Superconductivity News Update
Bringing New Power to Electricity

FAULT CURRENT LIMITERS: AN OVERVIEW

The Department of Energy's Office of Electricity Delivery and Energy Reliability's mission is to lead national efforts to modernize the electric grid, enhance the security and reliability of the energy infrastructure, and facilitate recovery from disruptions to the energy supply. To support this mission, the DOE's superconductivity program supports HTS power cable and fault current limiters technology development in an effort to modernize the electric grid.

For the past several years, Superconductivity News Update has provided, on behalf of the DOE's superconductivity program, news and educational information concerning superconductivity products. Our mission has been to educate and inform individuals on the benefits of superconductivity. In the past, our issues have focused on research milestones, DOE/private company news, superconductivity cable project statuses, and whatever newsworthy related information was available. However for this issue we would like to take a different approach. Instead of the normal newsletter, we would like to discuss what may be an unfamiliar superconducting product; fault current limiters (FCL).

WHAT IS A FCL?

A fault current limiter is a device that uses superconductors to instantaneously limit or reduce unanticipated electrical surges that may occur on utility distribution and transmission networks.

WHY DO WE NEED THE FCL?

When an unplanned event, such as lightning or downed power lines, occurs, a large surge of power can be sent through the grid resulting in a fault. A fault is any abnormal situation in an electrical system in which the electrical current may or may not flow through the intended part/s at an abnormal level and can result in a partial or total local failure in the functioning of an electric system. Serious faults can generate surge currents more than one hundred times the normal operating currents. These faults can result in damage to expensive grid-connected equipment.

The development of new generating facilities and network upgrades can greatly increase the potential fault current on a network. The FCL eliminates or limits the fault current increases resulting when new generation and network upgrades occur. This potential for increased fault current makes it imperative that utilities invest in protective measures such as: new substations, splitting existing substation busses, or using multiple circuit breaker upgrades. These protective measures are extremely expensive to install and maintain. FCL's eliminate or greatly reduce the financial burden on the utilities by reducing the wear on circuit breakers and protecting other expensive equipment.

WHAT ARE FCL BENEFITS?

According to the DOE, utilities pay hundreds of millions of dollars each year to maintain and add new circuit breakers to their transmission systems to protect the grid. The DOE then explains that investing in “smart technologies” such as FCL can save billions of dollars on transmission and delivery (T&D) equipment and power plants. Utility benefits from FCL include increased safety, reliability, and power quality. Utilities can reduce or eliminate the cost of circuit breakers and fuses by installing FCL. At the same time, these allow utilities to avoid or delay upgrading existing circuit breakers and electrical substations to handle ever higher electrical surges. Fault currents in transformers, for instance, can run 10-20 times the steady state design current. FCL can reduce these fault currents to levels not exceeding 3-5 times the steady state current, protecting and extending the life of transformers and associated utility equipment.

OTHER FCL BENEFITS:

- Reduce or eliminate wide-area blackouts, far fewer localized disruptions, and faster recovery when disruptions do occur
- Provide protection to T&D equipment, eliminate or reduce replacement of T&D equipment (i.e. circuit breakers)
- Avoid split buses, opening bus-tie breakers
- Higher system reliability
- Reduce voltage dips
- Enhance grid stability. Enables the creation of a safer, more reliable, more efficient, and affordable power delivery system

WHO IS DEVELOPING FCL's in the U.S.?

- Air Products and Chemicals Inc. (Allentown, PA)
- American Electric Power (AEP) (Gahanna, OH)
- American Superconductor
- The BOC Group Inc. (Murray Hill, NJ)
- California Edison Inc. (Rosemead, CA)
- Consolidated Edison Company (New York, NY)
- Cryo-Industries of America Inc. (Manchester, NH)
- Delta Star Inc. (San Carlos, CA)
- DOE’s Los Alamos National Laboratory (Los Alamos, NM)
- DOE’s Oak Ridge National Laboratory (Oak Ridge, TN)
- EPRI
- Nexans (France)
- Nissan Electric Co. Ltd. (Kyoto, Japan)
- SC Power Systems
- Siemens AG (Germany)
- Southwire Company
- Sumitomo Electric Industries Ltd. (Osaka, Japan)
- SuperPower
- Trithor GmbH (Germany)
- United States Department of Energy (DOE)
- United States Department of Homeland Security
- The University of Houston (Houston, TX)

DOE FUNDED FCL PROJECTS

American Superconductor - (DOE cost share: $12.7 million)

American Superconductor is addressing the development and in-grid testing of a three-phase high-voltage, 115-kilovolt fault current limiter, called a SuperLimiter™, by using second-generation wire. The SuperLimiter™ features a proprietary Siemens-developed, low-inductance coil technology that makes the fault current limiter invisible to the grid until it switches to a resistive state. The demonstration will occur at a location operated by team member Southern California Edison. The team also includes: Nexans (France), the University of Houston (Houston, TX), DOE's Los Alamos National Laboratory (Los Alamos, NM), and Siemens AG (Germany).

SC Power Systems - (DOE cost share: $11 million)

On the Southern California Edison grid, SC Power Systems (San Mateo, CA) will design, test, and demonstrate a 138-kilovolt saturable reactor-type fault current limiter. In this type of fault current limiter, a high-temperature superconductor is used with a direct current power supply to saturate an iron core that interfaces with the line in which the current is to be limited. SC Power's team includes: DOE's Los Alamos National Laboratory (Los Alamos, NM); Air Products and Chemicals Inc. (Allentown, PA); Cryo-Industries of America Inc. (Manchester, NH); Consolidated Edison Company (New York, NY); California Edison Inc. (Rosemead, CA); Delta Star Inc. (San Carlos, CA); and Trithor GmbH (Germany).

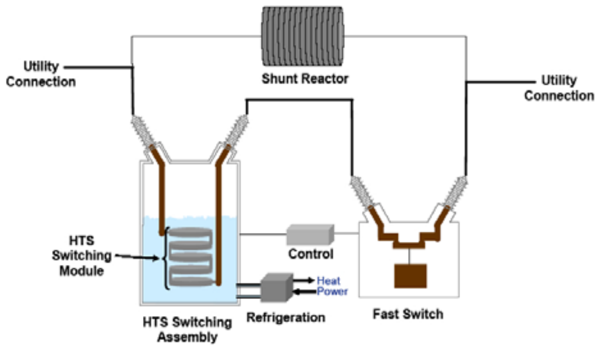
SuperPower Inc. - (DOE cost share: $5.8 million)

SuperPower Inc. (Schenectady, NY) will design, test, and demonstrate on the American Electric Power grid a 138-kilovolt fault current limiter that features a matrix design consisting of parallel, "second-generation," high-temperature superconductor elements and conventional coils. SuperPower's team includes: Sumitomo Electric Industries Ltd. (Osaka, Japan); Nissan Electric Co. Ltd. (Kyoto, Japan); The BOC Group Inc. (Murray Hill, NJ); American Electric Power (Gahanna, OH); and DOE's Oak Ridge National Laboratory (Oak Ridge, TN).

DISTINGUISHING FEATURES OF EACH DOE FUNDED PROJECT*

American Superconductor (AMSC)

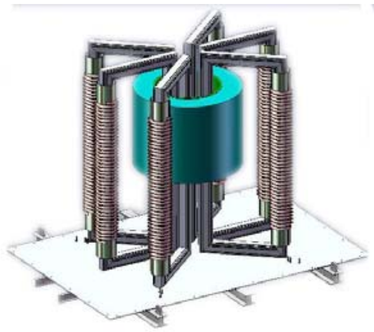
AMSC is employing resistive limiter concepts because they are expected to be simpler and more compact in design. They are also more cost-effective than inductive limiters. With its rapid progress on second generation (2G) HTS wire based on YBCO coated conductor, AMSC believes this wire provides an optimum vehicle for development of a practical resistive limiter. Increasing availability of YBCO wire can lead to a marketable, medium voltage (MV) - FCL in the mid term and high voltage (HV) – FCL in the long term. Other characteristics/benefits include:



Key Technology Component: SuperLimiter Shunt Configuration with Fast Switch (AMSC/Siemens)

- Shunted limiter allows adjustment of limited current and reduces wire costs;
- Technology proven world-wide: first pilot tests are underway or scheduled within the next 3 years - priority topic in the 2007 DOE application;
- Decentralized generation, steadily increasing fault currents in congested urban areas and the need for resilient grids will strongly promote FCL technology;
- Continued activities in cooperation with utilities and manufacturers: identifying grid sites and customer benefits developing reliable, low service cryogenic systems and refrigerators.

SC Power Systems


SC Power Systems' CAD Model of FCL

SC Power Systems' FCL is based on a concept called a "saturable reactor." In this device, the AC line current of the power grid is always carried by conventional copper conductors formed into coils – the AC coils. The high-temperature superconductor (HTS) material is used only to form a very strong electromagnet – the DC coil – that saturates an iron core inside the AC coils with a DC magnetic flux, hence the term "saturable reactor." By varying the degree of saturation of the iron cores, it varies the inductance (i.e. reactance – a reactor is a device that inserts reactance into an electrical circuit) of the AC coils, and thereby limits the current that flows in the power grid. In standby operation, the iron core is highly saturated by the HTS DC coil, which makes the reactance of the AC coils very low, and the overall insertion impedance of the FCL in the power grid very low. When a fault occurs, the FCL allows the increased AC magnetic flux from the fault current flowing in the AC coil to drive the iron core out of saturation, which very quickly and significantly increases the AC coil impedance and limits the fault current to the desired level. Think of the FCL device as self-healing fuse that works in conjunction with the self-healing grid of the future.

SC Power Systems is pursuing this type of FCL, because it is a new take on old technology. Reactors or inductors are widely used in the power grid to help balance electrical circuits, but conventional current limiting air reactors consume too much power in standby operation and cycle the power off and on under fault conditions. By using a HTS DC coil to saturate the reactor iron core, it greatly reduces the standby power consumption of the FCL and makes it more practical.

The main differences between SC Power Systems FCL and those of the other FCL programs are:

- The FCL employs the HTS material in a DC circuit (the application that is optimal for current HTS materials), which avoids issues with AC losses in HTS conductors.

- The AC line current and fault current is carried by conventional copper conductors, not the HTS material.

- The HTS material is not subject to the fault energy or the electromechanical and electrical stresses of the fault events, so the reliability and service life of the device should be high.

- The HTS material is not subjected to "quenching" during fault events, so it doesn't have any recovery time after a fault before the FCL is ready to protect again, and it doesn't experience thermal cycling of the HTS material.

- The FCL employs only one, DC HTS coil for a three-phase AC FCL, so it uses very little HTS material and has very little "cryogenic overhead" requirements (cryostats, cryogenic coolers, liquid nitrogen equipment, etc.) for a device with relatively high capabilities.

SuperPower, Inc.

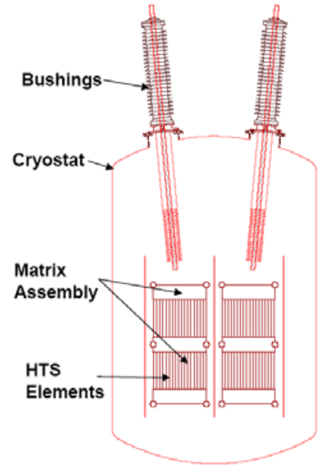
SuperPower's High Temperature Superconducting (HTS) Fault Current Limiter (SFCL) offers a device designed for transmission voltages, with the initial target for operation at 138kV. Operational feasibility is expected to be made possible by SuperPower's second-generation (2G) HTS material, which has very rapid response and recovery times compared to alternative materials.

Distinguishing features of SuperPower's FCL Program:

- Transmission-level device (138 kV) – highest voltage FCL to address utilities' most significant needs

- Cold shunt coil – no external or ancillary components or equipment is required. The device is self-contained

- Recover under load – the device can recover under load current so there is no need to take it out of service or off-line to enable it to recover. Also, no associated switchgear is required to isolate the device after a fault



Single Phase SFCL

* - Special thanks to American Superconductor, SC Power Systems and SuperPower Inc. for contributing their FCL information to our newsletter.

FOR MORE INFORMATION ON FCL, PLEASE VISIT:

Department of Energy Office of Electricity Delivery and Energy Reliability

American Superconductor

SC Power Systems

SuperPower, Inc.

ABOUT THIS UPDATE

The High-Temperature Superconductivity News Update is compiled by Bob Lawrence & Associates Inc. on behalf of the Department of Energy superconductivity program and is issued periodically as events warrant. Current and past issues are available at http://www.superconductivitynewsupdate.com/.

Please let me know if you would like more information or story ideas on any of these news items involving high-temperature superconductivity---a clean and capable new electricity technology for the 21st century. If you have any other comments or questions, please let me know.

Thank you very much.

Jodi Hamrick
703-836-3654