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Non-Standard Applications of High-Voltage Disconnectors and Earthing Switches

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***Abstract*—non-standard applications of disconnectors and earthing switches are structured and elaborated. Simple integrations as of arresters are investigated, as well as complex cases like neutral point devices. Showing demands and possibilities with indications for efforts and benefits – complexity contrasted by attractive opportunities.**

***Keywords*—disconnector, earthing switch, arrester, neutral point device, type testing, alternate current (AC), direct current (DC), current path, contact system**

I. Introduction

Different basic technical statements lead to the non-standard applications of high voltage disconnectors and earthing switches. Typical understandings of non-standard applications are designs for voltage ratings above 550 kV (e.g. 800 kV, 1100 kV or 1200 kV), TWIN solutions of certain devices (two disconnectors in line, sharing one counter contact), integrations (e.g. disconnector with arrester) or HVDC applications.

Finally, such products are not standardized within a typical high-voltage disconnectors and earthing switches portfolio and remain generally project specific solutions. Nevertheless, if a single customer specific solution has been established, it can lead with high potential to be a remaining standard solution for the customer. Fostering a certain business potential with such cases can be attractive [2-18].

II. Structuring

The wide field of non-standard applications of high voltage disconnector and earthing switches has led to the indicated structure, which is followed in the document.

Structuring of Non-Standard Applications

Applied structuring:

- Applications above 550 kV
- TWIN applications
- DS Integrations
- DS Integrated

The structure is following integration principles observable and providing necessary overview of possibilities and benefits.

III. Applications above 550 kV

Those are typically applications for 800 kV, 1100 kV or 1200 kV. This is including minor differentiations as e.g. 765 kV, depending on the specific market or project requirement. Principally known by AC applications, DC applications are upcoming.

Besides the reduced losses in regards of switching from AC to DC, the high voltage levels are fostered by more expensive land or higher economical restrictions (avoidance of wood extinction).

Applicable disconnectors, which bring the necessary mechanical stiffness and the security for contacting safely by closing, are the double side break disconnector and the knee-type disconnector. Up to 800 kV the pantograph disconnector and the semi-pantograph disconnector are possible and known.

The necessary mechanical stiffness needs for the big disconnector sizes (> 420 kV) bigger current paths, even though it would not be necessary for the needed current carrying capacity. The request for flexural rigidity is higher and will be even increased including e.g. ice load requirements.

A chosen drive needs to be slow enough, so that bouncing of the contact system due to the high peripheral speed of the current path (travel radius) will be avoided and contacting safely can be guaranteed.

A. HVDC Applications

Those applications are characterized by its specific di-electrical conditions, which imply that from this perspective there are no extraordinary requirements to disconnector and earthing switches.

Beside the typical disconnector and earthing switch applications, which can also be found in HVDC substations, the earthing switches have a specific focus. So called ‘valve hall earthing switches’ are specific HVDC

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applications. Bushings (lead through insulators) often require a usage of earthing switches.

Typical disconnector types realized for HVDC applications are the double side disconnector and the knee-type disconnector, or as well vertical break and less common the centre break disconnector and the pantograph disconnector.

UHVDC applications do not differ from here described disconnector and earthing switch applications. Partially it is preferred to talk about ultra-high voltage direct current depending on the specific voltage level.

IV. TWIN APPLICATIONS

TWIN applications are so far known by the Chinese and the Brazilian market. At those applications the current paths of two disconnectors share one common counter contact (substituted high voltage terminal). Basically, realized only on the voltage levels ≥ 245 kV. TWIN applications on lower voltage levels have been seen within special laboratory applications but are very seldom.

Fostered by the market for optimized space usage (land) and substation usability (substation layout). Herewith a circuit breaker integration seems to be suitable, but so far not observable on the market.

In China the TWIN applications are typically realized with the double side break disconnector on the voltage level of 363 kV and with the knee-type disconnector on the voltage level of 550 kV.

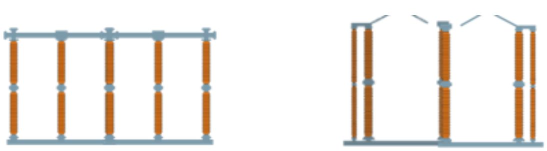

FIGURE 1
TYPICAL CHINESE TWINS

In Brazil the TWIN applications are typically realized with the vertical break disconnector on the voltage level of 245 kV and with a combination between knee-type disconnector and semi-pantograph disconnector on the voltage level of 550 kV.

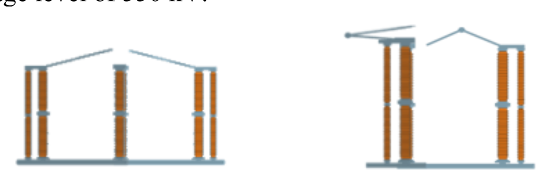

FIGURE 2
TYPICAL BRAZILIAN TWINS

Other disconnector designs practically aren't suitable for such twin solutions. The reasons are partially due to its physical kind and partially due to the missing economic benefit within accordingly substation layouts.

V. DS INTEGRATIONS

Not only combined disconnector solutions, as the TWIN solutions, are demanded on the market, but combination with other high voltage products as well.

A classical case is the integration of an arrester within a disconnector. In such a case an arrester (providing sufficient mechanical strength) replaces a post insulator, and an eventual grading ring needs to be segmented (half ring).

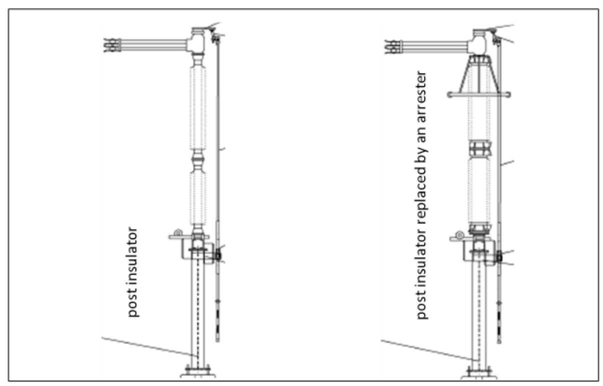

FIGURE 3
DS INTEGRATION EXAMPLE OF AN ARRESTER

The arrester integration (post insulator replacement) is done within centre break disconnectors, vertical break disconnectors and stand-alone earthing switches. This is surely possible with relatively low engineering efforts on other types, as well.

A. Suppliers Perspective of DS Integrated Arresters

From supplier's perspective it gives sometimes the impression, that the substation was running out of space (planning mistakes) and requires a solution with special space reduction.

An arrester is a safety element in the substation and at certain moment's it has the function of destruction. So, it would also destroy the disconnector. Consequently, it is a rare application.

B. True Potential of DS Integrated Arresters

In fact, this can be an economic advantage. The arrester as protection element of a station, protects e.g. a

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transformer, a circuit breaker or the whole station against over-voltages due to lightning strikes, switching operations or short-time power-frequency related over-voltages occurring in the network. Though the arrester is dimensioned for its rated voltage, its non-linear current-voltage-characteristic-curve defines a concretely determined protection level for the element to be protected. In the cases, where the arrester is loaded with higher or long-time over-voltages against its dimensioning, the arrester fails. With a failed arrester the accordingly protection element of the substation has disappeared, but the disconnector remains fully operational. The replacement of a failed arrester, integrated in a disconnector, is comparable easily realizable.

Also, a failed arrester doesn't lose its mechanical characteristics completely. Has an arrester to be integrated in a disconnector and to replace a post insulator, the chosen arrester needs to fulfil the requested mechanical characteristics also if it fails (70% of the mechanical characteristics of the chosen arrester need to match the requirements).

FIGURE 4
DS INTEGRATION FIELD EXAMPLE OF AN ARRESTER

Finally, the saved insulator costs must compensate the 30% over-dimensioning of the arrester to guarantee economy within this product view. Additional economic advantages for the customer regarding its substation design are given.

C. Neutral Point Devices

Complementary the neutral point devices (NpD's) must be mentioned as a DS integration example, as well. Known from the Chinese market, those devices have been procured and supplied via third parties (competitors) due to the mandatory need for package participations there, on the voltage levels of 126 kV and 252 kV. In fact, this can be an economic advantage. Those devices are known on the market as 'power transformer neutral point combination device', as well.

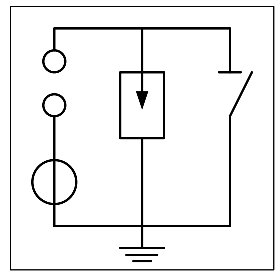

FIGURE 5
SCHEMATIC OF A NEUTRAL POINT DEVICE

Those devices are disconnectors, which appear as earthing switches (by physical/mechanical appearance) and are integrating a current transformer, an arrester (usually inclusive a surge / discharge counter – but more common in regards of market share without arrester) and a sparking gap.

FIGURE 6
FIELD EXAMPLE OF A NEUTRAL POINT DEVICE

A cost-effective solution would be an earthing switch with certain disconnecting capability and with an integrated arrester. The substructure would surely include the column for the current transformer and then the sparking gap on top, the drive connection rod for the motor drive would need to consist of insulating material. Nevertheless, so far available business opportunities on the market haven't allowed the development/design and accordingly type testing outside of China.

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VI. DS INTEGRATED

Where on the 'DS Integrations', the disconnector and earthing switch is the driving high voltage product for integrating other high voltage products, on the 'DS Integrated' the disconnector and earthing switch is the driven high voltage product to be integrated in another high voltage product, which is exclusively done by circuit breakers.

Generally, solutions are provided, which integrate an earthing switch to a circuit breaker. The comparable easiest case in regards of engineering efforts is the so called 'disconnecting circuit breaker' (DCB). An oversized circuit breaker provides by accordingly clearance of the open main contact system the required disconnector feature.

Other more specific cases

Full and partial disconnector integrated:

- integrated double side break disconnector on a common substructure between the circuit breaker and an integrated current transformer.
- Integrated centre break disconnector contact system between the circuit breaker and an integrated current transformer which can be moved to close and open the circuit.

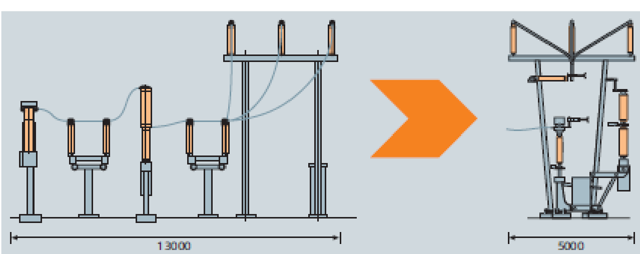

FIGURE 7
EXAMPLE OF AN INTEGRATED DISCONNECTOR CONTACT SYSTEM

VII. TYPE TESTING

If there are reference-devices within a portfolio, it is common practice to avoid any testing as far as possible. However, applications with no reference have a high risk for extensive type testing. Additionally, there are usually not sufficient market opportunities to be expected, so that developments for closing assumed portfolio gaps will not be initiated based on calculations for economic value add.

Such realizations highly depend on project opportunities (offer calculation). Accordingly, calculations need to consider specific testing, beside the specific additional design efforts. For example, it is known; that neutral point devices don't need new tests, as the applied high-voltage products are already tested. But the Chinese customers are insisting on specific type tests for the combined device [2-18].

A. Di-electric Testing

Di-electrical and radio interference voltage tests are mostly unavoidable, as portfolio references are usually missing.

For HVDC cases, it shall be known, that generally a requested voltage level will lead to a disconnector or earthing switch of the next higher AC voltage level. This means, the usual portfolio possibilities allow HVDC voltage level requirements of 420 kV. Within this limit a disconnector can be offered with comparable low engineering efforts.

DC applications include a significantly higher ionization, so that higher insulating and/or creepage distances are necessary. DC voltage levels are principally not standardized (therefore neither testing values). But the common levels are 330 kV, 412 kV, 515 kV, 680 kV and 800 kV (respectively 812 kV and 824 kV). Additionally the installation area, if indoor or outdoor, has a big impact, as dry and/or wet insulation has to be considered (e.g. 330 kV DC indoor is served in fact with a 330 kV AC disconnector, but 330 kV DC outdoor is served in fact with a 550 kV AC disconnector – a 'case by case' decision is necessary).

Corona rings are more common within HVDC applications, as those are tending to have higher requirements for the shielding, as the radio interference voltages are higher compared to AC applications. An interpolation from AC to DC applications is unfortunately not possible. So that the selection of the correct size is highly driven by experience. Confirmations from executed applications are very limited and mostly an accordingly type test is unavoidable [2].

B. Power Testing

Short-circuit tests are generally not necessary, but switching performance tests are mostly unavoidable, as portfolio references are missing.

Additionally, the switching performance tests have the challenge that laboratories are usually not offering DC options. Consequently, there are always estimations and interpolations for the applicability of the test results. Within HVDC applications, disconnectors with switching performance are often known as filter switching devices or cable discharging devices in case of earthing switches. Solutions are driven by known switching performance

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applications for AC solutions (e.g. the bus transfer devices, scarifying contact parts or combinations) [3,4].

C. Mechanical Testing

Mechanical endurance tests, ice load tests, continuous current tests (temperature rise tests) or seismic tests are usually not done but confirmed (via comparisons and/or calculations).

Individual installation requests, as in case of HVDC applications, lead to specific designs for the realization of the necessary kinematic chains. Therefore, usually high design efforts are required, and mechanical endurance tests are unlikely avoidable.

VIII. Conclusion

For complementary reasons e.g. linear disconnectors are to be mentioned. A known example is operated by air pressure. Here the high voltage conductor is a rope of 0.5..5 m lead through a tube and pushed out or in by air pressure, connecting or disconnecting. Such devices are applied in a laboratory in France and are quite old. Nevertheless, there will be new devices between 2010 and 2020, because the original manufacturer is not available anymore for this product. But small highly specialized designers are working on it.

This shows the wide range of possibilities to realize a disconnector within the world of high voltage applications. Some disconnector suppliers never say no to even exotic requests. But this needs a high organizational flexibility and a high level of mechanical and electrical high voltage knowledge.

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