Nexans

Superconductors provide fast response to fault currents

Dr. Joachim Bock, Director Sales and Market Development for Nexans HTS-Systems and Gerhard Novak, Technical Manager for Nexans UK, explain why innovative superconducting devices are set to play a key role in future smart power grids by providing an almost instantaneous response to fault currents - preventing damaging overloading of switchgear and other network components.

In general, power networks are designed with a relatively low impedance between the generators that provide the source of electrical power and the users of the power - the system loads. The aim is to maintain a fixed, stable system voltage while the current varies to meet the changing loads. The main advantage of this approach is that the individual loads are effectively independent of each other, so that network stability can be maintained as they change. It does though have an important downside, which is that substantial fault currents – typically between five and 20 times the nominal current – can develop during network disturbances.

Over time, the maximum fault current in a network has tended to increase for a number of reasons:

- Increasing demands for power and the resulting need for increased generation are pushing MV power grids to their maximum operating limits
- Parallel distribution paths are being added to networks to support load growth and there are a greater number of interconnections within the grid
- The development of distributed generation, such as wind power and CHP schemes, are adding complexity to an already complex system

The net effect is that short circuits can occur more often and are more likely to cause high, uncontrolled fault currents, leading to damage of electrical networks and consequent power failures.

Until now, operators of public and industrial electrical networks could only have limited protection against high short circuit currents, either by the use of complicated equipment or by over-rating of components. There are concerns that as potential fault current levels continue to increase they will soon exceed the protection capabilities of existing equipment.

There are two possible solutions to this challenge. Utilities could upgrade their substations to handle the new maximum short circuit currents - which would require multi-million pound investments in new infrastructure. Or they could add a device that reduces the potential short circuit currents to a level that their existing substations can handle – a fault current limiter.

The Superconducting Fault Current Limiter

Leading manufacturers and research establishments have been investigating fault current limiting devices for several years in order to offer an alternative to network reconfiguration/asset replacement in tackling rising fault levels. The Superconducting Fault Current Limiter (SFCL) is designed to be a low risk fail-safe device, utilising a non- linear 'high-temperature' superconducting (HTS) ceramic rather than electronic, electromechanical, mechanical or pyrotechnic components.

When the superconducting element is cooled below its critical temperature it loses all electrical resistance, thereby allowing normal load current to flow with negligible losses. The operating temperature of -196°C, that is well below such critical temperature, can be obtained using relatively inexpensive and readily available liquid nitrogen. Any rise in temperature – due either to the increased current density caused by the passage of a fault current, or the loss of the liquid nitrogen cooling medium – will cause the superconducting material to revert to a normal resistive state.

This added resistance has the effect of reducing the fault current to a lower, more acceptable level. This process is referred to as 'clamping' because it effectively sets a limit above which the fault current will not rise. The SFCL operates in a few milliseconds, after which its resistance remains high until the fault current is cleared by a circuit breaker. The SFCL's fast operation ensures that the first peak of the fault current is limited; this is vitally important when considering the closing of a circuit breaker onto a section of faulty network. The degree to which the subsequent current is limited can be set at the design stage to suit a specific application. In many cases this level could be selected so that existing protection arrangements do not need to be adjusted.

SCFCL advantages

Nexans has developed commercially available SCFCL devices that are capable of clamping fault levels to within network design limits. They offer a number of benefits:

- SFCLs could be strategically deployed onto the network in areas either with existing high fault level issues, or where there is a high degree of distributed generation connection activity (e.g. urban CHP schemes or wind farms). In this application SFCLs could provide a method of deferring the replacement of switchboards or reconfiguration of networks whilst ensuring fault levels are maintained within safe limits.
- Where fault levels are generally high, there may be operational benefits associated with minimising the often complicated switching required to ensure that equipment operates within its fault rating during network reconfiguration and outages. This could reduce the risk of incurring customer interruptions arising from either network switching or from operating parts of the network temporarily on single circuit security. An improvement in personnel safety may also be possible.
- If the size of network fault currents are restricted, equipment will be subjected to reduced electrodynamic and thermal stress (these are both proportional to the square of the current, so a modest reduction in fault level results in a considerable reduction in these stresses), potentially reducing the probability of consequent faults and prolonging the asset life.
- SFCLs may, subject to resolution of protection issues, allow existing radial circuits to be operated on an interconnected basis, with associated improvements in the continuity of supplies to customers and power quality (flicker and harmonics). This could facilitate a radical change in the way networks are designed and operated.

Deployment of first SFCL

The first field test of a Nexans SCFCL was carried out at an ENW (Electricity North West) substation in Bamber Bridge, Lancashire where it was live on the grid from October 2009 to June 2010. This site was selected as representative of a location where an SFCL might be installed in response to a real need.

The two 33/11kV transformers feeding the substation had been recently upgraded, with the result that the fault level increased to above the making and breaking capacities of the existing circuit breakers. It was therefore necessary to build a new substation and install a new 11kV switchboard of primary distribution circuit breakers comprising 10 feeders, two incomers and one bus-section. So, while the fault level problem was addressed in a conventional manner, the situation allowed the design of the SFCL to be determined according to realistic criteria, providing a solution to the fault level issue.

World's first SCFCL installation in a power plant

At the end of 2009, Nexans commissioned the world's first SCFCL to be installed in a power plant. In this pilot project for Vattenfall Europe Generation AG, the SFCL was used to provide short-circuit protection for the internal medium voltage power supply that feeds coal mills and crushers in the Boxberg brown coal power plant in Saxony, Germany.

The 12 month project enabled Vattenfall´s experts to gain valuable hands on experience with innovative SCFCL technology that they believe will offer significant benefits in personnel and plant safety. Not only was this the first time that this type of device had ever been used in a power plant, which is a highly challenging environment from a technological point of view, the project also was implemented without public grants, which is unprecedented on the world stage.

Vattenfall's SFCL, designed for a rated current of 800 A, received live testing by daily routine operation in a feeder circuit of the 12 kV power supply for rebound hammer mills (used for crushing coal). It was designed and built by Nexans according to specifications from Vattenfall and the Brandenburg Technical University in Cottbus (Germany), which provided scientific support for the project. The device could limit a 63 kA prospective short circuit current to less than 30 kA immediately and to about 7 kA after 10 milliseconds. A second field test is now planned using a new generation of superconductor tape.

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Also published in Electrical Review, Juli 2011