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Switching Capability of Air Insulated High Voltage Disconnectors

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Abstract

Need and realization of air insulated high voltage disconnectors switching capabilities (e.g. bus transfer switching), as well as its limits and challenges will be described and discussed.

Keywords: Arc Erosion, Arcing, Closing Time, Contact Erosion, Contact Finger, Contact System, Disconnector, Opening Time, Switching Capability, Secondary Contact

1. Introduction

Air insulated high voltage disconnectors need to be capable for switching negligible currents of 0.5 A for rated voltages up to 420 kV as per IEC 62271-102. This capability is a basic need given by the design standards of air insulated high voltage substation, where those disconnectors are applied. This minimum request is frequently exceeded by the need of certain design details of such substations and its specific applications. The exceeded values are mostly not standardized and will be requested project, order or substation design specific, so that it comes to customizations by disconnector manufacturers and suppliers. There are three main applications where exceeded values for the switching capability of air insulated high voltage disconnectors are of interest, which are no-load conditions of transformers (inductive), long high voltage conductors (overhead lines, capacitive) and bus-transfer cases within substations with more than one bus bar (for supply safety reasons bus bar are often given redundant, which will demand bus bar transfer conditions or operations). The bus bar transfer case is so common, that in this case standardized values are given within IEC 62271-102 and have been worked out in more detail, as well as partially increased, by the last edition of this IEC standard.

A disconnector in its standard configuration will not be able to switch exceeded values, as the damages (contact erosion) on the contact system would be too high in order to be still operational after such a switching case. Consequently features need to be implemented to the contact system, such as secondary contact arrangements (additional contact fingers), in order to achieve such switching capabilities.

2. Disconnector Types

2.1 Inline Disconnectors

Here in grouped disconnector types are the center break, the double side break, the side break, the V-type (based on center break or double side break disconnectors), the vertical break and the knee-type disconnector. A grouping for applying a switching capability feature needs to be done differently and is possible for the center break, double side break, side break (principle of contact system as per double side break) and V-type disconnectors. The vertical break and knee-type disconnector are to be

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grouped with its familiar devices of the grouping of bus bar disconnector.

2.2 Busbar Disconnectors

Here in grouped disconnector types are the vertical reach, the semi-pantograph and the pantograph disconnector. A grouping for applying a switching capability feature needs to be done for the vertical reach with its inline familiar, the vertical break disconnector and for the semi-pantograph with its inline familiar, the knee-type disconnector. The pantograph disconnector does not allow a specific grouping and needs specific solution consideration.

3. Secondary Contact Arrangement

Common solution for achieving a switching capability for an air insulated high voltage disconnector are arrangements for secondary contacts, which can take the occurring arcing (lightning) and protect the main contact system. Finally those are scarifying contacts (eventually additional contact fingers) and will suffer significant contact erosion depending on the quantity of switching cases. The design will and has to be done in order to sustain the minimum requested quantity of switching case respectively the values of voltage and current occurring and determined by specifications in regards of the individual application or just in accordance to a standard like the IEC 62271-102.

3.1 Closing Operation

While the closing operation of the disconnector the secondary contact arrangement needs to be in advanced position relatively to the main contact system. Voltage dependent a flashover or lightning will occur at a certain distance position of the secondary contact arrangement. At the moment of contact of the secondary contact, the current path is closed and the current flows via the secondary contact. It needs to be ensured that the secondary contact keeps the closed condition, while further closing operation. Accordingly contact pressure of the secondary contact needs to be maintained.

While further advancement of the closing operation the main contact system of the current path will contact. Due to the now given parallel current path by the secondary contact arrangement, the main contact can run-in de-energized without occurring damages on the main contact system due to arcing impacts.

While even further advancement of the closing operation and before the movement blocks at the stopper of the main contact system, the secondary contact arrangement needs to be decoupled. In normal operation conditions of the disconnector the secondary contact is decoupled and save from any eventual occurring damages, like e.g. a short-circuit, which is part of the normal operation condition of a disconnector to a certain specified limit (or according a certain applied standard).

3.2 Opening Operation

While the opening operation of the disconnector the main contact system start to disconnect and the secondary contact system contacts. Again while further movement of the opening operation the necessary contact pressure of the secondary contact needs to be maintained.

The parallel current path by the secondary contact arrangement is given again and the main contact can run-out de-energized. When the main contact system is disconnected, the flowing current is routed through secondary contact arrangement. The maintained contact pressure of the secondary contact needs to prevent a jumping or bouncing of the contact and finally any arc-back (reigniting) due to contact separation.

At the moment of a big enough distance of the disconnected main contact system and the secondary contact arrangement in contact, an arc-back on the main contact system is prevented. The secondary contact arrangement can now disconnect and an arcing will occur. This occurring arcing needs to be extinguished by a minimum necessary distance of the disconnected secondary contact. The time necessary to achieve this minimum distance determines the amount of contact erosion of the secondary contact due to the arcing time on the secondary contact.

A passive secondary contact arrangement will fully depend on the opening operation speed of the disconnector and respectively its current path. Alternatively the secondary contact arrangement can be realized active in order to significantly decrease the time of arcing on the secondary contact, the time to achieve the minimum necessary distance of the disconnected secondary contact arrangement. An active solution of a secondary contact will significantly influence the lifetime of a secondary contact arrangement or the possible number of such switching operations.

3.3 Passive and Active Solutions

A passive secondary contact arrangement will fully depend on the opening operation speed of the disconnector and respectively its current path, so that the requirements for the arc erosion resistance of the used material will be high. Further a passive system will be fully dependent on material properties of the used items for maintaining the necessary contact pressure of the secondary contact in operation.

Alternatively the secondary contact arrangement can be realized active in order to significantly decrease the time of arcing on the secondary contact, the time to achieve the minimum necessary distance of the disconnected secondary contact arrangement. An active solution of a secondary contact will significantly influence the lifetime of a secondary contact arrangement or the possible number of such switching operations (minimized requirement for arc erosion resistance). Further an active system will provide solutions for maintaining the necessary contact pressure of the secondary contact with higher independency of the material properties of the used items. This will ease material and supplier availabilities on the market for processing the same for manufacturing of air insulated high voltage disconnectors with features of switching capabilities.

Any solution may be designed in such a way, so that physical effects of environmental situations can be used supportively. Certain design shapes of applied items may provide advantageous air flows to the foot points of arcing (points of inception or origin of the arcing) in order to facilitate separation.

3.4 Market Understanding/Switching Needs

Driven by specific application needs or just understandings of cases and its solution the following names with its origins occur for secondary contact arrangements.

- Arcing horn – partially as such requested, without detailed specification of values to be switched (seems partially just to target ensuring of basic fulfillment of the capability for switching negligible currents).
- Guiding horn – partially as such requested, without detailed specification of values to be switched (seems partially just to target ensuring of basic fulfillment of the capability for switching negligible currents).
- Bus transfer device – used to specifically point to accordingly applications or solutions as per IEC 62771-102.
- Filter switching device – this expression is used specifically for switching capability requests of disconnectors for high voltage direct current applications.
- Load disconnector – Occurring expression for disconnectors with a feature for providing a certain switching capability.

Not to be confused with and being earthing switch specific (as air insulated high voltage disconnectors are usually discussed along with air insulated high voltage earthing switches):

- Secondary contact – used to specifically point to accordingly applications or solutions as per IEC 62771-102.
- Class A device – used to specifically point to accordingly applications or solutions for the 'Class A' definition as per IEC 62771-102.
- Class B device – used to specifically point to accordingly applications or solutions for the 'Class B' definition as per IEC 62771-102.
- Class B+ or B2 device – used to specifically point to accordingly applications or solutions for the 'Class B' as per IEC 62271-102 exceeding definition of Chinese standardization.
- Butcher's hook – this expression is known for a solution for achieving switching capability needs given by ferromagnetic resonances, which is then also suitable for 'Class B' applications as per IEC 62771-102.
- Cable discharging device – this expression is used specifically for switching capability requests of earthing switches for high voltage direct current applications.

As switching capabilities requested by customers for specific project or design needs are not always achievable or the disconnector designer or supplier can simply not afford to realize limit testing (also considering the limited availability of testing facilities), a common approach may be realized by the use of a cycles-voltage-diagram, Figure 1, derived from punctual measurements (based on the accordingly energy value). Finally it indicates the reduction of necessary inspection intervals in dependence of the residual voltage and the cable capacitance, which is then given to customers for verifying acceptance or coverage of needs.

4. Type Testing of Switching Capability

First of all, designers or suppliers have to handle the fact that the availability of testing laboratories for the testing of switching capabilities of an air insulated high voltage disconnector is limited.

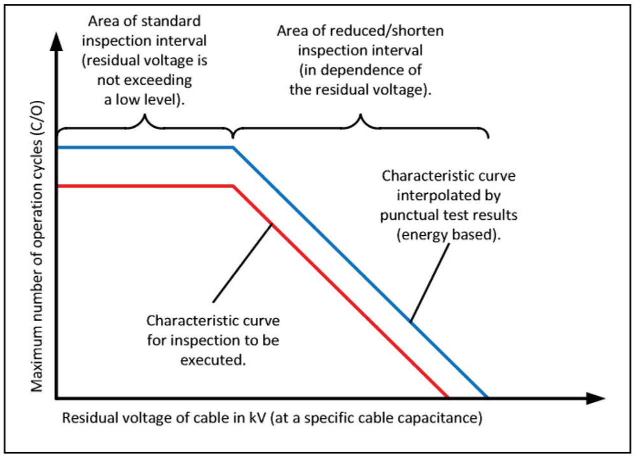

Figure 1. Cycles-voltage-diagram.

The classical high voltage laboratories for the execution of di-electrical tests will usually not provide the necessary currents and classical high power laboratories for the execution of short-circuit tests will usually not provide the necessary voltages.

Partially high power laboratories are known with extended equipment for delivering accordingly test possibilities or medium voltage power laboratories can be identified, which can provide the necessary values. Within the medium voltage laboratories it has to be considered, that the usual executed short-circuit tests demand low time frames for the test execution, where the here discussed switching capability tests demand significant higher time frames for the test execution, so for the provision of the test values. These boundary conditions may challenge the available equipment for their suitability.

Further space constraints will be faced or carefully need to be pre-analyzed, as medium voltage power laboratories will offer only limited space for the test object installation compared to the high voltage power laboratories usually used for the short-circuit testing of accordingly disconnector and earthing switch devices.

5. Passive Tungsten-Inlet Solutions

As tungsten provides a high arc erosion resistance, it is a primary choice for passive secondary contact arrangements. Its disadvantage is surely the market availability and consequently the costs implied than for the disconnector feature. This disadvantage is limited by the approach of using inlets only, in order to limit then necessary quantity to a minimum in accordance to the needs of the secondary contact arrangement (application only to primary area of lightning footage).

5.1 Passive Add-On Finger Solution

A classical solution for the center break disconnector application out of the Siemens disconnector portfolio, applied since long time worldwide and well known in the market.

This solution consists of a copper tungsten alloy stud and a copper zirconium alloy finger with a specific bended shape and a copper tungsten alloy inlet. The copper finger delivers the necessary flexibility for maintaining the needed contact pressure and the tungsten inlet delivers the necessary arc erosion resistance for achieving the needed quantity of switching operations, sustaining the needed quantity of arcing occurrences. The stainless steel part as counter part of this secondary contact arrangement is suitable for the contact pressure and the arc erosion resistance.

The specific bended shape of the add-on copper finger guarantees a disconnected state of the secondary contact arrangement, while the main contact system is in its fully closed position.

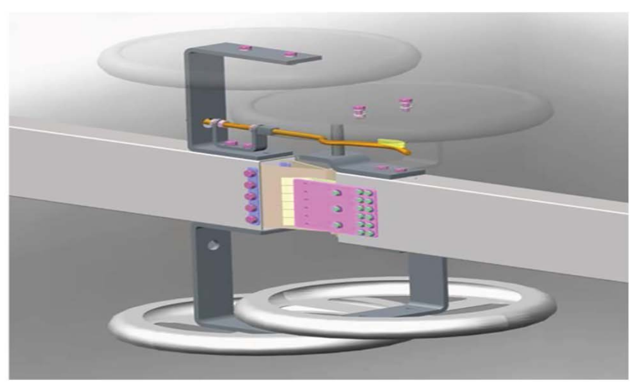

Figure 2. Passive add-on finger solution.

5.2 Passive Add-On Needle Solution

A classical solution for the pantograph disconnector application out of the Siemens disconnector portfolio, applied since long time worldwide and well known in the market.

This solution consists of copper zirconium alloy crossbars with copper tungsten alloy inlets for the moving arms of the contact system and an add-on device for the crossbar of the mating contact (counter contact) to complete the secondary contact arrangement. The add-on device is called as 'tungsten needle', as its design and shape provides the necessary material flexibility for the contact pressure of the secondary contact arrangement including tungsten inlets for the necessary arc erosion resistance. Also here the copper alloy crossbars as counter part of this secondary contact arrangement are suitable for the contact pressure and the arc erosion resistance.

As the passive add-on needle solution as secondary contact arrangement is not disconnected while the main contact system is in its final closed position, it needs to be and is short-circuit proof (a specific pantograph disconnector constraint challenging the design and material cost intensity of this kind of secondary contact arrangement).

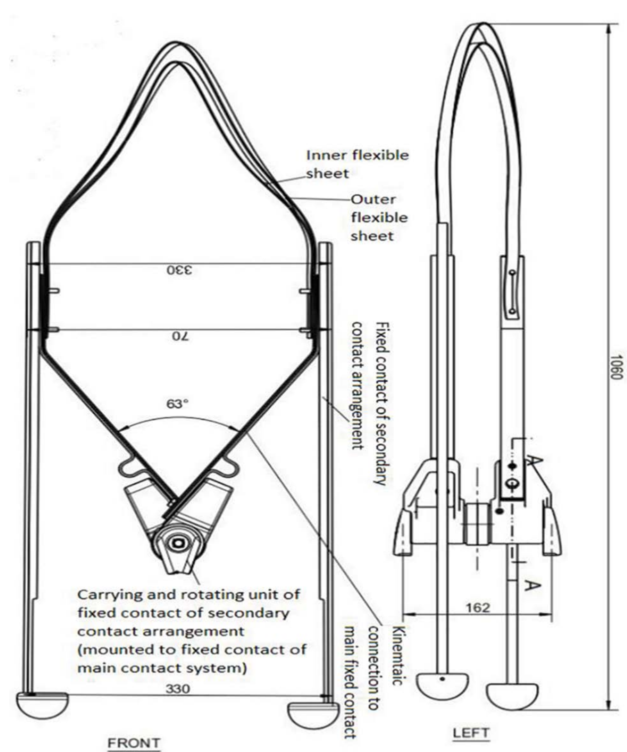

Figure 3. Passive add-on needle solution

5.3 Other Passive Solutions

Another known and applied passive solution without tungsten inlets is the application of simply 'bus transfer proof contact strips'.

Figure 4. Passive 'bus transfer proof contract strips' solution.

For this solution contact strips are not only applied to the moving arms of the main contact system, but also to the crossbar of the mating contact. This increases the necessary quantity of those contact strips, which are finally material cost intensive and deliver a more limited switching capability for the pantograph disconnector.

5.4 Sustainability of the given Passive Solutions

The mentioned given solutions are providing limited switching capabilities to the disconnectors where applied. Given have been solutions, which were so far capable to suffice the needs given by the bus transfer switching capabilities requests as per IEC 62271-102 before the last release (Edition 2.0) in dependence of the rated voltage accordingly.

The past market requests went frequently beyond the values given as per IEC 62271-102 and the latest release of the IEC 62271-102 is reflecting this particularly, where it cannot be judged that markets requests may still partially exceed values as per latest IEC 62271-102, as well.

Consequently suppliers or designers of disconnectors with switching capability will need to enhance so far achieved solutions in order to cope with the latest standardizations and the frequently higher market expectations. Certain active solutions have been already designed and partially tested as individual solutions, which will need to be verified, optimized, standardized and/or enhanced. It is expected that there will occur a strong tendency to active solutions, as the known passive solutions are at their limits and mainly not capable for the higher switching capabilities nowadays demanded. Further it is very probable, that future active solutions will integrate vacuum chambers or similar known solutions in order to cope with highest requirements demanded, which will challenge additional overall mechanical situations of the product designs respectively their main contact systems within their current path assemblies.

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