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2SIS technology in MV switchgear easily adapts to harsh environments while minimizing internal arc probability

by Jean-Marc Biasse, Venanzio Ferraro, and Gang Wang

Abstract

The availability of medium-voltage (MV) networks is critical to efficient smart grid deployment. The Shielded Solid Insulation System (2SIS) in Premset™ MV switchgear enables harsh environment resiliency and greatly reduces the probability of an internal arc.

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Introduction

Smart grids have two main objectives: to optimize the relationship between energy supply and demand, and to provide the necessary conditions to integrate more distributed and renewable energies.

Considering the two-way flow needed for these objectives, and the simple one-way flow still valid for centralized energy production, it's clear we still face great challenges. The question then becomes: Is MV switchgear ready for this challenge, or is an evolution necessary?

Looking at existing grids and experiments, it appears that one important parameter is the ability of MV switchgear to withstand harsh environmental conditions without losing insulating performance. Insulation failures that may provoke internal arcs between live conductors and earth, or between phases, should be avoided.

Choice of technology

Ensuring durability and prolonged operational lifespan of switchgear requires the consideration of environmental and installation conditions — in addition to the technology. Variable environments can render switchgear technologies unequal.

Classification of environmental conditions

S. Milan[1] describes three classes of external conditions. The "normal conditions class" corresponds to normal service conditions that are defined in standards such as IEC 62271-1 "common specifications."[2]

In reality, more severe conditions are often met. Therefore, two other classes were defined: the "severe conditions class" and the "aggressive conditions class."

In the latter and most difficult one, both poor installation conditions and harsh climatic conditions are considered, such as a dusty, salty, or polluted atmosphere, the presence of water, or heavy pollution. Depending on the environmental condition class, the long-term behavior of different switchgear technologies varies.

Air Insulated Switchgear behavior

Air Insulated Switchgear (AIS) is a mixture of live conductors surrounded by air or encapsulated by insulation materials.

S. Milan[1] describes the process of aging of these systems. Any deposit of pollution, either liquid or dust, has higher conductivity than air or the insulating material. In the case of harsh environmental conditions, humidity may vary in the ambient air, and some conductive dust particles may settle on insulating parts. These events can vary the electrical field.

Variations of the electrical field bring additional constraints on insulating parts, especially at triple points, and create a corona effect and partial discharges that can lead to negative consequences for the equipment and accelerated aging.

In worst case scenarios, an internal arc in the switchgear occurs, irreversibly damaging the cubicle. As a consequence, AIS is not suitable for harsh environments belonging to the "aggressive condition class."

AIS has many advantages, i.e., there is often a high level of modularity and high levels of electrical performance can be reached. However, good installation conditions must be ensured for a long life expectancy. Those conditions can include: indoor installation, proper ventilation, normal humidity and temperature, and a very limited presence of dust in the room.

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[1] S. Milan, 2011, "Installation conditions and improved MV air insulated switchgear are key factors for an extended service life," CIRED Conference, Paper 0091

[2] IEC 62271-1, 2011-08, Ed. 1.1, "High-voltage switchgear and controlgear – Part 1: Common specifications"

Solid Insulated Switchgear behavior

In Solid Insulated Switchgear (SIS), the main MV circuit is generally encapsulated in insulating materials (e.g., epoxy resin).

Fundamentally, there is no difference in behavior compared to AIS. There is no visible live part along the main circuit. However, the issue of electrical field variation still exists when harsh environmental conditions are present. Conductive deposits may cause corona effects and partial discharges with the same potential consequences as AIS.

Therefore, SIS is not recommended for the worst condition class of harsh environments, i.e., the "aggressive condition class."

Classification of switchgear

With respect to the criterion "sensitivity to harsh environmental conditions," it is possible to classify switchgear into two categories:

1. Switchgear that is totally insensitive to harsh environments
2. Switchgear that is sensitive (at different levels) to environmental conditions

Gas Insulated Switchgear (GIS) and 2SIS belong to the first category of switchgear that is totally insensitive to harsh environments. AIS and SIS belong to the second category.

It is possible to illustrate the difference between both categories. In AIS and SIS, the electrical field lines go through all insulating parts and then pass through air areas, as shown in Figure 1.

In GIS or 2SIS, a metallic enclosure or shield is permanently connected to the earth, fixing the potential to zero. Then the electrical field lines are blocked by this zero potential barrier, as shown in Figure 2.

In GIS or 2SIS, the electrical field stays constant as it is contained in the insulating medium — either SF6 as in GIS or solid insulation as in 2SIS. Whatever the external climatic conditions are, they cannot influence the electrical field.

Keeping the electrical field constant is crucial to a long life expectancy, despite possible harsh environmental conditions around the switchgear.

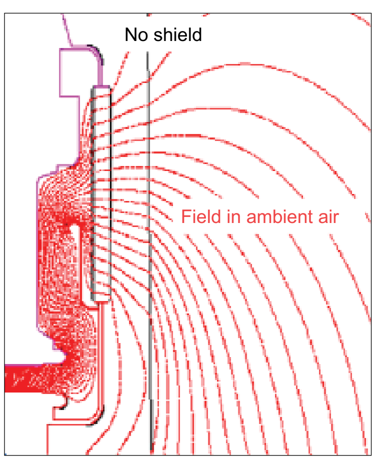
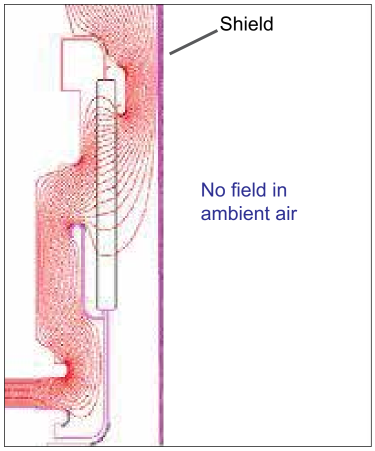


Figure 1

Electrical field distribution around live parts of the circuit breaker with no metallic shield

Figure 2

Electrical field distribution around live parts of the circuit breaker with metallic shield



2SIS: An original architecture

The 2SIS consists of three concentric layers:

- A live part
- An insulating layer
- A conductive layer

Live part

The live part (main conductor, insert, or vacuum interrupter) is permanently connected to the MV network and is therefore subject to voltage variations (i.e., fault, overload, etc.).

Insulating layer

An intermediate insulating layer wraps the live part in close contact and is covered by a conductive layer that is connected to the earth.

The purpose of the insulating layer is ensure that the insulation functions in all operating conditions during the entire life expectancy of the MV equipment.

The insulating layer could be made by synthetic resin, elastomer, or silicon depending on the application. These insulating materials are well-known to be of high quality and are widely used for MV insulation applications. Their manufacturing process, though sometimes complex, is now well-mastered thanks to real-time monitoring possibilities.

Conductive layer

An external conductive layer closely wraps the insulating layer on all accessible surfaces of the installed product.

The conductive layer could be made by overmolding or coating.

The 2SIS product of protection grade PA according to IEC 62271-201[3] can be accidentally or inadvertently touched by people (e.g., during maintenance operations).

The conductive layer has a relatively low resistance in order to ensure electrical continuity and an effective earth connection.

[3] IEC 62271-201, 2014-03, Ed. 2.0, “High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV”

2SIS: A large variety of interfaces

Open system

In order to satisfy the large variety of MV connection systems available on the market, 2SIS is open and may be interfaced with many existing types:

- Conical interface complying with EN 50181 standard[4]
- Conical interface complying with other national standards (i.e., ANSI/IEEE)
- Conical interface in accordance with particular user or manufacturer specifications

In addition, a specific flat interface has been developed, improving the performance of MV connections for — particularly, but not limited to — busbar arrangement.

Innovative flat interface

The flat interface is an evolution of the conical interface; keeping the strong points of the insulated and screened connections, and adding simplicity of installation, compactness, flexibility, and increasing safety.

The flat interface (Figure 3) consists of a conducting insert in a compressible insulating elastomer or silicone that is coated with a shielding layer. The connecting surface of the conducting insert is recessed from the connection surface of the insulating support.

When connection is performed, the insulating surfaces come into contact. Compression is then performed, enabling the interface to become airtight, while at the same time bringing the conducting surfaces into contact. The assembly is kept compressed by means of a central screw.

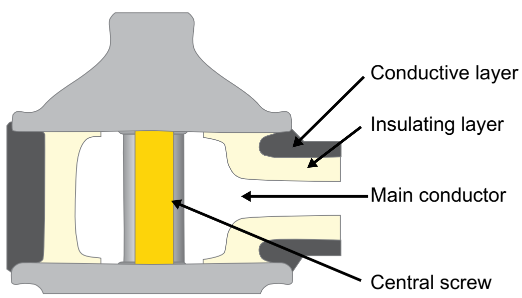


Figure 2

Cross section of flat interface

All of the external surfaces of the installed interconnector system are screened and connected to the earth. The electrical field is included and fixed in the insulating layer without affecting the surface of the interconnector — avoiding any superficial electrical aging.

The assembly procedure is simple due to the reduced number of components and dielectric interfaces. The sequence of assembly is intuitive with an easy visual assessment (i.e., the cleanliness of both contact and insulating surfaces).

The flat interface is more compact compared to the conical interface, and the space needed to make the installation is extremely reduced. This creates an important advantage for compact units that are increasingly used in MV substations. The earth continuity is automatically obtained when tightening the interconnectors — having a flat interface without the need of any additional components, dedicated tooling, or specific sequences of assembly.

The flat interface ensures more reliable assembly and increases the safety of the installation.

[4] EN 50181, 2010-07, Ed. 2.0, "Plug-in type bushings above 1 kV up to 52 kV and from 250 A to 2.50 kA for equipment other than liquid filled transformers"

Reduction of arc fault risk

Arc fault risk depends on switchgear design and external parameters. D. Fulchiron[5] describes several types of causes for arc fault occurrence, each of which has a very low probability.

Some are linked to aging of the insulation material of the switchgear, wear, and ingress of animals; while others are linked to external, abnormal electrical characteristics such as overloads and overvoltages.

It is necessary to carry out type tests when internal arc classification is claimed. The tests of this optional performance are defined in IEC 62271-200[6] and are carried out in all MV compartments.

Even if internal arc faults are rare globally, the most frequent events occur in cable compartments. Regarding the possible occurrence of internal arc faults in a cable compartment, 2SIS technology provides many advantages. As the electrical field in the insulating material is kept constant, there is no aging due to external environmental conditions. The same applies for circuit breaker and busbar compartments. This contributes to a drastically lower internal arc probability.

Additionally, and again thanks to the conductive layer on the insulating material of each separated phase, three-phase or two-phase faults are made impossible by design. Internal arc faults, when they occur, are single-phase to earth faults only, which has been proven through numerous tests.

Last but not least, this is of great advantage for all power systems, where the neutral system is earthed through an impedance. For such systems, the phase-to-earth short-circuit current is usually 10 or 20 times lower than the three-phase short-circuit current, and therefore the internal arc effects are mitigated to a very low level by design.

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[5] D. Fulchiron, 2007, "Safety analysis of a MV electrical installation regarding arcing fault risk," CIRED Conference Vienna 21 – 24 May 2007, Paper no 0133

[6] IEC 62271-200, 2011-10, Ed. 2.0, "AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV"

Conclusion

2SIS fulfills harsh environmental resiliency requirements through industry-leading technology. It is equivalent to GIS against the "aggressive" class of environmental and installation conditions. The probability of arc fault is lowered by phase segregation including conductive layers. For many neutral systems, 2SIS maintains a low magnitude of single-phase arc fault current that greatly limits damage.

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