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Applications of Disconnecting Circuit Breakers

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***Abstract*— Development of Circuit Breakers (CB's) has made maintenance on them less frequent. Maintenance of open−air Disconnectors (DS's) for Air Insulated Substations (AIS) has remained unchanged. DS's primary contacts are exposed to pollution, which lead to frequent maintenance and unavailability of adjacent circuits. The Disconnecting Circuit Breaker (DCB) for AIS was introduced in 2000 in order to make use of the higher availability of CB's and at the same time overcome the problems with DS's. The DCB performs both the breaking function and the disconnecting function, using the same SF_6 encapsulated contact(s). This integration makes it possible to build AIS without any DS's. Having all primary contacts encapsulated in SF_6, will give a big decrease of maintenance work and increase reliability of the primary system. The main reasons for selecting the DCB instead of traditional solutions are system reliability, availability, maintenance aspects, space requirements, easier rehabilitation work and life cycle costs.**

Fig. 1. DCB in Lindome 400 kV substation

Index Terms—Availability, Life Cycle Cost (LCC), Renewal, Space saving, Substations

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I. Introduction

Maintenance requirements of CBs have been very much decreased through the years, while open-air DS's have remained their high maintenance requirements. DS's are considered as a "low tech" product and have not been technically developed in the same way as CB's. Instead it has been a price pressure on DS's that, according to some utilities, had led to decreased quality.

Traditional bay configurations use DS's on both sides of CB to allow for maintenance on the CB. Such configurations will give poor solutions with regards to the total maintenance requirements since DS's themselves require much more maintenance [1] than the CB, which they are to enable maintenance on. Please note that DS's only task in the substation is to enable maintenance and since open-air DS's primary contacts are exposed to atmospheric and industrial pollution, their maintenance interval can be as short as about 2 years for sites with high pollution. Modern CB's have a maintenance interval of 15 years, and putting in DS's for enabling maintenance of CB's is therefore not a very good idea.

The above reasons led to the introduction of Disconnecting CB's (DCB) for AIS Substations in 2000 [2], [3], [4], [5], [6]. The DCB performs both the breaking function of CBs and the disconnecting function of DS's, using the same SF6 encapsulated contact(s). This integration of dual functions into the DCB makes it possible to build AIS without any open-air DS. Having all primary contacts encapsulated in SF6 and protected from industrial and atmospheric pollution, will give a big decrease of maintenance work and increase reliability of primary system thus improving the overall availability of substation.

II. Description of Disconnecting CB

A DCB has in principle the same properties as a traditional CB. It has the same failure rate and maintenance requirements but is additionally fail-safe lockable in the open position to function as a disconnector for the associated objects, e.g. lines, transformers, reactors etc.

The DCB is tested to fulfill both CB and DS requirements according to their IEC-standards. The new standard IEC 62271-108 "Combined function disconnecting circuit-breakers" which covers all requirements was issued last year, Oct 2005. In order to assure the external dielectric requirements during the whole life length, DCB is equipped with polymeric insulators of silicone rubber type. This material is of hydrophobic (self-cleaning) type and will minimize creepage currents across interrupting chamber(s) when DCB performs the disconnecting function, i.e. energized on one side and earthed on other side.

Modern SF6 CBs maintenance interval, requiring outage of primary circuit, are about 15 years, whereas open-air DS maintenance interval are about 5 years, or even much shorter for polluted environment. This development has gradually lead to that today DS's are the apparatus requiring most maintenance in AIS substations [1].

Integration of both breaking and disconnecting function into the DCB also give space-savings, which makes rehabilitation of existing substations easier and at the same time minimizes the environmental impact.

DCB has the following three positions:-

Closed (as normal CB)

- Open (as normal CB)

- Disconnected position.

In the disconnected position the primary contact is mechanically locked in open position but remains in the same physical position as for open position.

In order to guarantee personnel safety and prevent unintentional closing, the following is done when DCB goes from open to disconnected position.

- Electrical blocking of operating device.
- Mechanical blocking of pole, see fig. 2, 3 and 4.

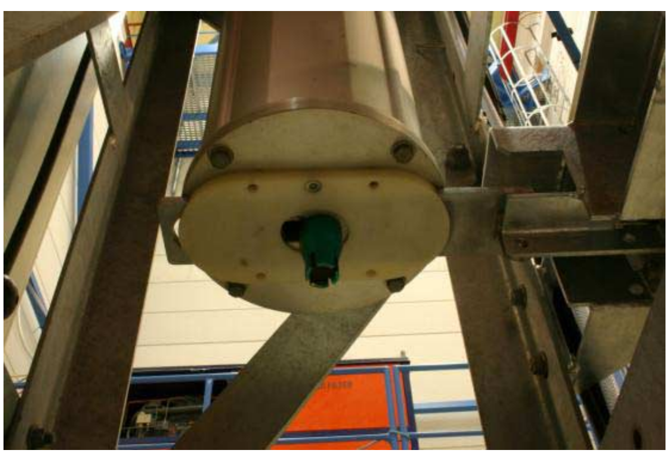

Fig. 2: Mechanical blocking device in blocked position

Fig. 3: Blocking device in blocked position

Fig. 4: Blocking device in open position

The mechanical blocking of the pole is performed with a separate motor operating device that can be padlocked for maximum personnel safety. From operational point of view the mechanical blocking can be regarded as similar to open the DS for traditional switchgear.

When using traditional solutions with DS's + CB's the "visible open gap" of the DS's is observed before maintenance work is done. When using DCBs this is not possible and personnel safety is instead assured by observing the closed earthing switch. Each electrical point of the switchgear for DCB-solutions is equipped with a motorised earthing switch (ES). Before working on a primary circuit in the switchgear, maintenance personnel should ensure that part to be worked on is earthed. The closed ES will ensure that primary circuit is de-energized. Padlocking of DCB in open position and ES in closed position will ensure 100% safety for personnel during maintenance work.

III. Space requirement and availability for 400 kV substations.

Space and availability has been compared for 400 kV substations using 1 ½-breaker configuration, one traditional solution with DS's + CB's versus solution using DCB's. In fig. 5 single line diagrams and corresponding space is shown, for a typical 400 kV substation with three diameters, to which it is connected three overhead lines, two power transformers and one shunt reactor. By using DCB the outdoor switchyard area is reduced with about 50%.

Outages due to maintenance and failures for an outgoing bay with single line configuration according to fig. 3, is shown in fig. 4. By using DCB's instead of traditional solution with CB's + DS's, outages due to maintenance are reduced with 90% and outages due to failures with 50%, please see fig. 6.

Similar comparison can be done for other voltage levels and busbar configurations where Combined is a possible solution.

The disconnecting facility [4] shown in single line diagram in fig. 5 makes it possible to disconnect the DCB, in de-energized condition, from other part of switchgear. Section clearance is achieved after disconnecting, which means that surrounding switchgear can be kept energized during maintenance or possible repair of DCB.

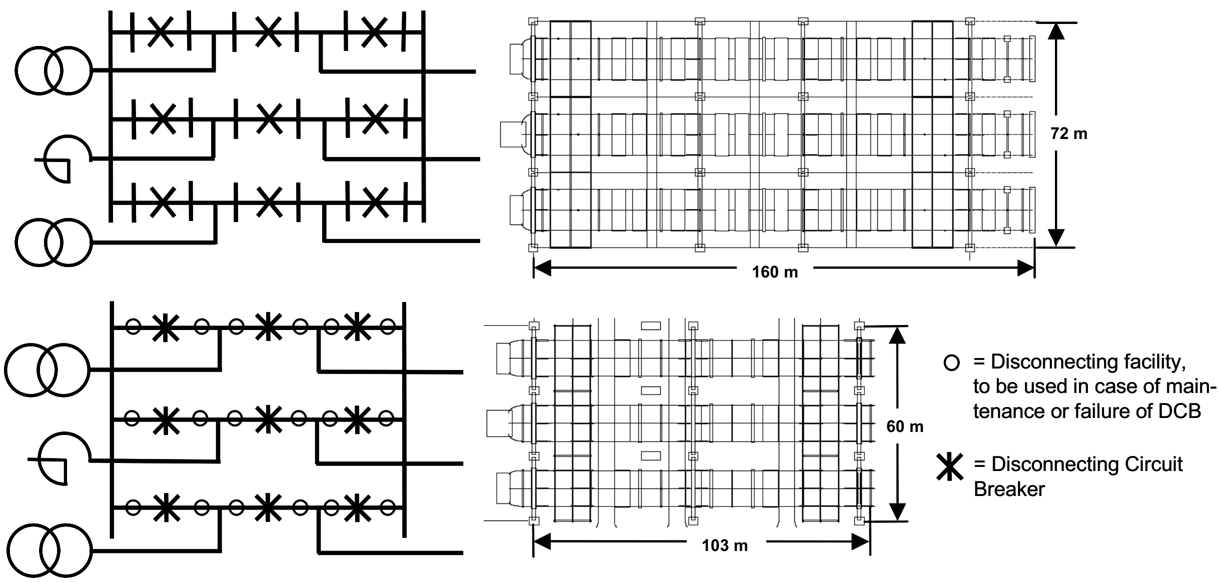

Fig. 5: Single line diagram and layout for 400 kV traditional solutions with CBs and DS's vs solutions with DCB's.

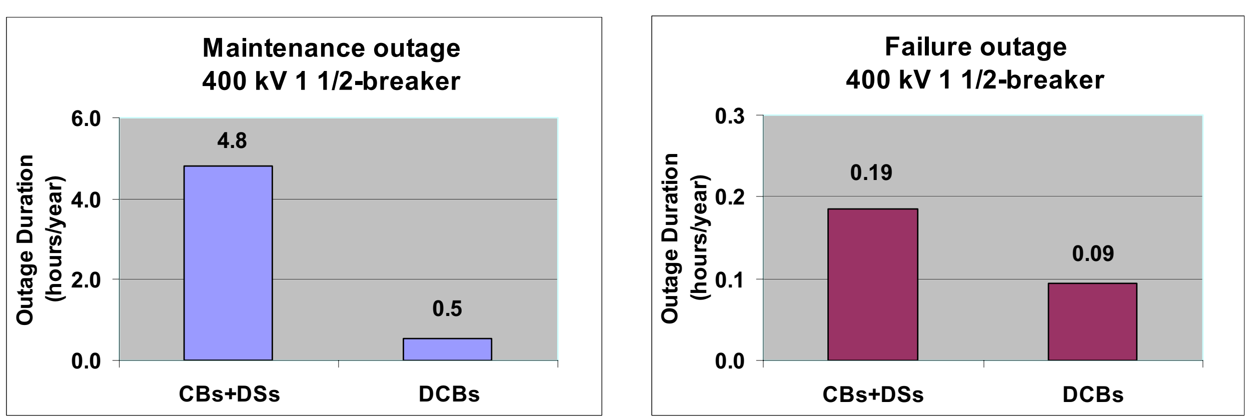

Fig. 6: Average outage duration for an outgoing bay due to maintenance and failures for 400 kV traditional solutions with CBs and DSs vs solutions with DCBs.

IV. DCB APPLICATION IN A 400 KV TRANSMISSION SUBSTATION IN SWEDEN.

As an example of DCB's major advantages compared to traditional AIS technique a rehabilitation of a 400 kV substation in the western part of Sweden will be described.
The substation, called Lindome, is owned and operated by Svenska Kraftnät. The substation was completely rebuild during end 2003 - beginning 2005, i.e. all primary and secondary equipment was replaced.

As seen from the single line diagram in Figure 7, the 400 kV Lindome substation includes three OH-line bays and two transformer bays. The transformer bays are connected one to each busbar with a dedicated existing CB. For a busbar fault one of the transformers will be lost. The concept of manual disconnection possibilities is utilized towards the busbars and the OH-line connections. This will enable the "second" DCB to sustain service to these objects in case of the "first" DCB needs to be taken out of service.

Lindome is an important substation for the feed of the Gothenburg area and there are also connections to the DC-connection Kontiskan to Denmark. Gothenburg is the second largest town in Sweden. The existing busbar configuration was single busbar and was converted to a double-breaker configuration when rebuilt. Thus, a busbar fault will not have that major impact on the service of the substation when the busbars are redundant with one breaker towards each of the busbars. This is the standard configuration used for important 400 kV substations in Sweden.

In the rehabilitation of the substation, the existing busbar could be retained, and after extension, be used as one of the busbars (B-bus) in the new substation.
By using the DCB concept it was possible to rebuild the substation on the same area as the existing substation even with the "extended" busbar arrangement. This means less outage time, minimum work for re-arrangement of line connections and no need for utilizing other land which is highly valued in this area by others.

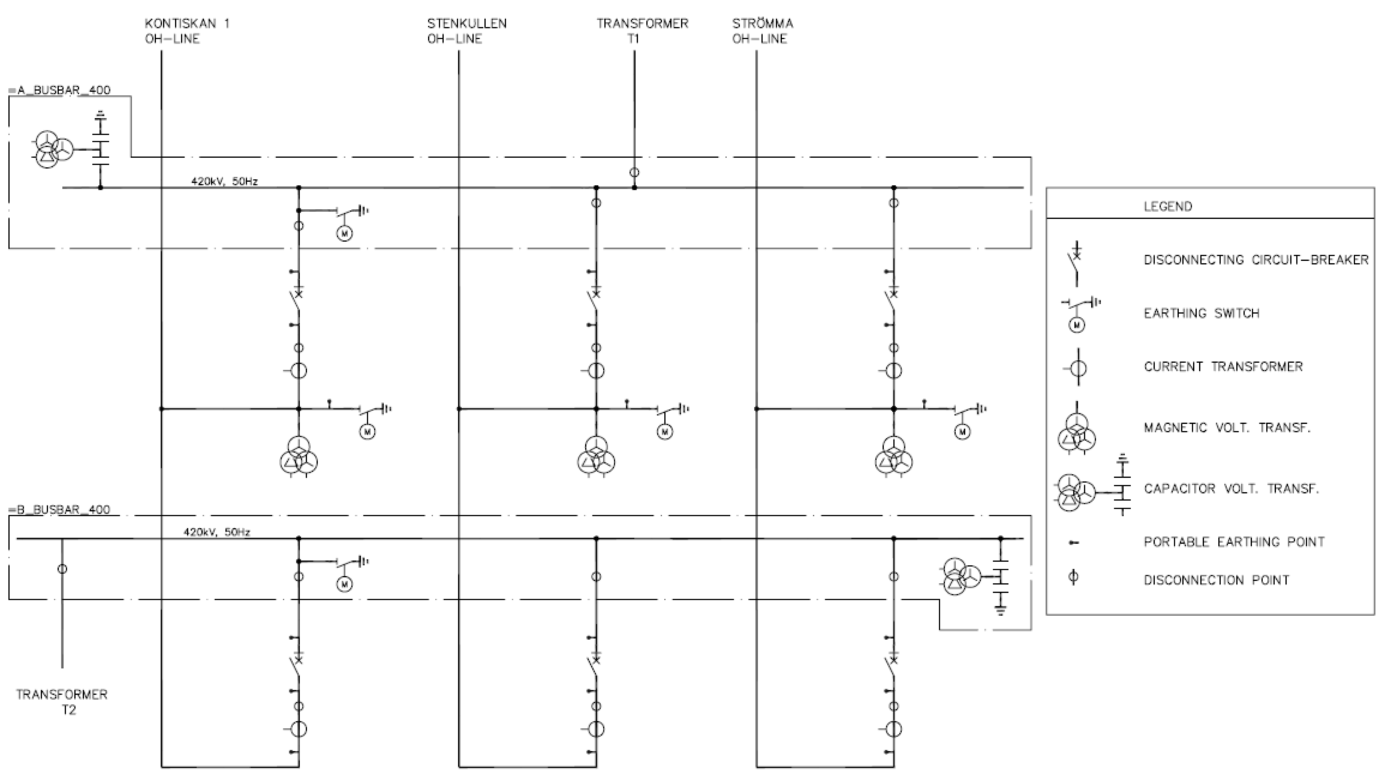

Fig. 7: Single line diagram, Lindome 400 kV S/S

V. Conclusions

Fig. 4 and 6 shows that solutions with DCBs give a big reduction of outage duration due to maintenance and this can be of outmost importance for the operation of the whole network. The risk of big disturbances and blackouts in a network are much higher when primary faults occur during maintenance situations, when one or more bays are taken out of service. Minimizing the outage time, due to maintenance, by using DCB will lower the cost and trouble for the maintenance work. It will also reduce the risk of big disturbances and blackouts due to primary faults, since the outage time of bays can be kept down and therefore the risk of a primary fault during an outage situation is lower.
By using DCBs the outages due to failures in the substation will be reduced, see fig. 4 and 6. The increased availability will mean less cost for asset owner during the service life of the substation. The actual savings of costs by using DCBs instead of traditional solution with CB's + DS's depends on:

- Cost per kWh for non delivered energy due to maintenance and faults.
- Power flow in the substation, i.e. MW-loads of the different bays in the substation.
- Life cycle length of the substation.
- Real interest rate, used to recalculate future cost to present value.

If the availability with traditional solution using CB's and DS's is satisfactory it is possible to simplify the switchgear configuration using DCB, still keeping the same availability as before. This will be a very attractive solution, especially for rehabilitation of old AIS substations, since new equipment will take much less space. This will ease the rehabilitation work since part of the old substation can be kept in service while the new substation is built. Life Cycle Cost can also be kept to a minimum since outage and maintenance cost will decrease. From environmental point of view, a solution with less number of apparatus and foundations is also advantageous, giving minimum impact of the eco-system.
Regarding unavailability calculations it should be pointed out that failure frequency are based on actual statistics from CIGRE and CEA (Canadian Electricity Association).
Maintenance interval is taken from manufacturers instruction manuals.
The personnel safety is a very important aspect and need special care when new types of switching apparatus are introduced. The blocking system of DCB, to prevent unintentionally closing when used as a disconnector, has been designed in a very conservative way to ensure 100% personnel safety during maintenance work.

VI. References

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VII. Biographies

Per Michael Faxå. Was born in Uppsala, Sweden the 15th of July 1963. He has a Master of Science degree from Chalmers University of Technology in Gothenburg Sweden 1993. He was employed by ASEA/ABB June 1984.

He has been working with high voltage substations, in different roles and responsibilities such as mechanical, electrical, system engineering and also as manager for different design groups.

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