SIEMENS

Trade article

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Innovative switch disconnector key to sustainable power distribution on the secondary distribution level

In medium-voltage applications, economically and technically feasible SF6-free alternatives in gas-insulated technology were initially limited to switchgear on the primary distribution network level. The innovative switch disconnector from Siemens has changed this: This new development combines vacuum switching technology and an insulating gas consisting of the elements of the ambient air in one compact device, bringing the benefits of fluorine-gas-free, climate-friendly medium-voltage switching technology to the secondary distribution level.

Sulfur hexafluoride (SF6) is known to be ideally suited as an insulating gas in electrical systems, but it does contribute to global warming if released into the atmosphere. For this reason, the electrical industry entered into a voluntary commitment already in 2005 [1] to develop alternatives to SF6. The first feasible solutions resulting from these efforts were available in high voltage (>52 kV) applications and in medium-voltage switchgear for the primary distribution level. Until now, there were no economically and technically reasonable solutions for medium-voltage load-break switchgear widely used in secondary distribution networks. Eliminating SF6 requires finding a different way to achieve not just equivalent insulation properties but also an alternative to its outstanding arc quenching capabilities.

Until now, the approaches used for SF6-free load-breaking technology have typically been based on circuit-breakers with vacuum interrupters found in switchgear on the primary distribution level. However, since the secondary distribution level mostly handles load switching tasks to distribute power in the local grids, such vacuum circuit-breakers would be oversized and hence not cost-efficient. In addition, vacuum interrupters are installed in the primary current path where they are exposed to a constant power flow and therefore to a continuous load. Moreover, a second switching device is needed to safely meet the isolating distance requirements outside the vacuum tube.

blue Switch: fluorine gas-free switch disconnector

Siemens has been working on this challenge for a number of years. The core of the solution: A vacuum interrupter specifically designed for load breaking is used exclusively to quench the switching arc in its hermetically enclosed vacuum chamber while the other functions – switching on, conducting the operating, short-circuit and ground-fault current, and meeting the isolating distance requirements – are implemented in a fluorine-free insulating gas (image 1). Because of the compact dimensions of this switching device, the switchgear footprint does not need to be changed.

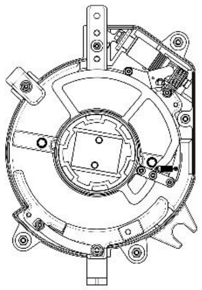

Image 1: Diagram of a switch disconnector with vacuum interrupter

The most recent result of this development work is the blue Switch disconnector for the Siemens blue GIS portfolio. In this full-featured three-position switch, a rotating switching contact coupled with a control disc is moved during switching operations. While the contact is moving from the ON position towards OFF, the current flow is directed to a parallel secondary current path where the vacuum interrupter (initially closed) is located. Further movement of the switching contact opens the primary current path, causing the current to commutate completely to the secondary current path and briefly flowing exclusively through the vacuum interrupter. Then the vacuum interrupter is opened via the control disc and the resulting current breaking arc is reliably quenched in the vacuum in just a few milliseconds while the rotating primary current switching contact safely reaches the OFF position with zero current. Because of the distance achieved between the conducting parts, the isolating distance requirements are met in a single switch movement. The third position, GROUNDED, is reached by simply moving the switching contact from the OFF position to the grounding contact (image 2). The reverse operation, from the OFF position towards ON, is completed without the formation of a pre-ignition arc in the vacuum interrupter.

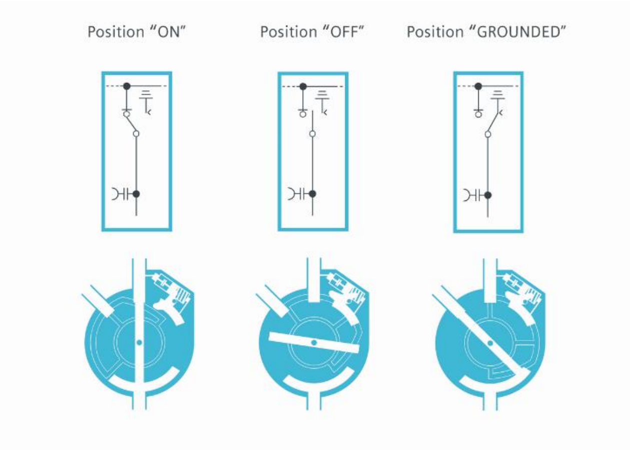

Image 2: Switch positions (diagram) of the switch disconnector with vacuum interrupter

The safe and long-lasting functionality of the switch disconnector as ring cable switch in a ring main unit (RMU) has been proven by type testing in accordance with IEC 62271-103. Its disconnect function and the short-circuit making towards the GROUNDED position meet the requirements of IEC 62271-102.

Image 3: blue Switch disconnector with vacuum interrupter

In the innovative Siemens design, the slightly pressurized Clean Air insulation gas, which consists entirely of the naturally occurring elements of the ambient air, ensures the safe gas insulation of the electrically conducting parts within a hermetically enclosed compartment. Enclosing and managing the switching arc in a vacuum interrupter ensures that the insulating gas is not subjected to increased energy input. As a result, the insulating gas can be discharged without special measures when the switchgear reaches its end of its life instead of requiring costly disposal as is needed or recommended for substances that contain fluorine.

The insulating properties of an insulating gas increase as the pressure increases. The compartment's internal pressure of Siemens load-break switchgear that uses Clear Air insulating gas is comparable to that of similar SF6 equipment. For this reason, no special measures are needed during transport or operation.

Local substations as standard use case

The first switchgear using such new and innovative switch disconnectors for 12 kV have been in use at customer sites since 2019 (image 3). Norwegian power grid operator BKK Nett AS is one of the companies using the new technology. Another is German Netze BW GmbH, the largest distribution grid operator in the EnBW Group. As part of a research partnership with Siemens, Netze BW is currently testing the a 24 kV load-break switchgear in daily operation (image 4). Installed in a non-accessible substation building, the switchgear is connected to Netze BW's grid control center via an integrated remote terminal unit.

Image 4: Substation at Netze BW GmbH

Such local medium voltage/low-voltage substations, many of which are found in urban areas, are the standard application on the secondary distribution level. On the medium-voltage side, they comprise ring main units (RMU), which typically consist of two ring cable feeders and a transformer feeder: One ring cable feeder switches the input of the cable from the energy provider's supply ring. The second ring cable feeder feeds back into the medium-voltage supply ring leading to the next substation. In local substations, medium voltage (typically 12 kV or 24 kV) is converted to low voltage (400 V) using a transformer connected to the RMU's transformer feeder. In addition to a switch disconnector, this transformer feeder panel requires a method of protection for the connected transformer; up to certain transformer outputs, fuses are often used.

Conventional SF6-free alternatives frequently use a circuit-breaker instead of a switch disconnector-fuse combination. In addition to the disadvantages already mentioned regarding complexity, oversizing, and cost, a separate protection relay is needed to protect the transformer against overloads and short circuits. Such a relay is dependent on a reliable, uninterrupted power supply and initiates a chain of command up to trigger a switching operation. In contrast, fuses respond directly to and limit fault currents, and they are intrinsically safe and cost-effective. At the usual transformer power, they are often the first choice for RMU designs.

The new Siemens switch disconnector can easily be combined with fuses to create an advantageous switch disconnector-fuse combination for use in transformer feeders. Results from tests in accordance with IEC 62271-105 have even shown that significantly higher transfer and take-over currents (1300 A or higher) can be achieved compared to other SF6-free switching principles (image 5). This paves the way to connecting transformers with even higher power when corresponding fuses are available.

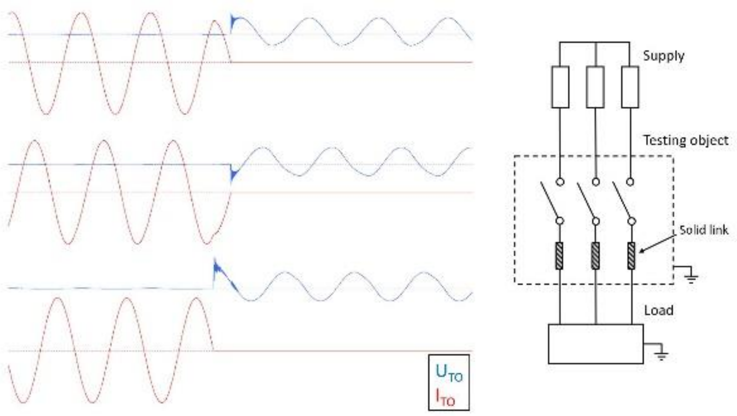

Image 5: Testing the fuse take-over current

Furthermore, it is important that SF6-free switchgear alternatives do not require a larger footprint in the station. A width of 1,050 mm has become the de-facto standard for RMUs, and many substations have been designed for this size. The compact design of the Siemens blue Switch makes it possible to build switchgear with the same dimensions so it fits into existing stations. This saves time and cost during station construction and makes it easy to retrofit legacy SF6 switchgear.

Image 6: Siemens blue GIS 8DJH switchgear

Sources:

(1) VDN, VIK, ZVEI, Solvay: Selbstverpflichtung der SF6-Produzenten, Hersteller und Betreiber von elektrischen Betriebsmitteln >1kV zur elektrischen Energieübertragung und -verteilung in der Bundesrepublik Deutschland zu SF6 als Isolier- und Löschgas (Voluntary commitment of SF6 producers, manufacturers and users of electrical equipment >1kV for electrical power transfer and distribution in the Federal Republic of Germany regarding the use of SF6 as insulating and extinguishing gas)

Image source:
Siemens AG (all images)

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