Simplifying circuit-breakers

Dead tank circuit-breakers for 80 kA and 145-242 kV

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The next time you reset a 10-A miniature circuit-breaker in your home, spare a thought for the breakers, perhaps just a few miles away, that have to handle currents as high as 80,000 A. Up at the 245-kV level, these highly engineered devices, each the size of a small car, are traditionally of the oil or two-pressure type. In short, they are relatively complex and cumbersome.

A third, altogether simpler, cheaper and easier-to-use type of breaker, the SF₆ dead tank puffer breaker, has never been used before for these elevated and highly demanding ratings. Now, ABB is doing just that, with a new 80-kA design that combines a single-break puffer interrupter with the proven type PM dead tank breaker.

Years ago, Westinghouse and ITE built two-pressure, SF₆ circuit-breakers for 80-kA applications, and many of these units are still in service today. They work by blasting high-pressure SF₆ gas (at about 1900 kilopascals, or 260 psig) across the arcing contacts during the interrupting process. SF₆ at a much lower pressure is used as the insulating medium for the interrupter tanks, columns and bushings. The good performance of the breakers stemmed from the fact that a large volume of instantly available high-pressure SF₆ gas is applied through a large-diameter, two-break interrupter.

This design has a definite performance advantage over puffer interrupters, which take some time to compress the gas during the opening stroke. However, the two-break, two-pressure system, with its gas manifolds, compressors, dryers, high-pressure feed tubes and insulated, heated high-pressure tanks, is quite complex and expensive. This has resulted in single-pressure puffer interrupters becoming the design standard for new power circuit-breaker production around the world.

Until now, SF₆ dead tank puffer breakers were not available for 80 kA; the single-pressure technology of puffer interrupters has lagged behind the performance capability of oil and two-pressure SF₆ breakers for the highest interrupting current ratings. More rigorous ANSI standards and greater demand for applications such as capacitor switching
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have further defined the limits of puffer technology.

ABB has overcome the problems that previously prohibited the use of puffer technology for 80 kA with a single-break puffer interrupter inside its dead tank breaker. The new device uses many parts of the already popular high-volume 63-kA breaker, thereby drastically reducing the need for new engineering.

ABB is on familiar ground in this area of technology, having developed an 80-kA puffer interrupter for 245-kV and 550-kV GIS breakers in 1992. The design was based on the SP interrupter that ABB has used in its 242-kV type PA breakers for the 63-kA range since 1988. This first 80-kA interrupter was limited to 170 kV per break, requiring two breaks for 245 kV and three breaks for 550 kV. Continued SP interrupter development has meanwhile improved the recovery voltage capability to 245 kV per break, allowing the same interrupter to be used for 145-kV and 245-kV ratings in a single break. The breaker may be three-pole-operated or independent-pole-operated, with the option of synchronous switching.

This breakthrough comes not a moment too soon: Worldwide, some 200 to 300 ‘old-design’ 80-kA breakers

Dead and Live

The distinguishing feature of dead tank technology is that the interrupter chamber is in a grounded metal housing. Thus, the SF₆ gas filling insulates the high-voltage live parts of the contact assembly from the housing. Outdoor bushings connect the interrupter chamber to the high-voltage terminals.

The interrupter chamber of a live tank circuit-breaker is in the insulator (porcelain or composite) and is at high potential, with the voltage level determining the length of the insulators for the interrupter chamber and the insulator column.
are in service and these units, oil as well as two-pressure SF₆ breakers, are nearing the end their service life.

Also, the extra demands being made on networks by new merchant plants (plants that are built outside the protection of regulatory oversight and which ‘go it alone’ in the new competitive power markets) have driven the need for higher interrupting performance. The need for 80-kA products is growing rapidly as a result.

**Part commonality reduces costs**

The SP 80-kA interrupter is being used to build a breaker for both the 145-kV and 242-kV ratings. A common platform has the benefit of maximizing production volume for the 80-kA rating.

Also available is a high (5000 ampere) continuous current option.

The present 63-kA-rated 242 PMG three-pole-operated breaker 1 and the 242 PMI independent-pole-operated breaker will have the 80-kA interrupters fitted to provide either operating configuration. The external breaker design remains unchanged for the higher current rating. Production of the 80-kA breaker benefits enormously from being able to share components with the higher volume 63-kA breaker, which already has a good service record. The design differences are only in the interrupter and the internal bushing connection to the interrupter.

It is possible to use the same operating mechanism and connecting linkage for both interrupters since the 80-kA interrupter does not require significantly more drive energy. The puffer cylinder and piston are not increased by the rating increase from 63 kA to 80 kA so the pressure area does not have to be greater. In addition, the SP interrupter piston has pressure relief valves that limit the pressure rise during the high-current arcing inside the interrupter.

The 63-kA and 80-kA ratings both work with the same pressure rise limit and the same opening stroke. This keeps the work done to compress the SF₆ gas the same for both interrupter ratings.

The moving contact mass is increased only very slightly, the arcing contacts are just a few millimeters larger, and the opening velocity has been kept the same. The opening velocity is determined primarily by the speed at which the dielectric strength across the opening gap must increase to resist the rising capacitor switching recovery voltage. Therefore, the kinetic energy \((1/2MV^2)\) that the mechanism has to provide has not increased. The total energy to be supplied by this mechanism is the sum of the SF₆ compression energy, the kinetic energy and the friction losses. Although very slightly higher, it is still within the capability of the present 242 PM mechanism.

The 242-kV bushing insulators will also be the same as those used on the 63-kA breaker, and the breaker may have either composite or porcelain bushings. The internal bushing conductor is different because it plugs into the larger interrupter housing, which has a double set of current transfer contacts for the higher current rating.

**Nozzle improvements**

There were two areas that required improvement in the new 80-kA interrupter design. The first was the nozzle flow channel, which was reshaped to handle the higher transient recovery voltage (TRV) for the 245-kV rating. The second was the interrupter housing 2, which has to contain and cool the exhaust gases following an 80-kA fault before venting them into the relatively small-volume 242 PM tank.

The improved nozzle was developed with the help of cold characteristic testing, which, together with advanced calculation software, simulates the opening TRV characteristic for capacitor switching. During an opening operation, high-frequency voltage impulses
are applied at points along the travel to determine the dynamic dielectric strength of the gap. The dielectric strength must exceed the wave-shape for the capacitor switching voltage with a big enough margin to ensure successful performance in actual capacitor switching tests. This technique determines whether there are any flow holes that could cause zones of dielectric weakness. Flow holes are low-density regions caused by gas expanding too rapidly through the nozzle, resulting in a sudden drop in dielectric strength at some point in the opening stroke.

Cold characteristic testing tends to be very complex because of the many operations that are required to develop the cold characteristic for the full opening travel with both positive and negative polarities. However, it does save having to perform different power tests and gives a detailed insight into how to improve the nozzle shape. As Figure 1 shows, the opening dielectric strength of the interrupter exceeds the 1-cosine waveshapes typical of capacitive switching recovery voltages. It should be pointed out here that cold characteristic tests are simulations carried out to help with the nozzle design, and do not replace actual capacitor switching tests or any other power tests.

**Improved interrupter housings**

During the interruption, the hot gases exit the nozzle in both directions. The moving contact and stationary contact housings must capture these hot gases,
mix them with cool SF₆ and vent them back into the tank after they have cooled sufficiently to recover their dielectric strength. The increased energy and volume of the exhaust gases is proportional to the square of the fault current; therefore, the 80-kA interrupter housing must be capable of holding 1.6 times the exhaust energy of the 63-kA interrupter. The new housing must balance the need for increased size against the dielectric clearance limitations of the existing 242 PMG tank.

shows the 80-kA interrupters next to the 63-kA units. The exhaust housing volume has been increased to match the higher fault current, and internal baffles have been improved to trap, mix and cool the hot gases better. Even though the unit is physically larger, it still fits into the same tank and is shaped to optimize the dielectric strength of the SF₆ insulation between them. Also, the bushing plug-in contacts on top of each exhaust housing have been improved to withstand the higher 80-kA fault current.

External capacitors
The 242 PMG 63-kA breaker requires a 10-nF line-side capacitor to reduce the rate of rise of recovery voltage across the contacts due to short-line faults. This is because the ionized SF₆ gas in the contact gap takes several microseconds to recombine sufficiently to resist the very fast voltage reflections that are caused when faults occur within a few kilometers of the breaker.

For the 80-kA breaker, the line-side capacitance must be increased to 30 nF. In addition, 15 nF is needed on the bus side to resist the new ITRV (Initial TRV) requirement in the latest revision of the standards. The external capacitors are quite large, but both the 15 nF or 30 nF units have a composite housing to reduce their size and weight as much as possible. They can be mounted directly across each bushing to eliminate the need for a separate foundation and capacitor stand. However, it is also possible to mount these capacitors on separate stands, allowing two or more breakers to share them. This option will reduce the number of capacitors needed and may improve the substation layout.

Making breaking easy
Now that puffer breaker technology has been extended into the 80-kA/245-kV range, operators have a fitting replacement for outmoded and over-complex traditional technology. It is also possible to upgrade existing 242 PMG/I breakers with the 80-kA interrupters since the external breaker design is unchanged.

SP interrupter and PM breaker technology has been improved to achieve this higher performance rating without having to forgo any of the benefits of a proven design. The options of three-pole and independent-pole operation, as well as synchronous switching, are available to meet specific application requirements. Most of all, though, this significant advance in breaker technology will make life easier and less costly for utilities and industry alike.

External capacitor mounted directly across a bushing, making a separate foundation and capacitor stand unnecessary
1. Composite capacitor
2. Composite bushing
3. CT housing on breaker tank

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