# Fault Current Limiters

## Protect Today's Electrical Grid for Tomorrow's Growth

Utility-scale fault current limiting has entered a new era with the commercialization of a practical superconductor saturated-core Fault Current Limiter (FCL).

Zenergy Power (AIM:ZEN.L) has developed a new type of FCL that is now ready for use in the electric power grid. Based upon original work by Zenergy Power teams in Australia and the USA, the FCL is the product of four years of intensive international development work.

In March 2009 Zenergy Power, with funding from the California Energy Commission and the U.S. Department of Energy (DOE) installed an FCL in the Avanti distribution circuit of Southern California Edison's Shandin substation in San Bernardino, California, USA. Rated at 15 kV and 1,250 amperes steady-state, the "Avanti" device is the first superconductor FCL installed in a US utility. In mid 2009 Zenergy Power, with additional funding from DOE and The Consolidated Edison Company of New York, built and fault tested four full-scale 15 kV FCL prototypes to validate an improved second-generation FCL design. Zenergy Power's new "Compact" FCL dramatically reduces the size and weight of FCL devices with similar electrical ratings by a factor of three as compared to Zenergy Power's original first-generation design.

The Avanti FCL installed at the SCE Shandin substation in San Bernardino, California, USA

Extensive testing also confirmed that the new "Compact" FCL can operate with "dry-type" conductive cryogenic refrigeration, eliminating the need for liquid cryogens entirely.

Subjected to a "lifetime" of faults during rigorous full-power testing at British Columbia Hydro's Powertech Laboratories in Surrey, British Columbia, Canada, Zenergy Power's FCL prototypes have demonstrated continuous operation at 15 kV and up to 4,000 amperes steady-state, and the ability to limit 59,000 ampere fault currents by up to 46%. Fault testing sequences have included literally dozens of faults per device ranging from single fault events of 30 cycles duration, multiple fault events in rapid succession of 20 to 30 cycles duration to simulate automatic circuit breaker re-closer sequence operations, and fault events up to 82 cycles duration to simulate stuck circuit breakers. In January 2010, the "Avanti" device successfully limited its first series of real-world faults when, during a storm, the Avanti circuit experienced multiple single-phase and three-phase line-to-ground and phase-to-phase faults.

### DC Magnet to Bias the Magnetic Core

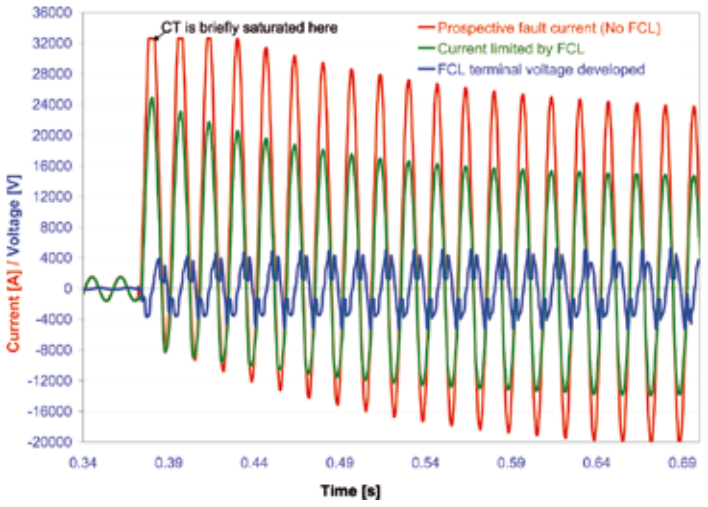
The technical design of the Zenergy Power FCL differs significantly from that of other types of FCL. In the Zenergy Power FCL, the superconductor forms a powerful, but efficient, DC magnet to bias the magnetic core. The superconductor is not in the circuit with the AC load steady-state or fault currents and voltages, and it is not subjected to the fault energy. The superconductor coil is always in the superconductive state, so the FCL recovers from a fault instantaneously and is ready to protect against another fault.

### Conceptual Advantages

The basic conceptual advantages of the Zenergy Power FCL include:

1. Totally "passive" design with no controls involved in sensing or limiting faults, and which does not rely on any type of circuit breaking or switching;
2. Inductive design eliminates the need to manage large amounts of energy dissipation in the device;
3. Dry cooling eliminates pressure vessel considerations and the need to employ liquid cryogens;
4. No-quench design eliminates superconductor hot-spot and burn-out concerns;
5. High-voltage components are separated from the cryogenic envelope; no parts need to be qualified for both high-voltage and cryogenic operation, and
6. All cryogenic components are completely outside of the AC circuit; facilitating easy extrapolation of the Zenergy Power FCL to higher AC voltages and currents.

Zenergy Power is currently contracted to install a 12 kV, 1,250 amperes FCL in the CE Electric UK Malleable substation, Stockton, UK, in late 2010. Zenergy Power is also under contract to demonstrate a 138 kV, 1,300 amperes HTS FCL in the American Electric Power Tidd substation, Steubenville, OH, USA in late 2011.




FCL Fault Test at Powertech Laboratories July 2009. The red curve is the prospective fault current, the green curve is the limited fault current, and the blue curve is the voltage measured at the terminals of the FCL. Note that the device limits the fault in the first ¼ cycle and continues to limit for all subsequent cycles.


# A Surge Protector for Substations
# Zenergy Power's Fault Current Limiter

Fault Current Limiters (FCL) have numerous and far-ranging applications throughout the entire electric grid. The risk of damaging electrical faults is increasing throughout the electric grid. More and more, utilities need technology solutions to protect their grid while increasing network connectivity to improve overall grid reliability and efficiency.

**Fault current limiting within first ¼ cycle**
- Self-triggered – entirely passive operation instantly boosts impedance during fault
- Low steady-state impedance – low losses during normal unfaulted operation
- Instantaneous and automatic recovery to normal operation – full recovery to low impedance state when fault clears
- Instantly available to limit faults - protection against prolonged or multiple fault events

**Demonstrated and proven performance**
- Extensive testing since 2007
- Protecting a distribution circuit in California since 2009
- Online in a distribution circuit in England in 2010
- Online in a transmission circuit in Ohio in 2011

**Economic advantages**
- Delay circuit breaker and bus bracing upgrades to defer capital investment
- Limit fault levels below substation ground mat ratings to protect equipment and personnel
- Extend the lifetime of substation equipment without upgrading circuit breakers and transformers
- Avoid interruption to circuits and critical loads

**Broad range of technical capability**
- 11 kV to 154 kV rated nominal voltage
- 1000 A to 4000 A continuous normal current
- 10 kA to 100 kA prospective unlimited fault current
- 20% to 50% reduction in fault current

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