Disconnecting Circuit Breakers
Buyer's and Application Guide

Power and productivity
for a better world™

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Introduction

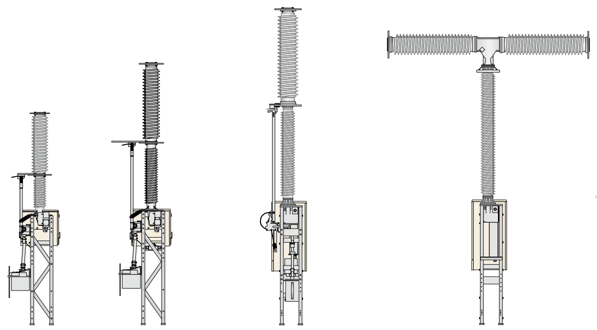
Compact air insulated HV switchgear with Disconnecting Circuit Breakers

ABB has a century-long experience of building substations for high voltage systems. In time with developing, designing and manufacturing of all vital switchgear apparatus also the switchgear design has been improved through the years.

One important step in the switchgear design during the latest years is that ABB's well known high performance circuit breakers now also are available as Disconnecting Circuit Breakers. This means that the disconnecting function is included in the circuit breaker and no separate disconnectors are necessary. By this move it is now possible to build substations with minimized need of maintenance and space, low failure rate, increased safety and low Life Cycle Cost, i.e. Compact Air Insulated Switchgear.

Product range

Disconnecting Circuit Breaker, DCB, can be delivered as separate apparatus or included in deliveries of complete switchgear bays.



Type	LTB 72.5	LTB 145	HPL 170 - 245	HPL 362 - 420	HPL 550
Rated voltage, kV	72.5	145	170 - 300	362 - 420	550
Rated current, A	3150	3150	4000	4000	4000
Circuit breaking current, kA	40	40	50	63	63
Rated frequency, Hz	50/60	50/60	50/60	50/60	50

Bay design

DCB use a circuit breaker support structure, on which also earthing switch and current transformer can be mounted. Further more a complete factory made busbar structure, with necessary primary electrical connections can be included.

Introduction

Line Entrance Module
A separate structure called Line Entrance Module, LEM, is available for supporting apparatus, which are not suitable to be erected on the circuit breaker structure. The breaker structure together with a LEM, are normally the only structures needed to house the HV-apparatus in a switchgear bay, built with DCB.

Primary switchgear apparatus
ABB offers a complete range of primary apparatus for use in Air Insulated Switchgear. Further information will be found in the Application and Buyers Guide for each product according to table below.

Product	Buyers Guide	Application Guide
Live Tank Circuit Breakers	1HSM 9543 22-00en	1HSM 9543 23-00en
Outdoor Instrument Transformers	1HSM 9543 42-00en	1HSM 9545 40-00en
Surge Arresters	1HSM 9543 12-00en	-

Abbreviations

In this document abbreviations according to the list below are used.

CB	Circuit Breaker
DCB	Disconnecting Circuit Breaker
DS	Disconnecting Switch
ES	Earthing Switch/Grounding Switch
SA	Surge Arrester
CT	Current Transformer
CVT	Capacitor Voltage Transformer
VT	Voltage Transformer
PI	Post Insulator
BB	Busbar
PT	Power Transformer
AIS	Air Insulated Switchgear
GIS	Gas Insulated Switchgear
SF_6	Sulphur hexafluoride gas
OHL	Over Head Line
CL	Cable Line
SLD	Single Line Diagram
LEM	Line Entrance Module
CCC	Central Control Cabinet
MDF	Manual Disconnecting Facility
IED	Intelligent Electronic Device
MV	Medium Voltage
HV	High Voltage
S/S	Substation
LCA	Life Cycle Assessment
LCC	Life Cycle Cost

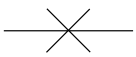
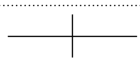
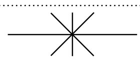
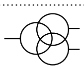
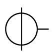
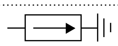
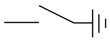
Definitions

Special definitions used in this document.
For definitions in general see IEC 60050.

Disconnecting Circuit Breaker	Circuit Breaker with integrated disconnector function. Interlocking of unintentional operation and blocking of closing function is integrated.
Line Entrance Module	Structure for supporting one or more switchgear apparatus such as Voltage Transformer, Surge Arrester and Earthing Switch.
Manual Disconnection Facility	A facility for manual disconnection of an apparatus, i.e. DCB or CT, in case of failure or for maintenance. Opening a bolted predefined connection normally performs the disconnection.
Availability (at a certain point of a network)	The fraction of time that the electric power is available at a certain point in the network • Availability depends on both planned and unplanned outages (maintenance and repair)
Unavailability (at a certain point of a network)	The fraction of time that the electric power is not available at a certain point of a network • Often expressed in hours per year
Reliability (at a certain point of a network)	The probability of failure-free supply of power at a certain point of a network during a specified period of time • The reliability concept only considers the system's ability to function correctly when it is in service, i.e. interruptions due to planned maintenance are not considered
Unreliability (at a certain point of a network)	The probability that one or more interruptions of the power supply will occur at a certain point of a network during a specified period of time • Often expressed as expected number of interruptions per 100 years
Intelligent Electronic Device	Unit equipped with a processor used for protection and control of electrical systems.

Symbols

In this document symbols as below are used in Single Line Diagrams.

Legend	
	Circuit breaker
	Disconnector
	Disconnecting Circuit Breaker
	Voltage transformer
	Current transformer
	Surge arrester
	Earthing switch

Switchgear specification

A complete Switchgear specification contains among other parts, specification of the primary electric apparatus and systems. Optimization of overall costs is a necessary measure in the deregulated energy market. The optimization of substations and their development is an objective continuously pursued by ABB. The focus is set on functional requirements, reliability and cost over the total life cycle.

Apparatus specification

The conventional way is to in detail specify all the equipment and the substation scheme. All apparatus are specified with quantity and data. Also the scheme, which often is based on traditional thinking, is fixed. In this case the asset owner get equipment which is exactly what he wants to have and what he is used to buy. This way of specifying the equipment normally gives no alternatives to propose other solutions with better performance to lower the Live Cycle Cost.

To open up for other solutions sometimes a clause saying that bidder are free to propose other equipment, is added to the inquiry.

Functional specification

The main task for a substation is to transfer power in a controlled way and to make it possible to make necessary switching/connections in the grid. Thereby another way of specifying the equipment when planning a new plant or refurbish an old, can be to make a functional specification.

In this case the bidder is free to propose the best solution taking in account all the possibilities that can be gained by using the best technique and the latest developed apparatus and systems, in combination with the requirements set up for the substation and the network.

For example, basic requirements in a functional specification can be:

- Number and type of system connections
- System electrical data
- Energy and transfer path through the system
- Unavailability related costs

Based on the functional specification ABB often can propose an alternative solution, which gives better performance to considerable lower costs.

To back up the decision-making, availability calculations, life cycle cost calculations, environmental influence report etc. can be provided by ABB.

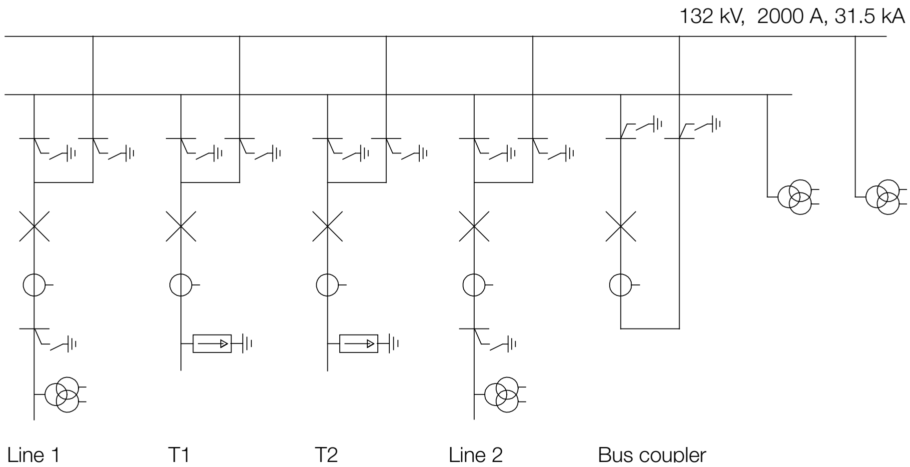
As the supplier takes a greater part of the design, it is important that all surrounding questions as scope of supply, demands from authorities, special design conditions etc. are known in the beginning of the project.

Switchgear specification

Example of apparatus specification

Inquiry:
Please quote for apparatus for a 132 kV switchgear in 5 bays according to specification and enclosed single line diagram:

5	High Voltage Circuit Breaker 145 kV, 3150 A, 31.5 kA
12	Motor operated Disconnector 145 kV, 2000 A, 31.5 kA with integrated motor operated Earthing Switch
6	Current Transformer 145 kV, 400/5/5/5/5 A. Core data……
9	Current Transformer 145 kV, 2000/5/5/5/5 A. Core data……
12	Voltage Transformer 145 kV, 132000/√3:110/√3:110/3 V. Core data……
12	Surge Arrester 132 kV……



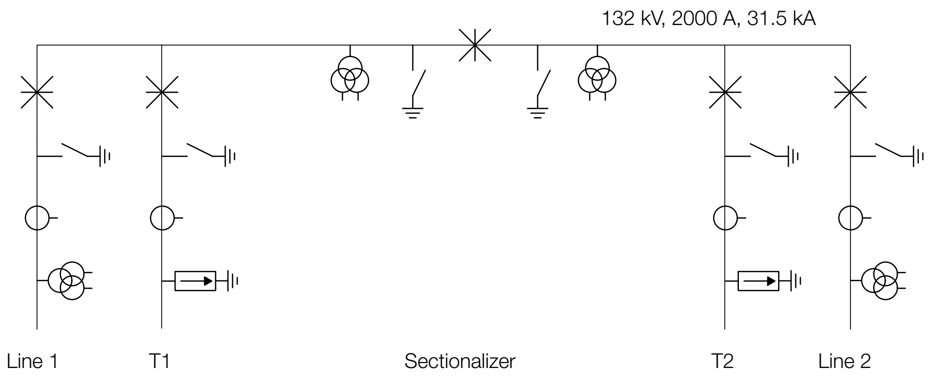
The suppliers will quote for their best prices for the apparatus and the customer can pick apparatus with the lowest price from different suppliers. The customer will hence have a cost optimized set of apparatus.

Example of functional specification

Inquiry:

Please quote for one 132 kV switchgear with 2 incoming lines and 2 transformer feeders.

An existing line shall be cut up and connected to the substation.
Maximum energy transfer through the substation is 120 MVA.
Power can flow in either direction. Maximum I_k 21 kA.
Transformer data 132/11 kV, 40 MVA, U_k = 8%
Planned maintenance can be done in low load periods but one of the transformers must always be in service.



In this case ABB will quote a solution with Disconnecting Circuit Breakers, which will give an optimized total cost. The customer will have a quotation of complete switchgear with a minimum of apparatus and high availability.

The Single Line Diagram shows a solution with Disconnecting Circuit Breakers.

Availability

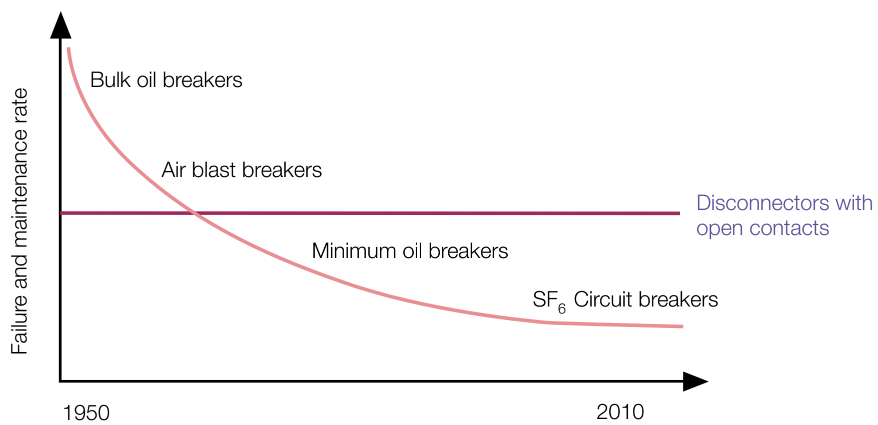
Availability and reliability

A major concern of a substation owner or operator is to minimize outages caused by scheduled maintenance, as well as repair work after possible failures. Ways to achieve this goal is equipment with low maintenance requirements, and suitable substation configurations. The "quality" of a certain substation in this respect is often expressed as availability (or unavailability). The availability, e.g. of an outgoing bay in a substation, is the fraction of time that electric power is available at that point. The unavailability, i.e. the fraction of time that electric power is **not** available, is normally expressed in hours per year.

Another major concern is to avoid any blackouts for power consumers, or loss of connection e.g. to generating power stations. Such events are entirely related to unplanned outages due to faults (since planned maintenance would not be allowed to give such consequences). The "quality" of a certain substation in this respect is often expressed as reliability (or unreliability). The reliability, e.g. of an outgoing bay in a substation, is the probability of failure-free supply of power at that point during a specified period of time. The unreliability may be expressed as expected number of interruptions per years, or as outage time in hours per year.

Evolution of circuit breakers and disconnectors

Development in CB technology has lead to significant decrease of maintenance and increase of reliability. Maintenance intervals requiring de-energizing of the primary circuit, of modern SF_6 CBs is 15 years or more. At the same time development of open air DSs has focused around cost reductions by optimizing the material used, and has not given significant improvements in maintenance requirements and reliability. The maintenance interval for open-air DS main contacts is in the order of 2-6 years, differing between different users and depending on the amount of pollution due to industrial activities and/or "natural" pollution such as sand, salt.



Reliability of CBs has increased due to evolution of primary breaking technology, from air blast to minimum oil, and into today's SF_6 type of CBs. At the same time the number of series interrupters has been reduced and today live tank CBs up to 300 kV are available with only one interrupter per pole. Removal of grading capacitors for live tank CBs with two interrupters has further simplified the primary circuit and thus increased the reliability. Today CBs up to 550 kV are available without grading capacitors, enabling the development of DCBs up to this voltage level. Operating mechanisms for CBs have also improved going from pneumatic or hydraulic to spring type leading to more reliable designs and less maintenance.

Calculations

Computer software for availability and reliability calculations is available within ABB. This makes it possible to compare different substation solutions. It is easily found that configurations containing conventional disconnectors in most cases give a higher unavailability and unreliability than configurations with DCBs.

Improved availability with DCB

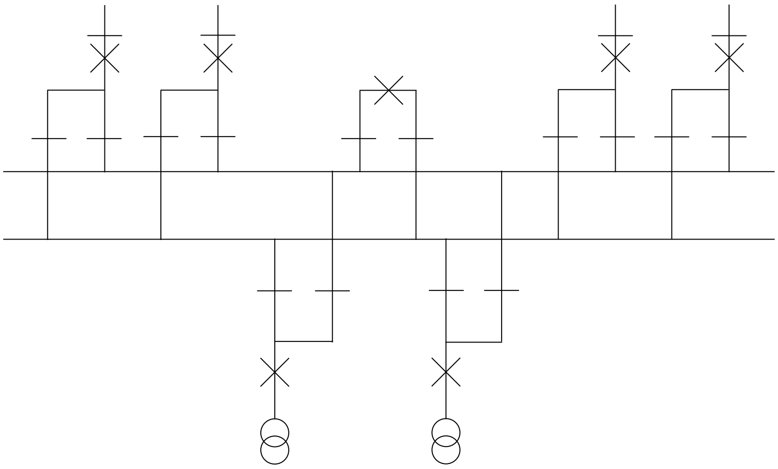
A typical power path through a substation may be divided into three main parts: line, power transformer and switchgear. Lines and power transformers have relatively high maintenance requirements. They are the dominating cause for maintenance outages in substations supplied by single radial lines, or with only a single transformer. In such cases maintenance of switchgear equipment is of secondary importance. On the contrary, if power can be supplied from more than one direction and the substation is equipped with parallel transformers, the overall unavailability of the substation, due to maintenance, may be directly related to the switchgear equipment. Decisive factors are then the HV equipment used, as well as the configuration (single line diagram) of the substation.

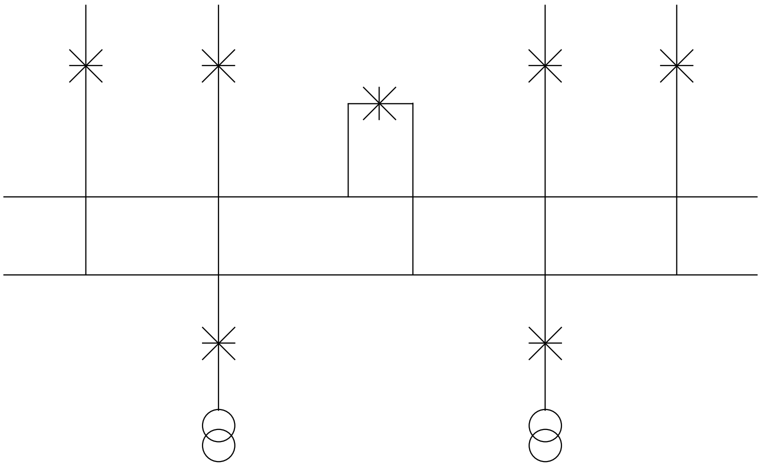
The dominating reason for unavailability of a certain part of a substation is (scheduled) maintenance.

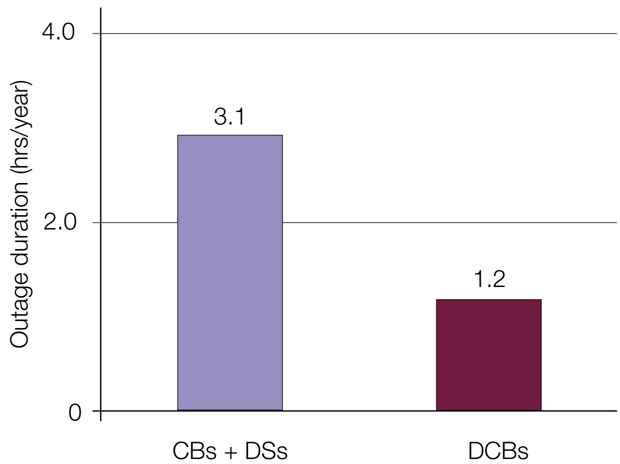
In the past when CBs were mechanically and electrically complicated and therefore needed a lot of maintenance the focus was on how to isolate the CBs for maintenance and keeping the other parts of the substation in service. The substations were accordingly built with CBs surrounded by a lot of DSs to make it possible to isolate and maintain the CBs. Now, since modern CBs need less maintenance than conventional DSs, it gives better results to use DCBs.

As an example, a comparison is made between a traditional double busbar solution with separate CBs and DSs versus a sectionalized busbar solution with DCBs including manual disconnecting facilities MDF. The 132 kV substation has four overhead lines, two power transformers and one bus-coupler or bus-section CB. Maintenance intervals assumed were 5 years for open air DS and 15 years for CB and DCB. Introduction of the DCB thus reduces the average unavailability due to maintenance from 3.1 to 1.2 hours per year.

Availability







The reduction of maintenance activities will give the following advantages:

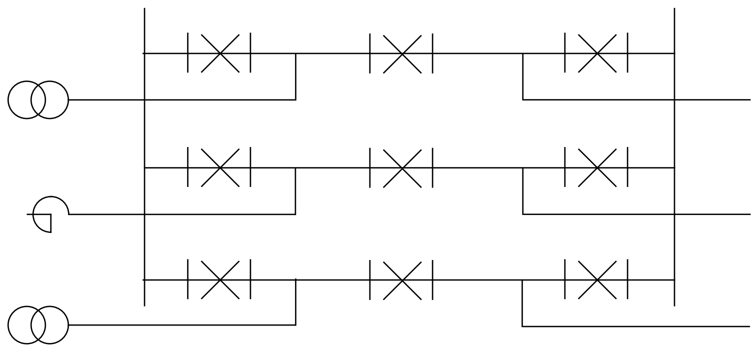
- More satisfied consumers, depending on substation/network topology the maintenance can lead to loss of power supply to some consumers
- Less risk for system disturbances (black-outs) since the risk for primary faults during a maintenance situation is higher than during normal service (people in the substation) together with a “weaker” system due to the maintenance (not all equipment in service)
- Less cost for manpower to make the actual maintenance work at site
- Higher personnel safety since all work in the substation high voltage system is a potential risk for injury of the personnel due to electrical shock, falling from heights, etc.

Improved reliability with DCB

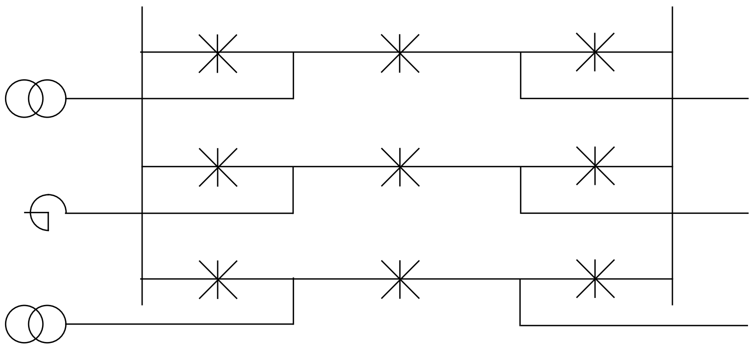
For single line configurations with only one CB per bay, a primary fault on one of the outgoing objects plus CB failure for that bay would lead to de-energization of one busbar section. A failure in the bus-section or bus-coupler breaker will lead to loss of the whole substation.

For important substations it might not be accepted from system security perspective to have a risk of loosing the whole substation at a primary fault. To make the substation “immune” against busbar faults and to minimize the disturbance if a CB fails to open at a primary fault, 1 ½-breaker or 2-breaker configurations can be used.

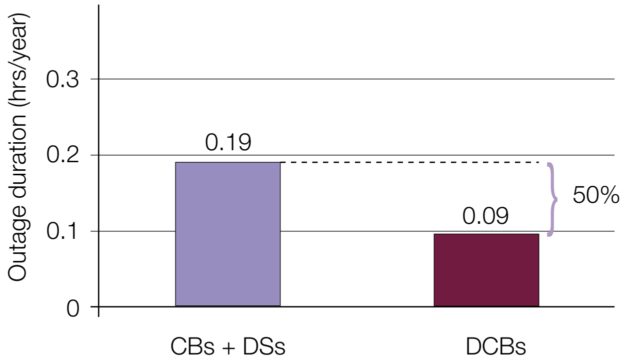
As an example, consider a typical 420 kV substation with three OH-lines, two power transformers and one shunt reactor. A comparison is made between a traditional type of solution with CBs and DSs versus a solution with DCBs including manual disconnecting facilities MDF.



Availability



Outages of an incoming/outgoing bay due to faults in the switchgear are shown in the diagram. Such unplanned outages may be very problematic and lead to unacceptable loss of power supply to consumers. Failure frequency input are taken from international statistics sources such as CIGRÉ, which gather information from actual apparatus in service. Since the DCB is very similar to a traditional CB, failure statistics is assumed the same for CB and DCB. Introduction of the DCB thus reduces the outages with 50%.



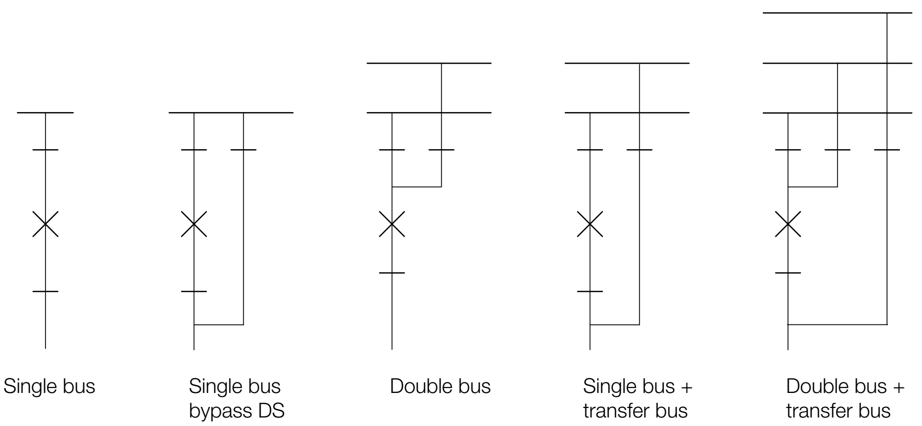
The examples shown are very typical. Substation solutions with DCB generally have much improved availability and reliability, compared to traditional solutions.

Switchgear single line philosophy

When designing a new substation a lot of considerations have to be taken. One of those is the Single Line Diagram (SLD). When elaborating the SLD the main goals are to create a solution, which gives highest possible safety for the staff and optimal service security. Many factors such as the load, the surrounding power network, effects of power loss, reliability and maintenance need for apparatus etc. are influencing the final decision.

Traditional approach

By tradition the most important aspect has been to isolate the circuit breaker in a system for maintenance or repairing. Examples of traditional SLD are shown below. Common for these is that the circuit breaker easily can be isolated without affecting the power flow in the busbar and, when bypass DS or transfer bus is used, not either in the actual load.



On the other hand, if a CB in such a system fails to open, all the busbars have to be deenergized before the CB can be isolated.

Furthermore even the disconnectors had to be maintained and to make that possible without taken the complete S/S out of service, double busbars were introduced. I.e. the main reason for double busbar systems is to allow DS maintenance.

Switchgear single line philosophy

New possibilities

As earlier shown under chapter Availability, modern SF_6 CBs have better maintenance and failure performance than DSs. That means that the traditional way of building S/S with many busbar systems and DSs rather decrease the availability than increase it. Taking only above into consideration the best way to increase the availability is to delete all DS and only use CBs. However, due to safety aspects a disconnector function is necessary. In a Disconnecting Circuit Breaker this disconnection function is integrated in the circuit breaker and it is then possible to design DS free S/S solutions.

DCB is suitable to be used in systems as:

- Single busbar system
- Sectionalized single busbar system
- Double busbar/double breaker system
- Ring bus system
- Breaker and a half system

If double busbar or transfer bus system is a demand it can preferably be replaced by a double busbar/double breaker system.

Where to place the earthing switch?

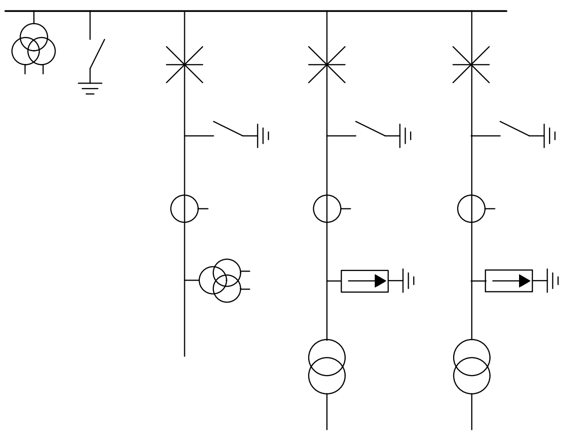
For single busbar applications the earthing switch is normally erected on the same structure as the DCB and the fixed contacts are placed on the lower connection flange. For higher voltages than 300 kV, the earthing switch is always placed apart from the DCB.

In systems where the object is fed from two directions, e.g. double busbar/double breaker or breaker and half systems, it can be more practical to place the earthing switch in the common connection point, separated from the DCBs. Operation of the earthing switches are recommended to be made from remote, hence a motor operated earthing switch shall be used.

There should always be one earthing switch placed on each busbar in the substation.

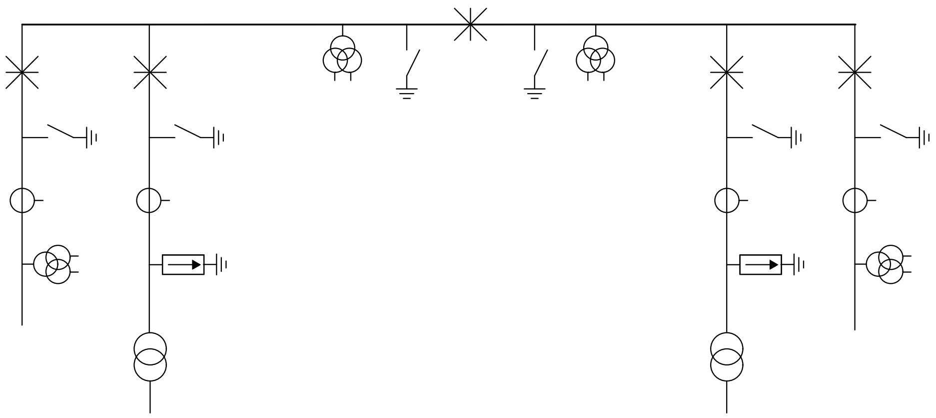
Single busbar

Single busbar is the least complicated system. It can preferably be used in smaller switchgear with single line feeding. The availability rate is almost similar to that for the line.



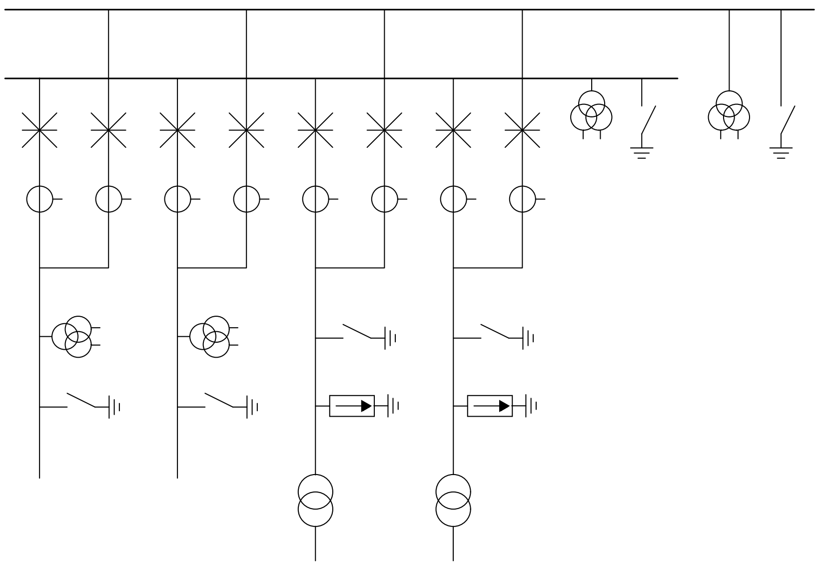
H-configuration/Sectionalized single busbar

H-configuration/Sectionalized single bus is used for smaller distribution S/S. With 2 incoming lines and 2 transformers, the probability that power is available on the MV bus is very high. For a distribution S/S a sectionalized single bus has better performance than a conventional double busbar system.



Double busbar/Double breaker

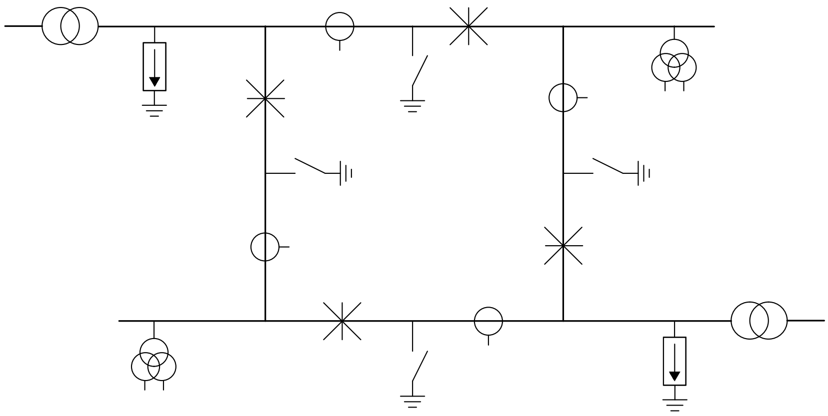
Double busbar/double breaker system has the best performance regarding availability, reliability and service conditions. As no DS are used there is no need for a bus coupler. By installing CTs in both CB branches all breakers in the S/S can normally be closed. If a failure appears in a line or busbar only the affected CBs are tripped.



Switchgear single line philosophy

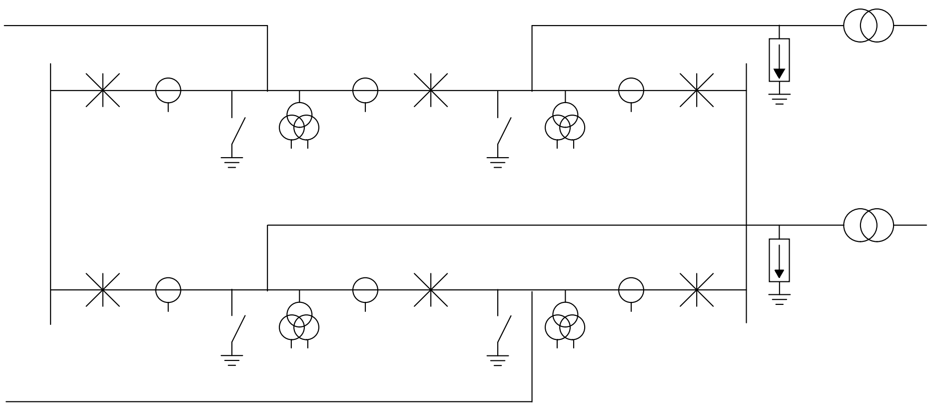
Ring bus

Ring bus is suitable for smaller S/S up to 6 objects. The availability performance is very good as each object can be fed from two directions. The disadvantage contra sectionalized single bus is that the busbar system is more complicated which need more space and affects the overview.



Breaker and a half

Breaker and a half system is used for bigger transmission and primary distribution S/S. Different ways of connecting the transformers are used. The availability and reliability is high as each object normally are fed from two directions. One disadvantage is that if one busbar is out of service, the two objects are connected to the other bus via one CB.



Disconnecting Circuit Breaker

The Disconnecting Circuit Breaker is based on ABB's well known circuit breakers LTB D and HPL B. The basic circuit breaker functions for a DCB are exactly the same as for a CB. The circuit breakers are described in the Live Tank Circuit Breaker, Buyers Guide, 1HSM 9543 22-00.

The additional feature for a DCB is that it is also approved as a disconnector. That means, when the CB is open, the normal CB contact set fulfills all DS requirements.

As the disconnecting function is inside the breaking chamber, there is no visible opening distance.

Blocking of CB

It is of highest importance that the CB remains in open/disconnected position when it is used as DS.

Because of that, the DCB is equipped with a mechanical blocking device which operates directly on the shaft that moves the CB main contacts. When the mechanical blocking is activated, it is impossible to close the breaker. Even if the closing latch of the CB accidentally releases, the CB will stay in open position.

This blocking device is operated by a motor unit, which allows remote operation.

The blocking device is prepared for manual operation but this is intended to be used only in emergency situations.

Electrical data according to Class 1 of IEC 62271-1: 110 VDC, 10 A, L/R = 20 ms

When the blocking is activated a padlock can be applied. The padlock mechanically prevents moving of the blocking device,

A clear sign indicates the position of the blocking device unit.

Three-pole operated CBs has one common blocking device for the three phases, while single-pole operated CBs has one blocking device for each phase.

Auxiliary contacts for the blocking unit

The motor unit is also equipped with auxiliary contacts for interlocking and indication purposes. The standard setup for the number of open and closed auxiliary contacts is specified for each product type.

Earthing switch (Grounding switch)

As there is no earthed part between live and disconnected contacts on a DCB, it is important to lead any eventual creepage current to earth just to secure that the disconnected part not will attain voltage. Because of that the DCB system shall be equipped with an earthing switch.

Design up to 145 kV
Locking device and earthing switch for Motor Drive

Blocking device, AD100, 72.5-145 kV DCB

The disconnecting circuit breaker is blocked in open position. The sign indicates blocked.

Blocking activated and padlock applied.

Blocking device AD100
The blocking device used, AD100, is mounted on the circuit breaker steel structure.

Blocking of the DCB is achieved when a steel plate is moved in position into the opening rod. In this way the circuit breaker is mechanically blocked in open position.

The blocking device is remotely or locally operated when both the DCB and earthing switch are in open position. This operation should be compared to blocking the disconnectors in open position in a conventional solution.

The standard setup contains 5 contacts NO and 5 contacts NC in open position and also 5 contacts NO and 5 contacts NC in closed position.

Electrical data:	Motor	450 W
	Heater	25 W

Earthing switch (Grounding switch)

The ES is placed outside the breaking chamber and the position of the earthing blades can clearly be seen from distance. I.e. you don’t have to come close to live apparatus to look through a peep-hole to see the position of the earthing switch. This is an important safety feature as the disconnection function not is visible.

For security reasons the operation of the ES shall be done remotely and hence it is equipped with a motor operated device AD350. It operates, via a linkage system, the earthing blades of the ES and indication labels shows the position clearly.

Electrical data:	Motor	450 W
	Heater	25 W

Earthing switch in unearthed position.

Earthing switch in earthed position.

Design up to 145 kV
Blocking device and earthing switch for BLK

Integrated blocking device for BLK, DCB 72.5 - 145 kV

Disconnecting circuit breaker unblocked in open position.

Disconnecting circuit breaker in blocked and padlocked position.

Integrated blocking device

The blocking device is integrated into the circuit breaker drive cabinet (BLK 222). LED indication shows blocked or unblocked status. There is a separate connection flange in the bottom of the cabinet for substation cable connections.

Blocking of the DCB is achieved when an aluminum plate is moved in position so that the operation lever in the BLK operating mechanism is blocked, hence operation of the CB is made impossible.

The blocking device is remotely or locally operated when both the DCB and earthing switch are in open position. The operation should be compared to blocking the disconnectors in open position in a conventional solution.

The standard setup contains 2 contacts NO and 2 contacts NC in open position and also 2 contacts NO and 2 contacts NC in closed position.

Electrical data:	Motor	50 W
	Heater	— W

Earthing switch (Grounding switch)

The ES is placed outside the breaking chamber and the position of the earthing blades can clearly be seen from distance. I.e. you don't have to come close to live apparatus to look through a peep-hole to see the position of the earthing switch. This is an important safety feature as the disconnection function not is visible.

For security reasons the operation of the ES shall be done remotely and hence it is equipped with a motor operated device, SM 800. It operates, via a linkage system, the earthing blades of the ES and indication labels shows the position clearly.

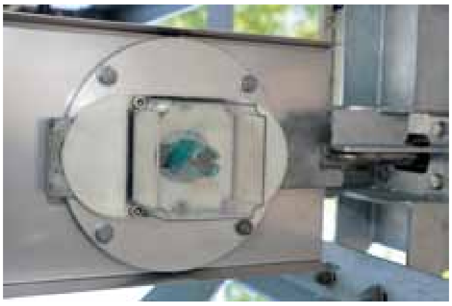
Electrical data:	Motor	800 W
	Heater	22 W

Earthing switch in open position.

Earthing switch in closed/earthed position.

Design 245 - 420 kV
Blocking device and earthing switch for BLG

Integrated blocking device for BLG, DCB 245 - 420 kV



Disconnecting circuit breaker unblocked in open position.

Disconnecting circuit breaker in blocked position.

Blocking device AD100

The blocking device used, AD100, is mounted on the circuit breaker steel structure.

Blocking of the DCB is achieved when a steel plate is moved in position into the opening spring rod. In this way the circuit breaker is mechanically blocked in open position.

The blocking device is remotely or locally operated when both the DCB and earthing switch are in open position. This operation should be compared to blocking the disconnectors in open position in a conventional solution.

Earthing switch (Grounding switch) for DCB 245 kV

The ES is placed outside the breaking chamber and the position of the earthing blades can clearly be seen from distance. I.e. you don't have to come close to live apparatus to look through a peep-hole to see the position of the earthing switch. This is an important safety feature as the disconnection function not is visible.

For security reasons the operation of the ES shall be done remotely and hence it is equipped with a motor operated device, BCM-F. It operates, via a linkage system, the earthing blades of the ES and indication labels shows the position clearly.

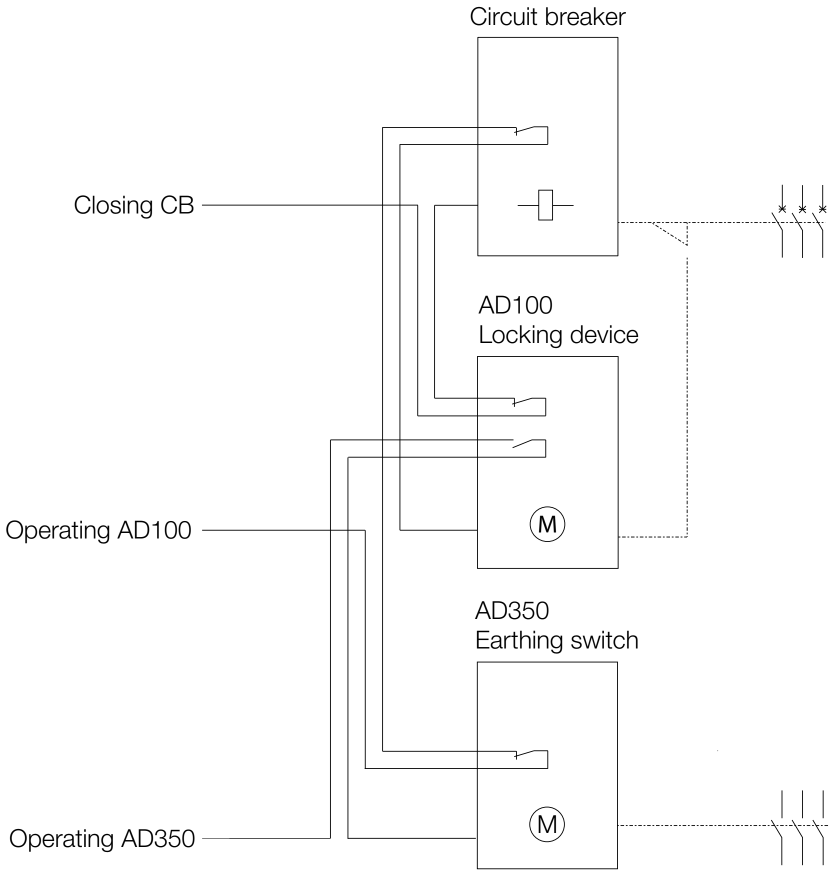
Electrical data:	Motor	650 W
	Heater	50 W

Earthing switch in open position.

Electrical interlocking

Besides the mechanical locking of an open DCB, electrical interlockings shall be applied as:

DCB closed	Locking inactivated and interlocked Earthing switch open and interlocked
DCB open and locking not activated	DCB can be operated Locking device can be operated Earthing switch operation interlocked
DCB open and locking activated	Earthing switch can be operated DCB operation interlocked
Earthing switch closed	Locking operation interlocked DCB operation interlocked
Earthing switch open and locking not activated	DCB can be operated Earthing switch operation interlocked
Earthing switch open and locking activated	DCB open and interlocked Earthing switch can be operated

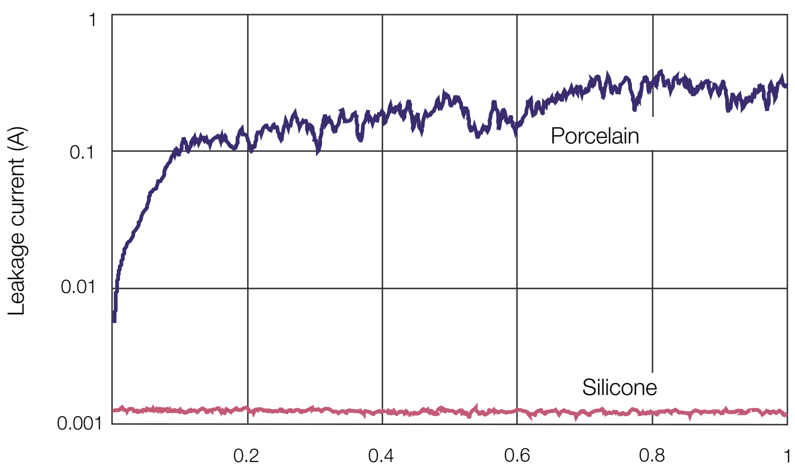


Principles of the electrical interlocking system

Design
Composite insulators

Composite insulators with silicone rubber shields (SIR) offer many advantages over traditional porcelain insulators and provide new possibilities to improve safety and availability. Distinguishing qualities are high flashover resistance, low weight and stability against UV absorption.

The high flashover resistance is obtained through the chemical nature of silicone which makes the insulator surface hydrophobic. As the hydrophobic surface prevents pollution to stay on it, the risk for current paths is minimized. The diagram shows the difference in leakage current between porcelain and silicone insulators during a salt fog test.



Leakage current over time at salt fog test

The low weight decreases the static forces on structures and foundations. This is also an advantage in earthquake areas as the dynamic forces will be much less. Easier transport and handling are also obtained by the lower weight.

The stability against UV absorption together with the high leakage current withstand give a product with eminent aging durability.

Furthermore the silicon rubber is non-brittle which minimize the risk for damages during transport, installation and service as well as in case of vandalizing. The non-brittle property also prevents scattering of pieces, dangerous for personnel and other equipment, in case off a puncture caused by internal overpressure or external damage.

More information about composite insulators can be found in the brochure “High Voltage products with composite insulators”, 1HSM 9543 01-06.

As a conclusion of above, ABB has chosen composite insulators with silicone rubber as standard for DCB.

Manual disconnecting facility

Sometimes it can be practical to disconnect a unit from the busbar or the line during maintenance or repair. This is not a special demand for solutions with DCB, but it has been emphasized as a tool to further decrease the unavailability.

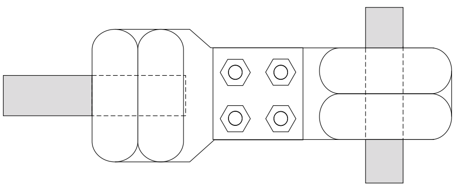
A Manual Disconnecting Facility, MDF, is a point in the switchgear prepared for fast opening up of the primary connection, e.g. between a line and the busbar. The work is so far intended to be done under voltage free and maintenance earthed conditions. When a DCB is disconnected in this way the other parts of the substation may be reenergized during work on the DCB itself.

The MDF consists of standard clamps and a wire or tube. The connection points for the MDF are arranged so that when the MDF is removed, there are necessary safety distances between the disconnected apparatus and the busbar or line. Thus the busbar and line can be reconnected to power during the maintenance or repair work of the apparatus.

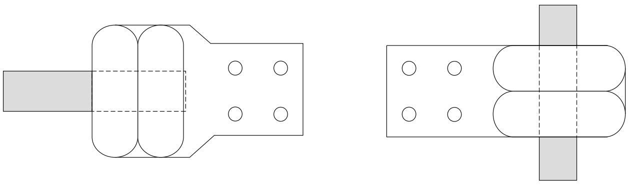
Operating a MDF for a three phase unit is intended to take less than 2 hours.

Note that a MDF is not to be compared with a disconnector as it is maintenance free and is intended to be used only on rare occasions.

Example of MDF



Closed



Open

Example from indoor substation, Sweden

Design

Steel structure

Steel structures for DCB, line entrance module and bay assemblies are made of hot dip galvanized steel.

Dimensions are adapted to the demands for mechanical endurance and electrical safety distances specified in applicable IEC standard.

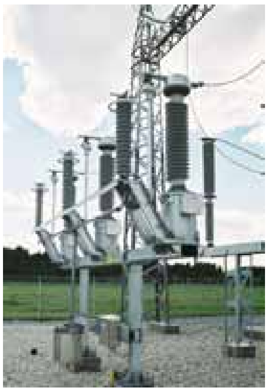
Necessary connection points for earthing grid are drilled in the structure.

For 72.5 – 145 kV the steel structure for the DCB also can house the current transformers. For 245 kV and above the CTs are placed on a separate structure.

Complete unit 72.5 kV

A complete unit containing DCB, ES, CT, CVT and SA on the same structure is available for 72.5 kV

Line Entrance Module



Line Entrance Module

Apparatus which not can be erected together with the DCB must have their own structure. For that purpose a line entrance module is available. The LEM can be equipped with CVT, ES and SA.

Bay design

For switchgear up to 300 kV pre-designed complete busbar systems with support structure and primary connections are available.

Hence it is possible to order complete factory made switchgear bays.

Seismic withstand capability

There are many zones in the world where earthquakes may occur, and where the equipment should be designed to withstand the corresponding stresses. To demonstrate the earthquake withstands capabilities ABB makes tests and calculations for the different apparatus and applications.

For seismic withstand capability please refer to Buyer´s Guide for respective apparatus.

Standards and testing

Applicable standards

Disconnecting Circuit Breaker

The applicable standard for DCB is IEC 62271-108. (High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72.5 kV and above)

This standard basically refers to the standard for Circuit breakers, IEC 62271-100 and for Disconnectors, IEC 62271-102.

That means that a DCB fulfills all normative demands for a CB as well as for a DS.

In addition to that, IEC 62271-108 provides how to interlock and secure a DCB against unintended operation as well as how to test the DCB to show the isolation performance after long time in service.

Other switchgear apparatus

All switchgear apparatus as Voltage Transformers, Current Transformers and Surge Arresters are tested according applicable standards. The apparatus are described in actual Buyer´s Guide as:

– Outdoor Instrument Transformers	1HSM 9543 42-00
– Surge Arresters	1HSM 9543 12-00

Type tests

All apparatus have passed type tests according to applicable standards. For further information refer to Buyer´s Guide according to above.

Selected specimens of complete switchgear bays have been type tested in order to verify the design.

DCB Combined function test (IEC 62271-108)

The DCB shall fulfill the dielectric requirements for the isolating distance not only in new condition but also after long time service. Therefore the dielectric withstand across the isolating distance shall be demonstrated after a mechanical operation test as well as after the specified short-circuit test duty.

Type test reports are available both as summary of type tests and as complete type test reports. The reports are distributed on request.

Standards and testing

Routine testing

The applicable standards for the different functions in a switchgear bay also describe the Routine Test procedure. Additional non-specified tests could also be performed if ABB finds it necessary to ensure safe and perfect operation.

Thus the Routine Test procedures for included apparatus are described in the Buyer's Guide for each apparatus as:

– Outdoor Instrument Transformers	1HSM 9543 42-00
– Live Tank Circuit Breakers	1HSM 9543 22-00

Quality control

ABB AB, 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.


BUREAU VERITAS Certification

Certification

Awarded to

High Voltage Products

consisting of HV Breakers and HV Components

Ludvika, Sweden

part of ABB AB, Division Power Products and Power Systems

Bureau Veritas Certification certify that the Management Systems of the above organisation has been audited and found to be in accordance with the requirements of the management system standards detailed below

Standards

SS-EN ISO 9001: 2008

SS-EN ISO 14001: 2004

OHSAS 18001: 2007

Scope of supply

Development, design, manufacturing, sales and after sales service of:

- Surge arresters and accessories of surge arresters including application for HVDC and reactive power compensation and transmission line arresters.
- Live tank breakers, breaker components and air insulated switchgear modules.
- Current transformers, inductive and capacitive voltage transformers and coupling capacitors for high voltage application.
- Power Capacitors and system for harmonic filtering and reactive power compensation.

Original Approval Date ISO 9001: 13 November 1992

Original Approval Date ISO 14001: 8 September 1998

Original Approval Date OHSAS 18001: 22 April 2009

Subject to the continued satisfactory operation of the organisation's Management Systems, this certificate is valid until: **25 April 2012**

To check this certificate validity please call +46 31 60 65 00

Further clarifications regarding the scope of this certificate and the applicability of the management systems requirements may be obtained by consulting the organisation

Jan-Olof Marberg, Technical Manager, Bureau Veritas Certification Sverige AB

Date: 22 April 2009

Certificate Number: 9000174/E

SWEDAC ACKREDITERING 1236 ISO/IEC 17021

Bureau Veritas Certification Sverige AB, Fabriksgatan 13, 412 50 GÖTEBORG, Sverige

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Environmental aspects

We in ABB have a clear direction to decrease the environmental stresses caused by systems and apparatus designed and delivered by us. Thus we are approved according to environmental management systems ISO 14001 and ISO 14025.

Therefore, during the development of DCB and systems based on DCB, the environmental aspects always have been in the centre.

SF_6 gas - Live tank Circuit breakers

DCB is based on ABB's SF_6 filled live tank circuit breakers.

SF_6 is a gas with outstanding isolating and extinguishing qualities and is for the time being the only technical and commercial alternative for HV CBs. However, SF_6 has the drawback that it contributes to the greenhouse effect and must therefore be handled with caution. First of all the used amount must be kept as low as possible, and that is the case for ABB's designs, which e.g. contains less than 10 kg for a 145 kV DCB. Then the leakage rate has to be minimized. IEC allows a leakage of maximum 0.5% per year which is fulfilled with good margins. Laboratory tests have shown leakage rates less than 0.1% for ABB's live tank circuit breakers. Hence, the low volume together with the low leakage rate leads to outstanding low SF_6 emissions.

Furthermore, ABB has well described routines how to handle SF_6 from production of the CB till taking it out of service.

Use of raw material

As the number of primary apparatus is decreased compared to conventional solutions, the total use of raw material is reduced significantly. This refers to all kinds of material which normally is used in switchgear apparatus as: steel, aluminum, copper, plastic, oil etc.

Number of foundations - use of concrete

Switchgear based on DCB need much less foundations than conventional switchgear as the number of primary apparatus is less. Also the system where apparatus can be mounted on shared structures minimizes the number of foundations. Typically, a substation with DCBs needs only half or less of the number of foundations compared to a conventional substation.

Transports

Transports are considered as a big contributor to the negative environmental influence. The DCB system will of course reduce that part as the less use of material and the decreased number of apparatus implies less transports.

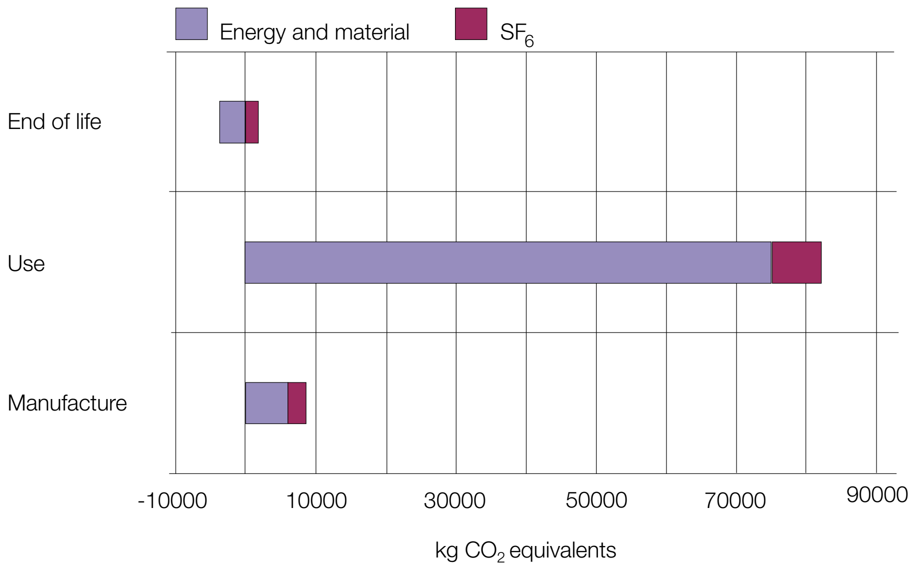
Example - LCA study for 145 kV DCB with earthing switch

A LCA study was made for a 145 kV DCB, including the operating mechanism, earthing switch and support structure. The study took into consideration the environmental impact of the entire life cycle, and fulfilled the requirements of ISO 14040. It was based on the following assumptions:

- 40 year life span
- Electrical losses for 50% of rated normal current, i.e. 1575 A per phase
- Three-pole operated DCB, resistance 32 μΩ/pole, heater 70 W continuous, plus 70 W thermostat controlled 50% of time

Several different environmental impact categories may be considered in LCA studies, such as acidification, ozone depletion and global warming.

In the present case, evaluation was made with regard to the global warming potential (GWP). This is generally the dominating impact category for products consuming energy during their lifetime. The result is expressed in kg CO_2 equivalents. The impact from electric energy consumption is based on a mix of power generation systems relevant for the OECD countries, and considering the LCA perspective: 0.6265 kg CO_2 per kWh.



As shown in the figure, electric energy consumption during the usage phase contributes most to the global warming potential. Resistive losses in the main circuit are responsible for 70% of this energy consumption. The rest is shared by the thermostat controlled heater (10%) and the anti-condensation heater (20%) in the operating mechanism. It was assumed that the thermostat controlled heater was connected during half of the usage phase.

The contribution during the usage phase related to SF_6 leakage to the atmosphere is less than 10% of the total. This is a result of the small gas volume and low relative leakage rate of the live tank design. The contribution was calculated assuming a relative SF_6 leakage rate of 0.1% per year, which is typical for this type of DCB. At end of life, it was assumed that 1% of the gas is lost, while the rest is recycled.

Example – Comparison of electrical losses

As seen in the previous example, electrical losses give the largest environmental impact. Therefore it is very interesting to compare the electrical losses for an arrangement with traditional DS-CB-DS to those of the DCB. The following additional data were used for the 145 kV DS-CB-DS arrangement:

- Three-pole operated CB, resistance 32 µΩ/pole, heater 70 W continuous, plus 70 W thermostat controlled 50% of time (i.e. the same data as for the DCB)
- Motor operated DS, resistance 59 µΩ /pole, heater 50 W continuous
- Connections between DSs and CB: 8 m Falcon ACSR, diam. 39.3 mm, 289 µΩ/pole

The results, valid for the 40 year time span, are shown in the table. The energy savings by using DCB correspond to almost 700 tons of CO_2, or around 17 tons per year. For a complete substation, with several bays, the difference will be even larger.

Switching equipment	Electrical energy consumed	Corresponding CO_2 release
	MWh	Metric tons
DS-CB-DS	1217	762
DCB	120	75

The losses also have a direct economical value. The difference in accumulated losses between the two solutions is more than 1000 MWh. (As an intellectual experiment you can compare the cost for these losses with the cost for the DCB system).

Substation design

Planning of a new S/S includes a lot of disciplines. In this document we will only touch those which are related to the difference between using DCB and conventional equipment.

Single line diagram

Factors influencing the SLD are the grid, the load, future extensions, unavailability aspects, costs, site etc.

By using DCB, complicated busbar systems can be avoided. This facilitates the switchgear design and allows solutions with highest availability rate and best overview to optimized cost.

Specification

The SLD is base for the specification which can be a complete apparatus specification or a functional specification.
An apparatus specification has the advantage that the projector exactly specifies what he wants and he will get equal quotations from all bidders.

A functional specification opens up for the bidder to propose other ideas regarding apparatus and systems and the bidder can sometimes quote more cost effective solutions.

Anyhow it is important that the inquiry allows the bidder to quote for alternatives to that specified in the specification, without being disqualified.

Switchgear Specification Manager

Irrespective of the way of specifying, the customer/projector may want to give technical requirements and data for the apparatus.

For this purpose a computer based tool, called Switchgear Specification Manager (SSM), is available by ABB.
Contact your local ABB representative for further information.

Safety distances

IEC and other standards prescribe distances in switchgear. Those standard values can sometimes be strengthened by the customer due to local conditions.

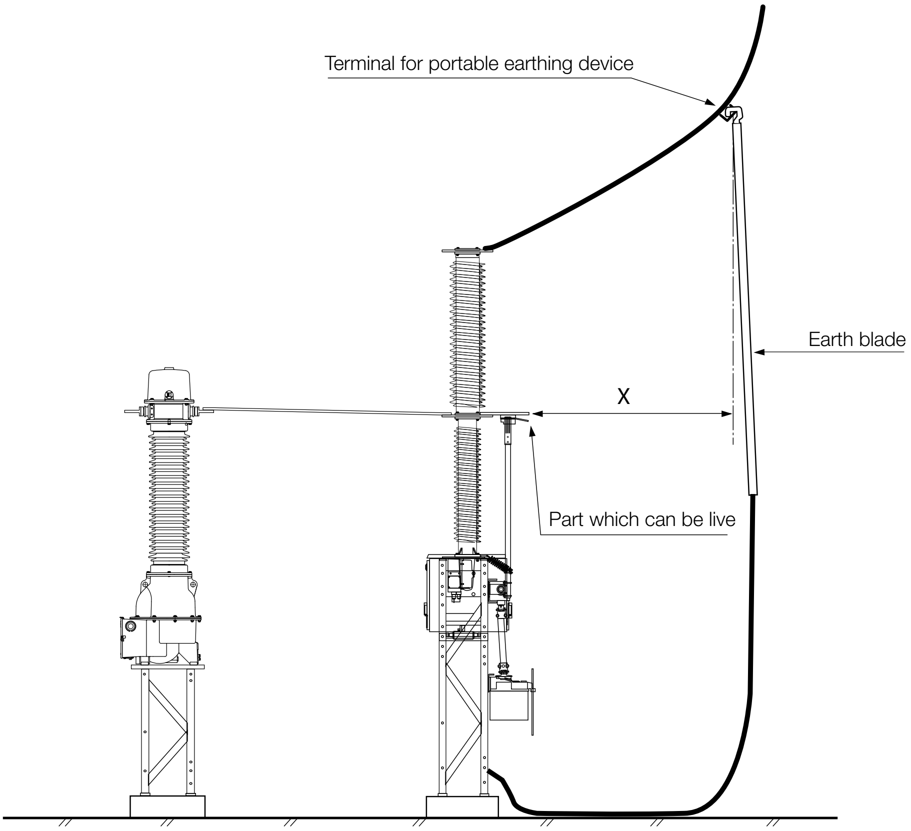
Special attention must be paid to the distance “To nearest live part” also called section clearance. This distance must be established between all live parts and the place in the switchgear where work shall be performed.

The table shows example values which always most be coordinated with the demands for the actual installation

	Example values for distances (mm)			
	72.5 kV	145 kV	245 kV	420 kV
Lowest insulator base to earth	2250	2250	2250	2250
Earth and lowest live part	3000	3770	4780	5480
Between phases	630	1300	2100	4200
Phase to earth	630	1300	2100	3400
Transport way profile	700	1520	2350	3230
To nearest live part	3000	3270	4280	4980

Maintenance earthing

When working in switchgear all metallic parts of apparatus or other parts, which shall be touched, must be connected to earth. This can be done either by fixed earthing switches or by portable earthing devices. Connection terminals for portable earthing devices are often preinstalled.



When installing the portable earthing connection terminals, it is important to consider all possible live parts and place the terminals so that the connection of the earthing device can be done in a safe way. See example distance X in the figure above.
X is dependent on voltage level and type of earthing device.

WARNING!

All work related to the circuit breaker shall be made with disconnected and earthed conductors. Follow all regulations and rules stated by international and national safety regulations.

Substation design

Three phase portable earthing device

Connection clamp for earth connection

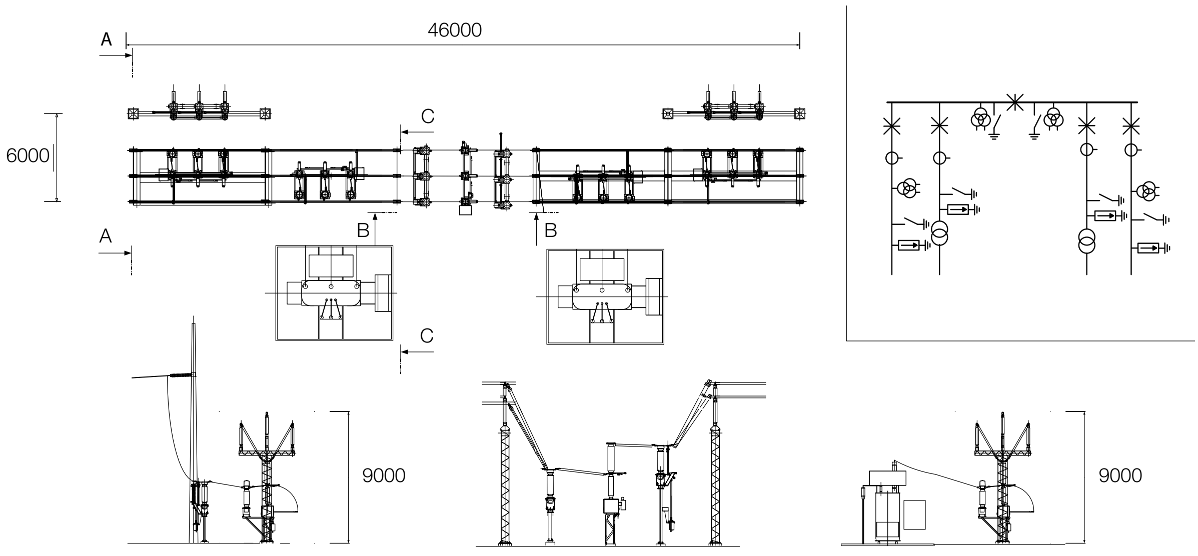
Phase connection terminal

Earthing device connected to phase terminal

Switchgear layout

ABB has the possibility to at short notice produce a layout proposal for DCB solutions, based on preconfigured building blocks. This early layout can be the base to find the best and final layout for the project.

The example below shows a switchgear for 145 kV with sectionalized single busbar system, two lines and two transformers.



Extension of existing substation

The different way to build a HV Switchgear bay with DCB compared to the traditional way with disconnectors makes the concept very useful when extending existing substations.

The disconnector free layout gives small dimensions for the extension. Very often it is possible to replace one existing bay with two new based on DCB

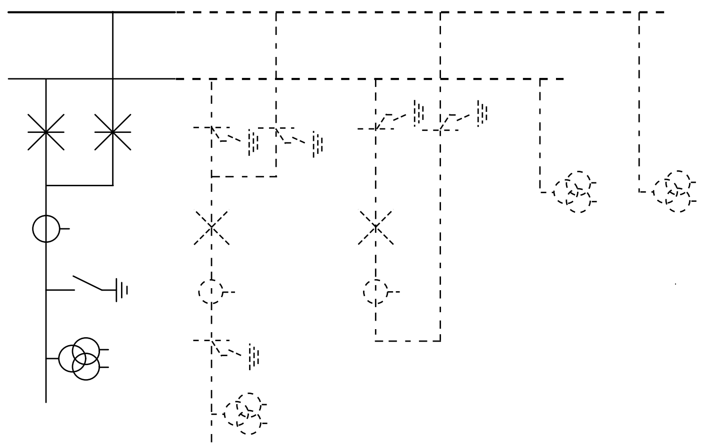
The solution depends on the new load, existing busbar system and space at site.

Single busbars are preferably extended just with a new bay with DCB instead of CB and DS.

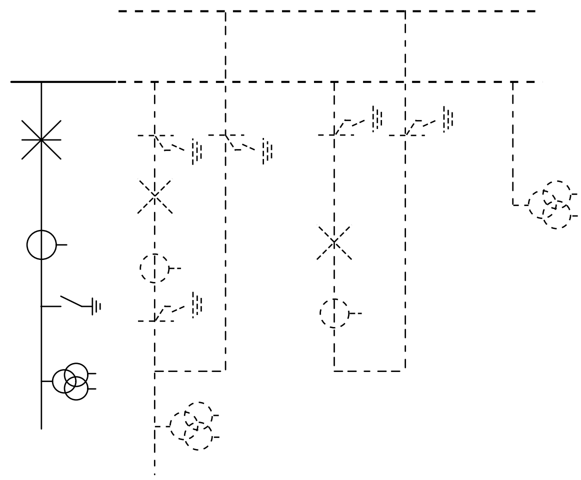
A double busbar can be extended as double breaker system with DCB.

Transfer bus system and system with bypass disconnector are preferably extended as a single bus system with just one DCB.

Substation design



Extension of traditional double busbar system



Extension of transfer bus system

Replacing of apparatus

It sometimes can be necessary to replace switching apparatus in existing switchgear apparatus by apparatus, but for some reason the same type is not available or suitable.

Even in this case DCB can be a good solution. In single busbar systems one DCB replaces the conventional setup of CB and DS. In a double busbar system the three (two) DS and the CB are replaced by a double breaker solution with two DCB. Transfer bus and bypass DS systems are preferably treated as single bus systems and thus the DS and CB are replaced only by one DCB.

The bay will have considerably lower unavailability and unreliability after refurbishing with DCB than after corresponding replacement apparatus by apparatus. This can be proven by calculations, and is due to the low failure and maintenance rates of DCB.

Cost optimizing

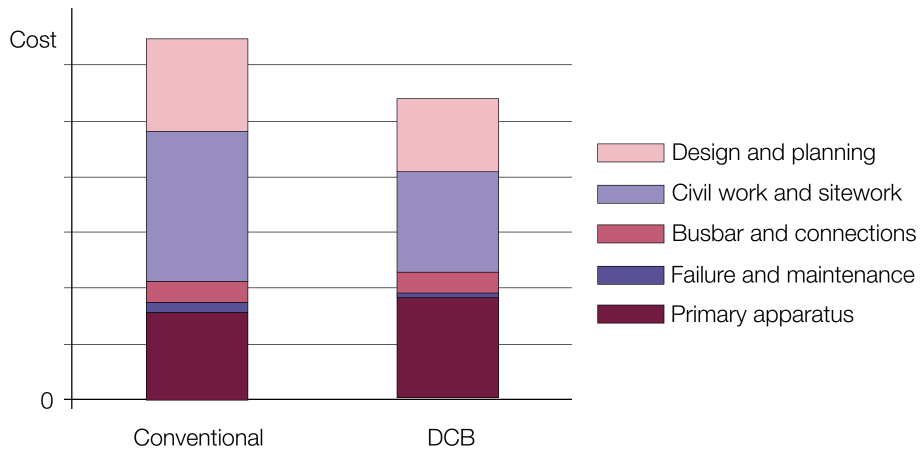
By omitting disconnectors when using DCB in the switchgear, the substation can be built much smaller and more cost effective.

The space saving can be in the range of 20 to 50%. All cost connected to planning, design, building, maintenance and service are lower due to less number of apparatus and partly pre designed solutions.

In the table you can put your own figures and make a cost comparison for your actual project.

	DCB	Conventional
Foundations		
Civil work		
Primary connections		
Connection tubes/wires		
Auxiliary cabling		
Erection and commissioning		
Design and planning		
Project management		
Primary apparatus		
Busbar system		
Failure and maintenance		
Other		
Total		

The chart below shows a cost comparison between a conventional solution and DCB. The example contains a five bay single busbar distribution substation.



Processes and support

Design support

ABB has a long experience in substation design and can support in all stages and to different extent according to the actual project.

Thus all cases from turn key to single apparatus delivery are supported.

For DCB solutions we have the possibility to create a layout proposal together with a SLD to be used for quotations and for early discussions regarding replacing traditional solutions with DCB.

Even if the delivery is limited to loose apparatus, some switchgear design support as switchgear layout, foundation plan, and support structure design can be supplied.

Delivery processes

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 & 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 handover 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 at regular intervals with respect to quality and OTD.

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.

Research & 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.

Erection and commissioning

Erection and commissioning is a part of ABB's engagements for turn key and complete switchgear deliveries. Even for other scope of delivery and for loose DCB deliveries ABB can take the responsibility for erection and commissioning.

Please include erection and commissioning in your inquiry.

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

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

Inquiring and ordering Disconnecting Circuit Breakers

The Switchgear Specification Manager (SSM) documents can preferably be used as enclosure to the inquiry for specification of DCB.

Otherwise, as a minimum the following information is required and can copied, filled in and sent along with your inquiry.

PROJECT DATA	
End customer	
Name of project	
Standard / Customer specification	
Number of circuit breakers	
Delivery time	

APPLICATION	
Line	
Transformer	
Reactor banks	
Capacitor banks	
Other service duty	
Number of operations per year	

SYSTEM PARAMETERS	
Rated voltage	
Rated frequency	
Rated normal current	
Maximum breaking current	
LIWL (Lightning impulse 1.2/50 μs)	
SIWL (Switching impulse 25/2500 μs, for Um ≥ 300 kV)	
Power frequency withstand voltage	
Grounded / Ungrounded neutral	

AMBIENT CONDITIONS	
Ambient temperature (max - min.)	
Altitude (m.a.s.l.)	
Earthquake withstand requirements	

BASIC MECHANICAL PARAMETERS	
Three-pole / Single-pole operation	
Type of high voltage terminal (IEC/NEMA/DIN)	
Minimum creepage distance mm or mm/kV	
Phase distance (center-to-center)	
Support structure (height)	

OPTIONAL MECHANICAL PARAMETERS	
Bursting discs	
Bracket for CT	
Primary connections CB – CT	
Manual trip	

DATA FOR OPERATING MECHANISM	
Control voltage (Coils and relays)	
Motor voltage	
AC-voltage (Heaters, etc.)	
Number of free auxiliary contacts	
Special requirements	

ACCESSORIES	
SF_6 gas for pressurizing	
Gas filling equipment	
Controlled Switching (Switchsync™)	
Condition monitoring (OLM)	
Test equipment - SA10 - Programma	
Tools	
Spare parts	

Protection and control IEDs

ABB Substation Automation Products has an outstanding experience of IEDs (Intelligent Electronic Device) for Protection and Control systems in substations for distribution, subtransmission and transmission networks.

IEDs for Distribution Switchgear

For Standard Distribution Switchgear, ABB Substation Automation Products can provide "Ready to connect" IEDs which give cost effective solutions for protection, control and monitoring of overhead lines, cables and power transformers.

Description of the IEDs

- Distance protection IEDs for main or back-up protection in solidly or high impedance earthed systems.
  Full scheme distance, overcurrent, residual overcurrent and voltage protection are examples of included protection functions.
  Synchro-check and energizing-check, autorecloser, disturbance/event recorder and fault locator are examples of included control and monitoring functions.

- Overcurrent and earth fault protection IED for back-up protection in solidly or high impedance earthed systems.
  Non-directional and directional overcurrent and residual overcurrent protection, voltage and breaker protection are examples of included protection functions.
  Autorecloser, event and trip value recorder are examples of included control and monitoring functions.

- Transformer protection IEDs for power transformers connected to ring bus, double breaker bus or 1 ½ breaker bus with solidly or high impedance earthed neutral points.
  Transformer differential, overcurrent, earth fault, thermal overload voltage protection are examples of included protection functions.
  Voltage regulation by controlling the on-load tap changer position, disturbance and event recorder are examples of included control and monitoring functions.

These pre-configured IEDs are easy to order, contribute to reduced engineering time and give efficient commissioning.

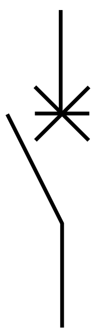
Enquires and orders must be sent directly to ABB Substation Automation through your local ABB representative.

Operation sequence

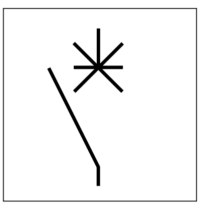
					Interlocking status			
Activity	**Order**	**Indication**		**Result**	**Electrical interlocking**	**Mechanical interlocking**	**Local / Remote**	**Padlocking**
Connect	Close	Closed	1	Breaker closed	AD100 open AD350 open	AD100 open AD350 open	Remote	
Open	Open	Open	0	Breaker open	AD100 open AD350 open	AD100 open AD350 open	Remote	
Disconnect	Disconnect	Blocked	1	Breaker blocked	AD100 closed AD350 open	AD100 closed AD350 open	Remote	
Earth	Earth	Earthed	1	Earthing switch closed	AD100 closed AD350 closed	AD100 closed AD350 closed	Remote	
Secure the disconnection							Local	Padlock the breaker in open position
Secure the earthing							Local	Padlock the earthing switch in closed position

Presentation of DCB in HMI

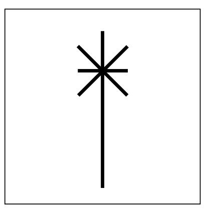
A new graphic symbol for drawings and illustration have been decided and introduced in IEC 60617, please se figure below. There is no standard for representation of DCB in HMI; however we recommend the following dynamic illustration to be used. The dynamic symbols shall be able to demonstrate the different operations modes or sequences for the DCB, se table of operational sequences.



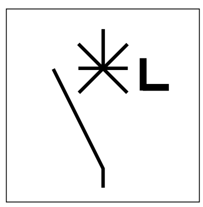
DCB symbol according to IEC 60617



Open



Closed



Open and Locked

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