>Seismic test</td>
</tr>
<tr>
<td>UV radiation tests</td>
<td>Overpressure test</td>
</tr>
<tr>
<td>Natural pollution test</td>
<td>Shatter test</td>
</tr>
<tr>
<td></td>
<td>Dielectric test</td>
</tr>
<tr>
<td></td>
<td>Short-time current test</td>
</tr>
<tr>
<td></td>
<td>High and low temperature test</td>
</tr>
</tbody>
</table>

**Main parts of ABB’s composite insulator:**
Composite insulators
Silicone Rubber

Flashover resistant
The chemical nature of silicone makes the insulator surface hydrophobic. The leakage currents are suppressed because the water on the surface stays as droplets and does not form a continuous film. Silicone rubber has the unique ability to maintain its hydrophobicity during the lifetime of the insulator.

Ageing withstand
As a consequence of the hydrophobicity and the suppression of leakage currents, the discharge activity is negligible even in areas with severe pollution.

Non-hydrophobic materials like porcelain and EP-rubber do not possess this property and are therefore affected by pollution to a greater extent.

Stability when exposed to UV light
Silicone rubber UV absorption wavelength is below those naturally occurring - over 300 nanometers. This means that it has inherent UV stability, and a higher resistance against breakdown than other polymers like EP-rubber and epoxies.

Deliveries
In addition to extensive type tests conducted on its composite silicone rubber insulators, ABB has a long list of field references worldwide, verifying the expected high performance and reliability of the insulation system.

ABB in Ludvika has delivered live tank circuit breakers with composite insulators for the most severe conditions, from marine climate to desert and/or industrial polluted areas.

Reference list can be presented on request.

Composite insulators with silicone rubber sheds
Because there is no need to compromise on safety and performance.
Controlled Switching with Switchsync™

Suppression of switching transients
There are several important circuit breaker applications where random closing or opening instants may lead to severe voltage and current switching transients. These transients occur in the main circuits, but may also induce transients in control and auxiliary circuits, as well as in adjacent low voltage systems. The switching transients are associated with a variety of dielectric and mechanical stresses on the high-voltage equipment, and may cause gradual or immediate damage to the system or the equipment. Induced transients may lead to a variety of disturbances, e.g., in substation control and protection systems, computers and processors, or telecommunications.

Normal energizing of shunt capacitors, shunt reactors and power transformers may cause severe transients - high overvoltages, under-voltages, or high inrush currents. Upon de-energizing of shunt reactors, reignitions will occur, resulting in steep voltage surges. The magnitude of the transients depends on the point-on-wave where closing or opening of the circuit breaker contacts occur. In a situation without controlled switching, sooner or later the switching instant will occur at the worst possible phase angle.

Even though a modern circuit breaker will have very low re-strike probability at switching of capacitive loads or harmonic filters, for statistical reasons a few occasional restrikes may occur during the course of a large number of switching operations. This risk of occasional restrikes may be eliminated by means of controlled opening operations.

Conventional countermeasures such as pre-insertion resistors, damping reactors or resistors, or arresters are used to limit the magnitude and effect of the switching transients, after they have occurred. In addition, system and equipment insulation may be upgraded to withstand the stresses. These methods, however, may be inefficient, unreliable or expensive, and do not treat the root of the problem.

Principle of Controlled switching
Controlled switching is a method for eliminating harmful transients via time controlled switching operations. Closing or opening commands to the circuit breaker are delayed in such a way that making or contact separation will occur at the optimum time instant related to the phase angle.

By means of Switchsync™ controllers, both energizing and de-energizing operations can be controlled with regard to the point-on-wave position, and no harmful transients will be generated.

The following example illustrates the general operating principle of a Switchsync™ controller, for energizing of a capacitor bank. In order to avoid switching transients, the making instant in this case shall be at voltage zero. For simplicity, only a single phase is considered.

Suitable circuit breakers
ABB live tank circuit breakers and disconnecting circuit breakers have spring operating mechanisms. For some of the variants, a motor drive is incorporated as an alternative. All these circuit breakers have stable operating times, which vary only to a limited extent with factors such as ambient temperature and control voltage.

For good results, and appropriate limitation of the switching transients, we recommend use of Switchsync™ controllers only with ABB’s SF₆ live tank circuit breakers.
Switching of Capacitor banks and Harmonic filters

Switchsync™ circuit breaker controllers for shunt capacitor banks and harmonic filters are normally used for control of closing operations.

A discharged capacitor is similar to a momentary short-circuit when connected to a power source. If energized when the source voltage is high, the connection results in voltage and current transients that may cause serious problems. Depending on the network configuration, the voltage surge may cause dielectric breakdown somewhere in the high voltage network, and low voltage equipment may suffer insulation damage or malfunction. With back-to-back capacitor banks, the inrush current may have high frequency and high amplitude. In extreme cases, it may threaten the mechanical integrity of both the capacitor bank and circuit breaker. Controlling the circuit breaker to energize a capacitive load at zero voltage across the contacts will eliminate harmful transients.

Figure 3 shows by means of an example how efficiently controlled switching eliminates the harmful switching transients related to energizing of a capacitor bank.

Figure 3.
Voltage transients when energizing one phase of a 72 kV capacitor bank.  
a. At an unsuitable point-on-wave position, close to the power frequency voltage peak, a high voltage transient is generated.  
b. With Switchsync™ controller, energizing occurs close to voltage zero, and no transient is generated.

In a normal three-phase situation, the three circuit breaker poles should close at different time instants. The time differences depend on the application.

For capacitor banks with grounded neutral, the three poles should close in succession with a time separation of 1/6 cycle (3.3 ms at 50 Hz or 2.8 ms at 60 Hz).

For capacitor banks with ungrounded neutral, two poles should close simultaneously at phase - phase voltage zero, and the last one 1/4 cycle later (5 ms at 50 Hz or 4.2 ms at 60 Hz).

In case of a single-pole operated circuit breaker, Switchsync™ will control each pole individually to make it close at the right time. For a three-pole operated circuit breaker, with only one operating mechanism, the poles are mechanically adjusted (staggered) in order to close at the right instant. For switching of a shunt capacitor bank or harmonic filter, the actual choice of staggering depends on:

- Connection of the neutral of the load - grounded or ungrounded
- System frequency - 50 or 60 Hz

Opening of capacitor bank circuit breakers generally does not lead to any significant switching transients. The major reason is that the circuit breakers are designed to have very low risk of restrikes upon interruption of capacitive current. However, in special cases with severe conditions, the Switchsync™ may be utilized in controlled opening of capacitor bank circuit breakers. The aim is then to eliminate the small statistical risk that a re-strike may still occur, and the circuit breaker is controlled in such a manner that short arcing times are avoided.
Suitable Switchsync™ controllers for capacitor bank circuit breakers are:

- Three-pole operated breaker:
  - For only closing; Switchsync™ E213
  - For both closing and opening; Switchsync™ E213

- Single-pole operated circuit breaker:
  - For only closing or for both closing and opening; Switchsync™ F236

Switching of Shunt reactors

Switchsync™ for shunt reactor breakers are normally used for control of the opening operations. Uncontrolled de-energizing will cause re-ignition in at least one circuit breaker pole. The very steep voltage transients caused by reignitions will be unevenly distributed across the reactor winding, with the highest stress on the initial turns. There is a risk that the voltage stress will lead to puncture of the winding insulation in the reactor, which in the long run may lead to complete breakdown. Insulation of nearby equipment may also be damaged. By controlling the contact separation to be sufficiently early before current zero, re-ignitions can be eliminated. The remaining voltage transient is a chopping overvoltage with relatively low frequency which is normally quite harmless. Controlled closing of shunt reactor circuit breakers is also applied in several cases. The switching case is similar to energizing of no-load transformers, and may cause high inrush and zero sequence current with associated electromechanical stresses. With controlled closing of the circuit breaker these phenomena are minimized.

Shunt reactor circuit breakers are normally single-pole operated due to the high rated voltages.

Suitable Switchsync™ controllers for shunt reactor circuit breakers are:

- Three-pole operated circuit breaker:
  - For only opening; Switchsync™ E213

- Single-pole operated circuit breaker:
  - For only opening or for both opening and closing; Switchsync™ F236

Switching of Power transformers

Switchsync™ for transformer circuit breakers are used for control of the closing operations, in order to limit inrush currents. Uncontrolled energizing, at unfortunate points-on-wave, causes high and slowly damped inrush currents. The result is mechanical stress on the windings, interference on secondary circuits from high zero-sequence current, and network disturbances by current harmonics.

![Graph of transformer operation](https://via.placeholder.com/150)

Figure 5.
Power transformer in steady state no-load conditions.

Figure 6.
Conditions with uncontrolled energizing of power transformer.

With symmetrical magnetic flux in the transformer core the current is small, but it increases rapidly even with moderate asymmetry due to increasing core saturation. Controlled energizing makes the flux symmetrical from the start.

The making operation should be made at an appropriate time instant, under consideration of the residual flux of the transformer core.
There are basically three ways to operate the circuit breaker:

1. When residual flux may be disregarded, it is sufficient to control the closing operations. This straightforward method will limit the highest inrush current magnitudes even if there should be residual flux.
   A suitable controller is Switchsync E213.

2. The opening operations of the circuit breaker are controlled in order to achieve a defined and repeatable residual magnetic flux in the transformer core. The procedure is normally to interrupt the no-load current close to a natural zero passage, which results in minimum flux in the core. The subsequent closing operation is then controlled in order to minimize the inrush current, based on this knowledge. Sometimes, however, a higher value of residual flux is chosen, as this will be associated with lower pre-arcing stress of the circuit breaker at the subsequent closing operation. This also improves the precision of the targeting process.

   The method is suitable for regular planned switching of transformers under no-load conditions. It is applicable in situations where the same circuit breaker will always perform the making and breaking operations.
   A suitable controller is Switchsync™ F236.

3. Opening operations are performed at random, while the resulting residual flux is determined by integration of the transformer voltage. The voltage signals to the controller for this process may be taken from normal VTs or CVTs adjacent to the transformer.

   Based on the calculated residual flux, the subsequent closing operation is then controlled in such a manner that the inrush current is minimized. In this mode of operation, the residual flux may vary considerably from one operation to another and the actual controlled making operations will take place at varying time instants in relation to the supply (reference) voltage.

   The method is mainly suitable for situations with unplanned operations, under varying switching conditions and also works when opening operations occur in connection with faults in the system. Since each pole needs to be controlled independently, the method requires single-pole operation of the circuit breaker.
   A suitable controller is Switchsync™ T183.

Switching of EHV lines

The traditional method for limitation of switching overvoltages during closing or reclosing operations of unloaded EHV lines is to use circuit breakers equipped with closing resistors. However, controlled switching of the line circuit breakers is increasingly considered as an alternative, and then often as part of a solution where surge arresters are also applied for optimal limitation of the switching overvoltages. Circuit breakers at this voltage level are generally single-pole operated.

For uncompensated lines, controlled switching of the circuit breakers may be arranged in two different ways:

1. Trapped charge on the line, resulting from the opening operation, is not recorded. When closing, the circuit breaker is controlled to make the current approximately when the instantaneous voltage in the substation is zero. In this manner limitation of high overvoltages is achieved irrespective of the actual trapped charge. This is a straightforward method, and often the resulting overvoltage level is acceptable, especially when applied in combination with surge arresters. In many cases the trapped charge will actually be zero or close to zero. This will be the case when sufficient time has elapsed from the opening operation, or even at rapid reclosing operations, if the line is equipped with magnetic voltage transformers.
   A suitable controller is Switchsync™ F236.

2. More efficient limitation of the switching overvoltages is achieved when the trapped charge on the line is recorded, and taken into consideration by the controlling device. This solution is especially useful in situations when considerable trapped charge is to be expected; i.e. for rapid reclosing operations in situations when CVTs are used. The initial magnitude of the trapped charge can be recorded by the CVTs.
   A suitable controller is Switchsync™ L183.

For shunt compensated lines, the interaction between line capacitance and reactor inductance will lead to voltage oscillations of the healthy phases after interruption. In this case, due to the oscillating voltage shape on the line, the voltage transformers connected to the line will provide correct voltage signals.

Controlled switching requires use of single-pole operated line circuit breakers. Reclosing may be set to occur slightly after phase-to-ground supply side voltage zero.
   A suitable controller is the Switchsync™ F236, connected in the same manner as for uncompensated line.
Adaptation control

All Switchsync™ controllers are equipped with special functions to control the result of a controlled switching operation.

The adaptation control can be arranged in different ways and for both controlled closing and controlled opening.

Deviations from the intended targets may be caused by variations in the operating conditions. The operating conditions that may cause changes of the circuit breaker operating times are, for example, gradually increasing contact burn-off caused by many switching operations, change of ambient temperature and variations of the auxiliary voltage.

The functioning principle of the adaptation control is that a detected error from the target will be compensated for in the next controlled operation.

If the circuit breaker should have a change in operating time from the value assumed by the Switchsync™ controller, then the adaptation feedback signal from a sensor or transducer will appear either slightly later or earlier than expected. When an error has been observed by the controller, the internally created waiting time will be modified for the next operation in such a way that the circuit breaker will be guided back to the intended target.

A typical arrangement for detection of current start is shown in Figure 7.

![Figure 7. Example of shunt capacitor bank energizing with current start feedback loop.](image)

For single-pole operated circuit breakers, the adaptation control can be arranged for each pole individually.

In the case of three-pole operated circuit breakers with mechanical staggering, only one pole will be supervised. The other two poles are mechanically linked to the controlled one.
Range of Switchsync™ controllers

The Family of Switchsync™ controllers consists of:

<table>
<thead>
<tr>
<th>Switchsync™ controller</th>
<th>Main application</th>
<th>Controls circuit breaker operation</th>
<th>Circuit breaker operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>E213</td>
<td>Shunt Capacitor Banks, Shunt Reactors</td>
<td>Open and/or Close</td>
<td>Three-pole</td>
</tr>
<tr>
<td>F236</td>
<td>Shunt Capacitor Banks, Shunt Reactors, Transformers</td>
<td>Open and Close</td>
<td>Single-pole</td>
</tr>
<tr>
<td>T183</td>
<td>Transformers</td>
<td>Close</td>
<td>Single-pole</td>
</tr>
<tr>
<td>L183</td>
<td>Uncompensated Transmission Lines</td>
<td>Close</td>
<td>Single-pole</td>
</tr>
</tbody>
</table>

All controllers have provisions for adaptive input to compensate for systematic variations in operating time of the circuit breaker.

In addition, Switchsync™ F236, T183, and L183 have provisions for two external, predictive inputs (e.g., temperature variation, control voltage). These functions make it possible to achieve added precision in the timing of the controlled circuit breaker. They also have a data memory that stores information on switching times, thus permitting condition monitoring of the circuit breaker. Sensors for compensation purposes and communication software for all controllers except E-model are accessories that are ordered separately.

Type designation
The type designation of a Switchsync™ controller gives information about its functionality.
The letter is a generation and application identification, while the subsequent numbers provide the following information:

<table>
<thead>
<tr>
<th>Type designation</th>
<th>Number of command inputs (open or close)</th>
<th>Number of adaptive channels</th>
<th>Number of command outputs to controlled circuit breaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>F236</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T183</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L183</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Installation
The point-on-wave controllers type SWITCHSYNC are type-tested with respect to immunity against vibrations with normal severity. The controllers shall NOT be installed in a cubicle directly attached to the circuit breaker frame work.
The recommended location for installation of the POW-controllers is in a control cubicle in a control room or in a relay house.

More information
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.
The OLM2 monitor is a measuring data acquisition unit optimized for on-line analysis of high-voltage circuit breakers. The electronic circuit is fitted into an EMC shielded aluminum profile housing. The aluminum housing has screw terminals for all external connections.

The OLM2 units have a limited data storage capacity. To fully use the flexibility of the OLM System, a data storage device (server computer) is required at the substation level. Communication to and from the monitoring units within a substation is done using an OLM-bus (a modified RS 485 bus), using a twisted pair shielded cable suitable for RS 485. Another option is using optic fiber, this requires optical modems at both ends.

From the server computer in the substation to the location where detailed analysis is performed, data can be transmitted using any existing communication means supported by Windows®. External systems, such as SCADA can easily make use of the data obtained through the OLM.

Data acquisition starts when an OLM2 is triggered by either a coil input (trip or close), an input to the motor of the operating mechanism or an alarm. For each operation of the circuit breaker a complete image of the recorded parameters is stored into the unit, including local time and temperature (ambient and inside operating mechanism).

The stored data is then transferred to the server computer and is then accessible for remote analysis using the OLM Explorer software. With this software a detailed analysis of all circuit breaker parameters is possible including trend analysis.

The following parameters may be monitored: operating times, coil currents, contact travel (giving information about speed, overtravel and damping), motor current including spring charging time, SF₆-density. Phase currents can be measured as an option to determine the contact erosion.

**Design**

An OLM2 unit consists of a signal processor with programmable logic. Most internal functions can be modified by firmware or software changes, which means that it can easily be adapted to any type of equipment. The OLM2 units have their own internal watchdog with alarm function.

The software provided together with the OLM consists of three parts:

1. **OLM Installer**, used for installation of the individual units
2. **OLM Server**, used for communication with the individual OLM2 units on a bus and the server computer (usually a PC) in the substation;
3. **OLM Explorer**, the data analysis and supervision tool. The OLM Explorer software also hosts a server engine that communicates with server computers.

Example of the presentation of the motor current.
Monitored data

**OLM2-unit:**

- Internal temperature
- Power supply voltage and current
- Coil circuit and operating currents
- Motor circuit, operation current and time
- Operating times
- Time between operations
- Monitoring equipment functions (watchdog)

**Storage capacity OLM2-unit:**

- Last 32 alarm status records
- Last 8 contact status records
- Last 16 motor operation records

**Monitored function categories through OLM Explorer:**

- Status signals (circuit breaker open or closed)
- Closing operation
- Opening operation
- Close-open operation
- Motor operation

From the function categories the following parameters are derived and supervised:

- Operating times
- Operating speeds
- Coil armature time
- Coil peak current
- Damping time
- Overtravel and rebound
- Counters recording the number of operations and number of motor operations
- Motor peak current and spring charging time
- Internal temperature of the operating mechanism
- Ambient temperature;
- Power supply voltages and currents (OLM2 unit and heaters)
- SF₆ density, with trend analysis
- Contact wear (optional)
- Contact stroke and contact position

The software is delivered with the OLM System and it contains a feature for automatic update of the software free of charge.
OLM2
On-Line Monitoring System

1. Scope of supply
The following components are included in the delivery of the OLM System.

1.1 Hardware
1.1.1 OLM cubicle
The cubicle containing the OLM2 unit as well as the wiring of all hardware included in the cubicle.

Cable glands for cable entry in the operating mechanism are included.

1.1.2 Current transformers for trip and close coil currents
2 pcs. current transformers, one for measurement of close coil current and one for measurement of trip coil current, located in the OLM cubicle.

1.1.3 Shunt for motor current
1 shunt for measurement of motor current is located in the OLM cubicle.

1.1.4 Travel transducer
Incremental transducer for measurement of contact travel including hardware for fixing and cable. The travel transducer is fitted to the circuit breaker during installation of the OLM System.

1.1.5 Temperature sensors
Two PT 100 (including cable) for measurement of ambient temperature internal temperature of the operating mechanism.

The temperature sensor for the ambient temperature is fitted to the underside of the OLM cubicle and connected to the OLM2 unit. The temperature sensor for the internal temperature needs to be fitted during installation of the OLM System.

1.1.6 SF₆ density sensor
One or three SF₆ density sensors depending on whether the circuit breaker is three-pole or single-pole operated.

The density sensors are fitted during installation of the OLM System.

1.2 Software
The OLM2 System is delivered with a CD-ROM containing the following software:

− The OLM software with user manuals;
− Configuration file for the individual OLM2 units;
− Parameter file for OLM Explorer;
− The installation manual.

1.3 Drawings
When the OLM System is delivered together with the circuit breaker, the circuit diagram and wiring table are adapted to receive the wiring from the OLM cubicle.

2. Items not included in the delivery
2.1 Current transformers for line current measurement
Line current measurement is an option and the current transformers necessary are not included in the standard delivery.

2.2 Server computer
Necessary for storage of data retrieved from OLM units.

2.3 Field bus converter
Connection of the server computer to the OLM bus (RS 485 bus) requires a converter. There are two ways to connect the converter, through a serial RS 232 port or through a USB port.

2.3.1 RS converter
Connection of a PC to the OLM bus requires a RS-422/486 to RS-232 converter.

2.3.2 USB to RS converter
When connection of the OLM-bus to a PC is done through a USB port, a USB to RS converter should be used.

2.4 Connection between OLM and server computer
A shielded, twisted pair cable suitable for RS-485 is recommended.

Alternative: optical fiber (requires optical modems at both ends).
Optional Accessories for cable installation

**Easy installations for cables**
A Roxtec CF (Compact Frame) cable entry kit combines reliable sealing of cables in cabinets with easy installation. The CF can handle several even pre routed cables through the same opening.

**Multidiameter**
The CF uses adaptable Multidiameter technology. This enables cables of a wide range of diameters to be sealed with a perfect fit, even when tolerances and deviations from nominal dimensions are considered. The modules are delivered with a center core as a substitute for a cable. This means the entry kit is adaptable to different cable sizes, and to different numbers of penetrations.

**Kit supplied**
This Roxtec CF kit are designed following the flange standard FL33 with a customized set of sealing modules to suit the most common cables sizes on up to 12 cables in the cabinet (as shown below).

For other dimensions, please contact:
ABB, High Voltage Breakers, Ludvika, Sweden.

**Simple maintenance**
A Roxtec CF can be opened and closed repeatedly for easy installations and simple maintenance. Another benefit is a built in spare capacity for possible new cables in the future.

**Benefit summary**
- Seals several cables and diameters
- Openable frame for pre routed cables
- Quick and easy installation
- Cable retention
- Small footprint in cabinet
- Rodent proof
- Halogen-free

Roxtec CF (2x) PS 80x120/ FL33: Handles 12 cables with outer diameter between 9.5-32.5 mm.
Seismic withstand capability

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 62271-300 specifies three values of maximum horizontal acceleration, 2, 3, and 5 m/s², corresponding to 0.2, 0.3, and 0.5 g, while IEEE 693 specifies 2.5 and 5 m/s², corresponding to 0.25 and 0.5 g.

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 will be amplified due to mechanical resonance. The degree of amplification depends on the eigenfrequency and damping of the circuit breaker, and is given by the response spectra, specified by IEC 62271-300 or IEEE 693. Sometimes also other response spectra are used, e.g. from Endesa or Edelca.

For the same maximum ground acceleration, the requirements of IEEE 693 are more stringent than those of IEC 62271-300. The major reason is that IEEE applies a safety factor 2 for the mechanical strength of the insulators, while IEC uses a factor 1. In addition the IEEE response spectra are more severe than those of IEC.

Seismic capability of LTB and HPL circuit breakers
All standard versions of HPL- and LTB-circuit breakers can withstand seismic accelerations below 0.3 g in accordance with IEC 62271-300 and below 0.25 g in accordance with IEEE 693 (see page 59 and 82). In order to withstand higher earthquake stresses the circuit breakers may be provided with reinforced support structures and/or reinforced insulators. In addition, and in order to handle the highest stresses, earthquake dampers may be applied on large circuit breakers.
Earthquake dampers
An earthquake damper will increase the damping of the natural oscillations 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.

Fig. 1. illustrates the principle of a damping unit. The support frame (1) is mounted on the bottom plate (3) on which four damping cylinders (2) are assembled. The piston rods (4) are fixed to the foundation bolts. Between the piston rod and the cylinder there is a piston system working, which is absorbing friction energy during motion. This provides damping for the complete circuit breaker.

Since the circuit breaker is hanging in the dampers, the forces of inertia during an earthquake can easily initialize the motion of the dampers without having to overcome the forces of gravity.

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. See Fig. 2.

An alternative method is to determine the eigenfrequencies and damping of the circuit breaker. This can be done e.g. by a snap-back test, where a mechanical stress is applied to the breaker, and suddenly released. Based on eigenfrequencies and damping, the resulting mechanical stress in critical parts of the breaker may be determined by means of calculations.

Fig. 1. Support column of HV circuit breaker with earthquake damping unit.

Fig. 2. 550 kV circuit breaker subjected to earthquake test on a shaker table. The highest mechanical stress occurs in the lower end of the vertical support column. The circuit breaker is equipped with composite insulators.
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 test 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</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(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>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mechanical operating test</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Resistance measurement (Main circuit)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric test (Auxiliary and control circuit)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Overpressure test</td>
<td>N/A</td>
<td>X</td>
<td>X</td>
</tr>
<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>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

A summary description of the ABB production and routine tests process is provided in the brochure 1HSM 9543 21-03. A detailed description of the routine tests is given in the document 1HSB 4154 09-646.
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.
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 $U_m \geq 300$ 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”.