

**2010 Advanced Cables and Conductors Peer Review
Project Summary**

Project Title:	Design, Test and Demonstration of Saturable-Core Reactor HTS Fault Current Limiter
Organization:	Zenergy Power Inc., Zenergy Power Pty Ltd., Zenergy Power GmbH, LANL
Presenters:	Franco Moriconi, Robert Lombaerde, Albert Nelson
FY 2010 Funding:	\$2.34 M (SPE), \$145 K (DOE to LANL)

Overall Project Purpose and FY 2010 Objectives:

The overall purpose of the project is to design, build and test a saturable iron-core type of 2G HTS FCL that is a prototype for a commercial product suitable for operating in a typical 138 kV transmission grid substation. The prototype will demonstrate the performance parameters and provide the data necessary to subsequently design a commercial product. The test device will undergo long-term demonstration in the electric grid of an electric utility partner to ensure that the operational, maintenance, repair and coordination issues associated with a commercial product are realistically assessed and accurately documented. As deliverables, Zenergy Power will design, build, test and demonstrate HTS FCLs at sites in the electric grid at distribution voltage and at transmission voltage of at least 138 kV.

The primary objectives for FY 2010 were:

- Gain operational experience with 12kV device installed at SCE's Avanti Circuit of the Future
- Finalize host utility for 138kV demonstration device
- Finalize design of 138kV device based on host utility input
- Initiate construction of first phase of three-phase device

Partners:

Zenergy Power Inc., headquartered close to San Francisco, was founded as SC Power Systems Inc. in 2004 and has been part of the Zenergy Power Group since 2006. Zenergy Power Inc. designs and manufactures fault current limiters. **Zenergy Power Pty. Ltd.**, headquartered close to Sydney, Australia, was founded as Australian Superconductors in 1987 and became part of the Zenergy Power Group in 2006. Zenergy Power Pty. has built up a wealth of expertise in HTS technology and its application in protection equipment for power grids. **Zenergy Power GmbH**, headquartered close to Bonn, Germany, was founded as Trithor GmbH in 1999 and became part of the Zenergy Power Group in 2006. Zenergy Power GmbH manufactures all HTS components for the Group and is expert in coil fabrication and cryogenic integration. **Los Alamos National Laboratory** is responsible for providing analytical support for design and optimization of components/systems, for support and assistance for testing of the FCL, and for analysis of test results.

FY 2010 Approach and Results:

A summary of FY 2010 accomplishments include:

- Gain operational experience with the 12kV device installed at SCE's Avanti Circuit of the Future.

In addition to the DOE SPE project, Zenergy Power had a contract with the California Energy Commission (CEC) to design, build, test, and install a saturable-core FCL in the Southern California Edison (SCE) Circuit of the Future. On March 9, 2009 SCE energized Zenergy Power's FCL in the Avanti Circuit of the Future. This device will be operated by SCE until the end of 2010. During the past year the device responded by limiting multiple real faults on the

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system as well as being subjected to a number of unexpected equipment events such as loss of station power and loss of the HVAC system. Analysis of real-world events in cooperation with SCE led to modifications in controls and subsystems to better integrate the FCL with the utility SCADA system and operational control protocols. Subsequently, the FCL has responded to contingency and upset conditions in all cases as designed and desired by SCE. Zenergy Power and SCE have jointly published IEEE papers on the FCL and its operations, including establishing a methodology and protocol for evaluating the placement of the FCL in electrical circuits in its capacity as a variable-inductor to ensure stable electrical circuit operations.

- Finalize host utility for a 138 kV demonstration device.

In September 2009 American Electric Power agreed to host the installation of a 138 kV demonstration device at the Tidd substation in Steubenville, Ohio. The utility's requirements are 138 kV, 1300 A_{rms} steady-state operation with the capability to reduce a 19 kA_{rms} prospective fault by 50% and to recover under load and be operational to limit four subsequent fault events in relatively rapid succession according to the utility's breaker reclose protocol.

- Finalize design of 138 kV device based on host utility input.

In January 2010 Zenergy Power presented its preliminary design to the Readiness Review Team. Based upon their suggestions for risk mitigation Zenergy Power built a large (but subscale) single-phase device for fault current testing at the Lane Cove test facility in Sydney, Australia. The tests revealed that the design was electrically unbalanced and generating excessive short-circuit stresses. Accordingly, Zenergy Power has modified its design and is now constructing a second, redesigned device for additional fault current testing in July. Additionally, Zenergy Power will build a full-scale, high-voltage, single-phase prototype in accordance with the modified design to test later in 2010 with a set of HTS magnets that are being built for another application. The testing of this prototype, which will effectively be a demonstrator for the AEP application, will be completed in October/November 2010 and will serve to validate the final AEP FCL design. Reviews with the host utility have been occurring on an on-going basis.

- Initiate construction of the first electrical phase of the three-phase device. The DC magnet and cryogenic system of the first electrical phase has been fully designed and modeled for magnetic flux, mechanical stresses and vibration, and thermal stability. AC loss estimates have been included in the thermal budget. Construction and testing of the "DC circuit" has begun with building a subscale coil and thermal bus to qualify the thermal circuit. The magnet mechanical components have been tested to failure under actual conditions to verify the design. Due to the electrical imbalance discovered during the testing mentioned above, Zenergy Power is redesigning the "AC circuit" and will build and test multiple prototype FCL devices during the period July through November 2010.

FY 2011 Plans and Expectations:

- Decommission the 12kV device installed at SCE's Avanti Circuit of the Future and perform post-mortem
- Test experimental AEP devices and finalize design of 138kV device based on host utility input and test results
- Build and test the first electrical phase of the full-scale, three-phase device
- Initiate construction of the second and third electrical phases

Technology Transfer, Collaboration, Partnerships:

- Southern California Edison – participant in Circuit of the Future through contract with CEC.
- American Electric Power – participant as host utility for 138 kV demonstration project.

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- Consolidated Edison – participated in study of compact device and participates in regular progress updates.
- LANL – contributed in the areas of magnetic modeling, testing and data analysis.
- ORNL – contributed in the area of ac loss measurements of different conductors.
- NEETRAC – Zenergy is a member of organization providing guidance to steer FCL performance and testing requirements. NEETRAC technical program advisors include members from AEP, BG&E, ConEd, Entergy, Exelon, First Energy, SCE, and Southern Co.
- CIGRE Working Group A3.23-Fault Current Limiters – member of working group
- IEEE Task Force on Testing of Novel Fault Current Limiters – member of task force
- Technical publications – two papers published at IEEE PES T&D Conference in April 2010 and one paper accepted for publication at IEEE PES General Meeting in July 2010.