Ames lab physicist develops 'electrifying' theory on superconducting fault-current limiters

August 16 2008

John R. Clem

(PhysOrg.com) -- John R. Clem, a physicist at the U.S. Department of Energy's Ames Laboratory, has developed a theory that will help build future superconducting alternating-current fault-current limiters for electricity transmission and distribution systems. Clem's work identifies design strategies that can reduce costs and improve efficiency in a bifilar fault-current limiter, a new and promising type of superconducting fault-current limiter.

"I was able to theoretically confirm that planned design changes to the current bifilar fault-current limiter being developed by Siemens and American Superconductor would decrease AC losses in the system," said Clem. "My calculations are good news for the future of the device."

Fault-current limiters protect power grids from sudden spikes in power, much like household surge protectors are used to save televisions and computers from damage during a lightning strike. Limiting fault currents is becoming an increasingly critical issue for large urban utilities, since these currents grow along with growing electric power loads.

Superconductors enable a novel and very promising type of fault current limiter — or "firewall" — that rapidly switches to a resistive state when current exceeds the superconductors critical current. At the same time, in normal operation, the superconductors' near-zero AC resistance minimizes power loss and makes the fault current limiter effectively "invisible" in the electric grid.

Clem analyzed a type of fault-current limiter, called a bifilar fault-current limiter, developed by Siemens and American Superconductor Corporation, who are now under contract with the DOE to demonstrate the technology at transmission voltages in the power grid of Southern California Edison. The team also includes Nexans, which is developing the terminations for the transmission fault-current limiter, and Air Liquide, which is providing the cryogenic cooling system.

Bifilar fault-current limiters are made from many turns of insulated superconducting tape wound into a coil shaped like a disk or a pancake. The tape consists of a thin, flat strip of superconducting material sandwiched between two strips of stainless steel. In the bifilar fault-current limiter design, adjacent tapes in the pancake coil carry current in opposite directions to effectively cancel out each tape's magnetic fields, thereby limiting electrical losses.

Siemens and American Superconductor were seeking to optimize the performance of their bifilar design. They asked Clem to predict how AC losses would change as the width of the tape is increased. Clem reported his findings in a recent issue of *Physical Review B*.

"I modeled the bifilar design as an infinite stack of superconducting tapes, in which adjacent tapes carry current in opposite directions," said Clem. "I was able to find an exact solution for the magnetic fields and currents that are generated in such a stack of tapes. Once I calculated how the magnetic flux penetrates into the tape, I then could calculate how much energy is lost in each current cycle for different tape widths and spacings between adjacent tapes."

"Clem's result was not obvious since there are competing mechanisms for AC loss in the bifilar configuration. It turns out that for typical parameters, when the spacing between adjacent tapes is small enough, the result is very simple: AC losses decrease as the tape width increases and the spacing decreases," said Alex Malozemoff, chief technical officer of American Superconductor. "This result is helping to guide us and our partner Siemens in an optimized design for a fault- current limiter in a major DOE-sponsored program, and it is expected to open a path to a commercial product in the future."

Article: link.aps.org/abstract/PRB/v77/e134506

Provided by Ames Laboratory