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Switchgear - HV switchgear – there is a green alternative - part 2

High voltage switchgear is one of the few applications where the use of SF6 gas is still permitted under Greenhouse Gas Regulations. This is based on the premise there is no viable alternative. However, in the range 1-52kV there is a perfectly viable option in the form of vacuum switchgear with solid dielectric insulation. Vacuum switchgear is similar in size and technically equivalent, if not superior, to SF6 switchgear. It is being used increasingly by utilities in Europe for medium voltage (1-52kV) applications say W Porte and GC Schoonenberg from Eaton, in the second instalment of this two-part article
****the first part of this article can be found at www.electricalreview.co.uk***

Vacuum interruption is a proven technology, introduced more than 40 years ago. Arc interruption takes place in a vacuum 'bottle'. Vacuum interrupters do not require costly leakage monitoring equipment. Electrical performance is comparable and, at times, better than SF6 switchgear. While capital cost is slightly higher, total life-cycle cost is lower due to the lower maintenance costs. All materials can be recycled at end of life.

Continuous development has seen the size of a 15kV vacuum interrupter bottle come down from180mm diameter in 1967 to 50mm today. Meanwhile modern sealing techniques ensure that units retain their vacuum for more than 25 years. On the rare occasions when leaks do occur, they normally manifest themselves early in life; so rigorous production testing helps identify such leaks before units reach the field. Any leaks are, of course, completely harmless to the environment.

Vacuum circuit-breakers are suitable for a wide range of medium voltage switching applications including transformer secondary protection, capacitor switching and motor switching. They are used by utilities for ring main units and MV switchboards in the range 3kV to 36kV. They are suitable for current ratings from 100A to more than 4,000A and fault levels from 6kA to 63kA.

Apart from compact size, vacuum circuit-breakers offer excellent electrical performance. They will normally withstand a rated a.c. power frequency withstand voltage (an overvoltage due to power system switching operations) of 2-4 times normal operating voltage. Rated lightning impulse withstand is 4-12 times normal operating voltage. However, in normal service the breaker contacts are closed so lightning overvoltages are mostly seen by the line-to-earth or line-to-line insulation; in the rare event of a lightning impulse appearing across the open contacts of the vacuum interrupter, the current will be quickly broken. Under similar conditions an SF6 puffer-type circuit-breaker, air circuit-breaker or minimum oil circuit-breaker would probably explode.

An interesting characteristic of the vacuum circuit-breaker is self-conditioning of the contacts. Rough spots that can occur on the contact surfaces are smoothed out by the discharge when the contacts are opened on-load.

Vacuum interrupters offer exceptional performance under load switching conditions, far exceeding the mechanical life of any circuit-breakers and reclosers of which they form a part. Consequently they are used in railway switching applications where electrical and mechanical life in excess of 250,000 operations is required. They are also suited to motor switching duties in excess of one million operations, arc furnace switching and capacitor switching. Contact resistance remains low throughout life because contact erosion only occurs at the cathode and eroded material is deposited uniformly on the anode; the contacts act randomly as cathode and anode so the effect is evened out. In SF6 circuit-breakers, contact resistance increases during life.

Vacuum interrupters are constructed from materials that can be recovered and recycled at the end of life. They do not contain greenhouse gases; nor do they present potential health hazards due to the products of decomposition. No special precautions are necessary to protect the environment from the results of leaks or during disposal.

The compact size of modern vacuum insulator bottles means special measures are necessary to improve insulation levels. A 150mm ceramic length will only have a basic insulation level (BIL) of 125kV in air. For this reason insulators may be immersed in a dielectric medium such as oil or SF6 gas to raise the BIL to 170kV. Oil is being phased out because of the fire risk, so SF6 insulation is favoured by many manufacturers.

However, an alternative approach is to enclose the vacuum interrupter in a potting compound such as polyurethane or epoxy. In some cases an epoxy insulator with a contoured profile, similar to the 'sheds' used on overhead line insulators, is used to increase creep distances. This is especially valuable when the equipment is used in industrial environments involving heavy atmospheric pollution or condensation. In some cases the entire interrupter and associated busbar are enclosed in solid insulation.

Modern vacuum switchgear with solid dielectric insulation is comparable in size to the SF6 gas insulated equivalent. The circuit-breaker assembly can operate in a normal enclosure with no special sealing or gas filling, and there is no need for costly monitoring equipment. Maintenance is negligible and life can be expected to be 30 years or more.

Total cost of ownership

While the unit cost for gas insulated switchgear is lower than for the solid insulated switchgear described above, total cost of ownership is much higher for the GIS equipment. The specialist nature of the pressure checks needed by GIS equipment means that trained personnel with specialist equipment will have to carry out the work. One estimate has put the annual cost of this maintenance as 9% of the equipment value per year. This does not include any other safety and insurance costs.

Disposal costs for GIS equipment at end of life are difficult to quantify. Recycling of parts and by-products is not practicable and dismantling, transport and disposal costs will be high. In contrast the solid-insulated equipment is fully compliant with ISO 14001, covering environmental management systems and standards. All parts are capable of being recycled.

Conclusion

There is no justification - environmentally, technically or financially - for using SF6 gas-insulated switchgear for circuit-breakers and ring main units up to 52kV. In fact vacuum interrupters up to 145kV are now in service. However, solid insulation has yet to catch up with this.