ABB's Disconnecting Circuit Breakers
Higher substation availability and lower environmental impact

Power and productivity
for a better world™

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Introduction

Field experience and Life Cycle Studies over the last decade have proved ABB made Disconnecting Circuit Breakers (DCBs) to be a revolutionary concept for improving substation availability and reliability while significantly lowering environmental impact and substation footprint of high voltage switchgear.

Introduction

The DCB is based on the conventional live tank circuit breakers and fulfils the function of one circuit breaker and two disconnectors - without adding any internal moving parts that require maintenance and increase the risk of failure in the apparatus and power grid.

Conventional air insulated outdoor high voltage substations are equipped with disconnectors, having current carrying contacts in open air. Disconnectors located on both sides of the circuit-breakers were originally introduced as a standard feature of substation design to facilitate rather frequent circuit-breaker maintenance and to isolate the circuit-breaker in case of its failure. However circuit-breaker technology has developed over the years, and now its maintenance needs are normally less frequent compared with outdoor air insulated disconnectors. Circuit-breaker de-energization due to recommended maintenance of modern circuit-breakers today is normally in the interval range of 12-20 years, enabling the outage to be planned to coincide with inspection and repair of the connected line, transformer etc.

The disconnecting circuit breaker (DCB) was thus introduced as a response to the scenario that it may not be logical any more to use open air disconnectors to facilitate maintenance of circuit-breakers. In the DCB the disconnecting function is integrated, which minimizes the maintenance need. DCBs are presently available for rated voltages up to 550 kV.

In a DCB, the normal interrupter contacts also provide the disconnecting function when in open position, see Fig. 1. A DCB has to fulfil both applicable CB standards and disconnector standards. A specific standard for disconnecting circuit breakers was issued by IEC in 2005. In the open position DCBs are locked in a fail proof way. The locking consists of electrical blocking of the operating mechanism, as well as mechanical locking of the linkage system to the main contacts. Thereafter the adjacent earthing switch is closed. The visible closed earthing switch verifies that the part of the system is de-energized and safe to work on, see Fig. 2.

Fig 1.
145 kV DCB with integrated earthing switch.

Fig 2.
145 kV DCB with built on current transformers and closed earthing switch

Significant reduction in maintenance and failure outage

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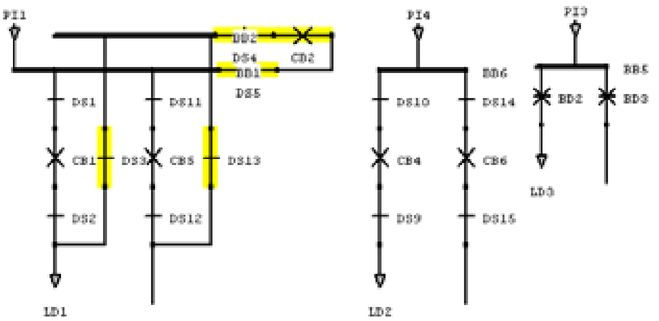
DCBs give a higher reliability of the disconnecting function since the primary contacts are SF_6 enclosed and protected from pollution. The maintenance intervals are increased giving an overall increase of availability of the substation.

To optimize availability of the power grid, different substation configurations such as single busbar, double busbar, breaker- and- a- half and double breaker solutions have been developed over the years. During the time when the breaker required the most maintenance, grid operators sometimes also implemented a transfer bus to enable the line to be energized during maintenance on the line circuit breaker.

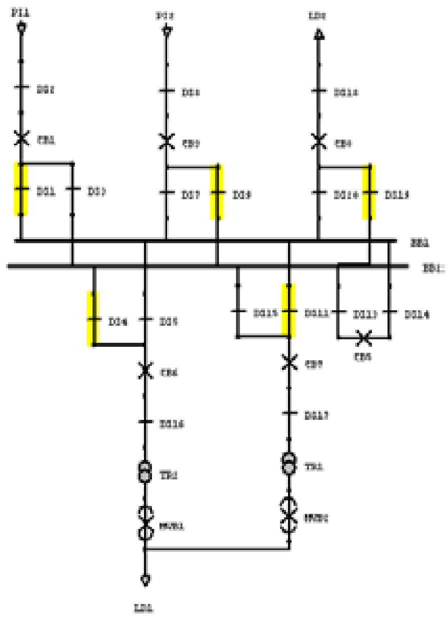
Due to the fact that the modern circuit breaker requires less maintenance than a disconnector, the transfer bus with its disconnector is no longer needed to increase the line availability – it actually decreases the availability, see Fig. 3. Therefore to maximize the line availability the grid operators should eventually remove the transfer bus, and move over to the disconnecting circuit breaker solution.



Solution Comparison 138 kV Load outages, minutes/year			
Maintenance	LD1 (Conv + T)	LD2 (Conv)	LD3 (DCB)
Failure	240.00	184.00	56.00
Maintenance and failure	12.03	10.48	7.71
Failure and failure	7.32E-3	5.71E-3	4.59E-3
Total outage	3.29E-4	2.67E-4	2.12E-4

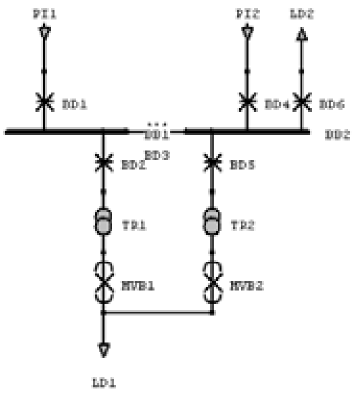
Fig 3.
Illustration and comparison of a conventional solution with and without a transfer busbar, and a DCB solution

The DCB solution provides outage reduction in both maintenance and failure, compared to the conventional solutions. In the example from Figure 3 the maintenance outage and statistical failure outage is reduced by 76% by using the DCB solution compared to the conventional solution with transfer busbar and by 67% by using the conventional solution without transfer busbar.
It was also found that a DCB singlebus solution performs better compared to a double bus solution with disconnectors.



Conventional Double Busbar Load outages, minutes/year		
Incident sequences	LD1 (MV Side)	LD2 (Line)
Maintenance	0.00	184.00
Failure	2.03	9.89
Total outage	2.03	193.89

Fig. 4
Conventional double bus solution with 3 incoming lines and two transformers and a bus coupler



DCB Solution Load outages, minutes/year		
Incident sequences	LD1 (MV Side)	LD2 (Line)
Maintenance	0.00	72.00
Failure	0.58	9.14
Total outage	0.58	81.14

Fig. 5
DCB solution with 3 incoming lines, two transformers and a bus coupler

Comparing the data in Figure 4 and Figure 5 it is found that the single busbar DCB solution performs better in terms of both maintenance and failure outages compared to the conventional double busbar solution.

Outage reduction with DCB solution from Figure 4 and 5:
- Line outage, maintenance: 60.8%
- Line outage, failure: 7.6%
- Medium voltage side outage, maintenance: 0%
- Medium voltage side outage, failure: 71.4%

Reducing environmental impact equivalent to removing an average of 5 cars

In order to illustrate the environmental benefits of the DCB technology, a LCA study was made for a 145 kV, three-pole operated DCB, including the operating mechanism, earthing switch and support structure. The study took into consideration the environmental impact of the entire life cycle.
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.

Several different environmental impact categories are 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, and is shown in Figure 6. 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.

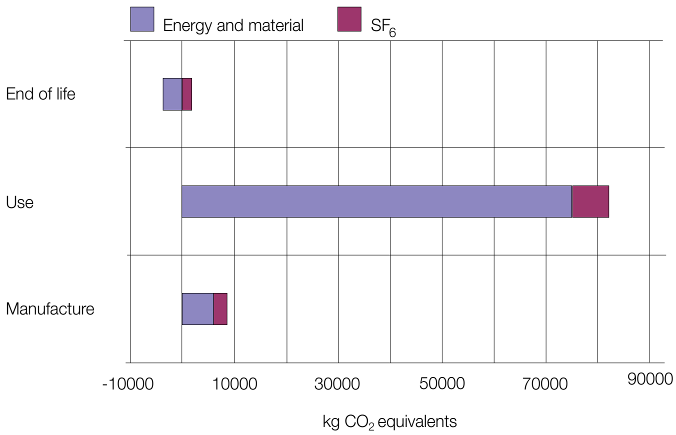


Fig. 6
Global warming potential GWP of a 145 kV DCB, expressed in kg CO_2 equivalents.

As shown in Figure 6, 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.

Energy savings

A major part of the environmental impact is related to the energy losses during the service life.

Given below are results of actual field studies for CO_2 emission reduction

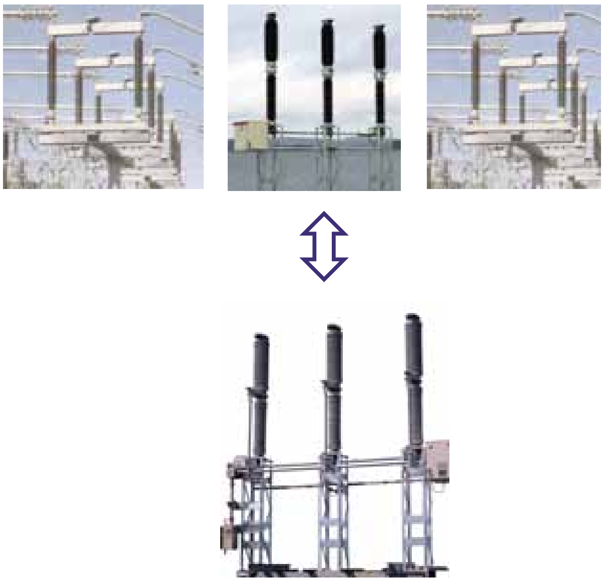


Fig 7.
Conventional disconnector/circuit breaker/disconnector combination, replaced by a single DCB.

Energy losses for the two alternatives of 145 kV equipment as shown in Figure 7 were calculated under the same assumptions as for the LCA study, i.e. 40 year operating time, 1575 A per phase, and 0.6265 kg CO_2 emitted per kWh. A realistic length and type of the connections between the two disconnectors and the circuit breaker was assumed: 8 m Falcon ACSR, diam. 39.3 mm. The power consumption of the heaters in the operating mechanisms was included.

The study showed that the energy savings per bay with DCB during 40 years of service corresponds to almost 700 tons of CO_2, or around 17.5 tons per year. In a complete substation, with several bays, the value will be correspondingly higher. To put the values in perspective, it may be noted that an average car will emit around 3 tons of CO_2 per year that is by replacing one conventional CB + 2DC combination with a DCB CO_2 savings equivalent to removing 5 cars can be achieved.

Simplification of substations

When used in a substation, the DCB replaces the conventional combination of circuit-breaker and separate disconnectors. Due to low maintenance requirements and high availability of the DCB it is also possible, in most cases, to simplify the substation configuration compared to a traditional substation. The overall result is considerable space savings – up to 50%, and less equipment. There will also be fewer foundations and steel structures, and less control cables. During construction, there will be less civil work, fewer transports, etc. These simplifications reduce the overall environmental impact of the substation during manufacture and construction, and also during the service life.

For small substations with DCBs the required space is reduced to an extent that it is quite feasible to make indoor solutions based on standard AIS equipment. The building architecture can be adapted to local preferences and surroundings, and the substation can easily be integrated into densely populated areas.

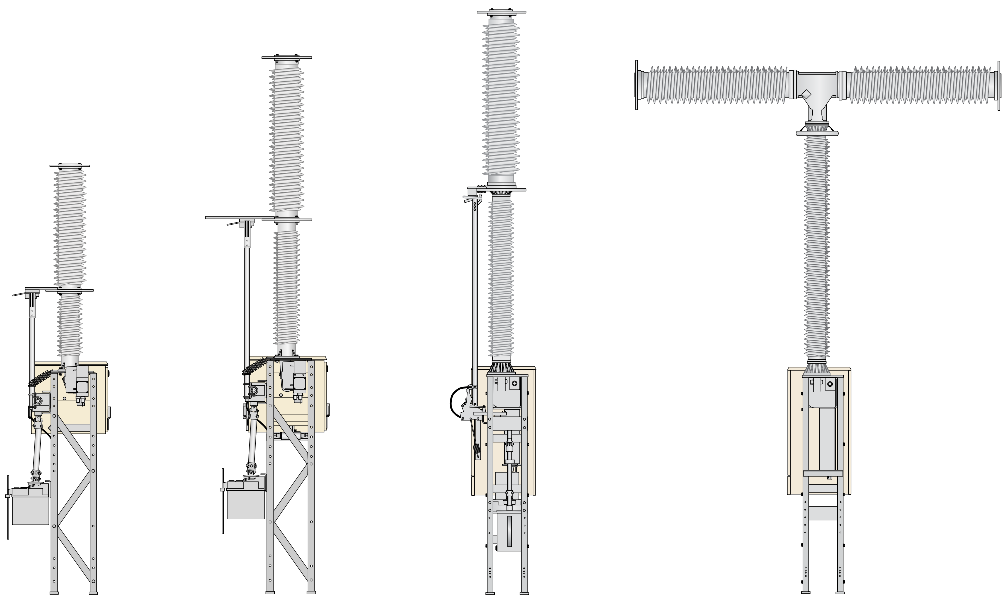
Figure 8 shows as an example a 145 kV substation located in the northern part of Sweden.

Figure 8.
Example of 145 kV indoor substation with DCBs.

The DCB technology is a recipient of the Swedish National Power Grid environmental price.

ABB's DCB portfolio

The substation solution with DCB portfolio consists of single busbar, double busbar, ring bus, breaker- and- half solution and combinations between double/single breaker solutions in the voltage range 72.5kV up to 550kV - all with higher availability and reliability compared to conventional solutions.



Type	LTB 72,5	LTB 145	HPL 170-300	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 capacity, kA	40	40	50	50	63
Rated frequency, Hz	50/60	50/60	50/60	50/60	50

Field experience

Back in the 1990's it was discussed among Swedish utilities to combine traditional circuit breakers and disconnectors into single devices, eventually to be called disconnecting circuit breakers. ABB developed and tested the concept, and in year 2000 the first installation was made in Sweden for the 245 kV substation Untra, belonging to Svenska Kraftnät. Since then the technology has become firmly established as a standard solution in Sweden. It is now also quite extensively applied in more than 25 other countries. IEC has introduced a specific standard for the device, and today other major suppliers also have disconnecting circuit breakers in their product lines. ABB has installed and received orders for approximately 800 three phase DCB units.

Recent significant DCB-orders awarded to ABB include:

- Storfinnforsen S/S (Sweden) 420 kV
- Hallsberg S/S (Sweden) 420 kV
- Rio Tinto S/S (Australia) 245 kV
- Hancheang S/S (China) 245 kV
- Rauma S/S (Finland) 420 kV

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NOTE! ABB AB is working continuously to improve the products. We therefore reserve the right to change designs, dimensions and data without prior notice.

ABB's Disconnecting circuit breakers - Higher substation availability and lower environmental impact, 2010-09

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