

An Assessment of Fault Current Limiter Testing Requirements

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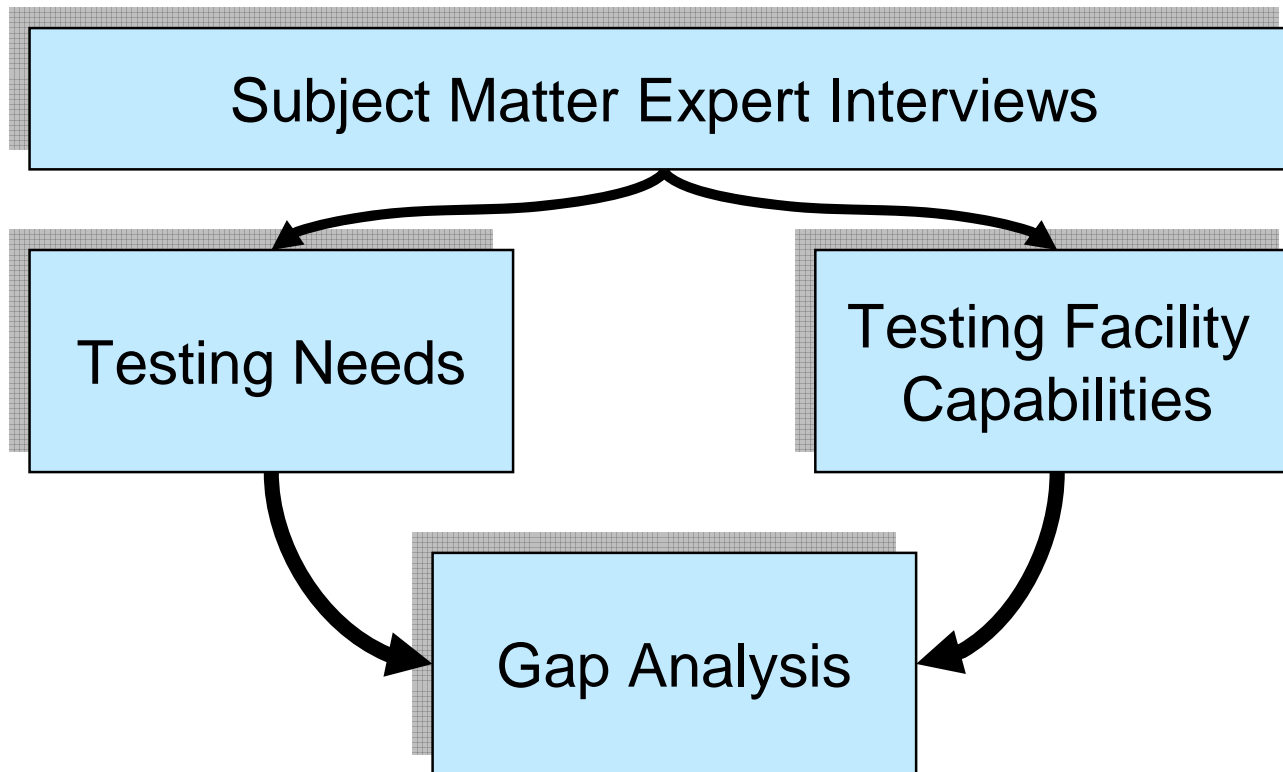




Project Purpose and Scope

- Identify testing requirements for advanced electricity-delivery devices such as fault current limiters
- Make an assessment of the existing capabilities of testing facilities in the U.S. and internationally
- Perform a gap analysis to determine where existing testing capabilities and facilities fall short
- The scope of the project includes solid-state and superconducting-based fault current limiters
- Focuses on projects sponsored by the U.S. Department of Energy

Methodology



Organizations Contacted



Electrivation

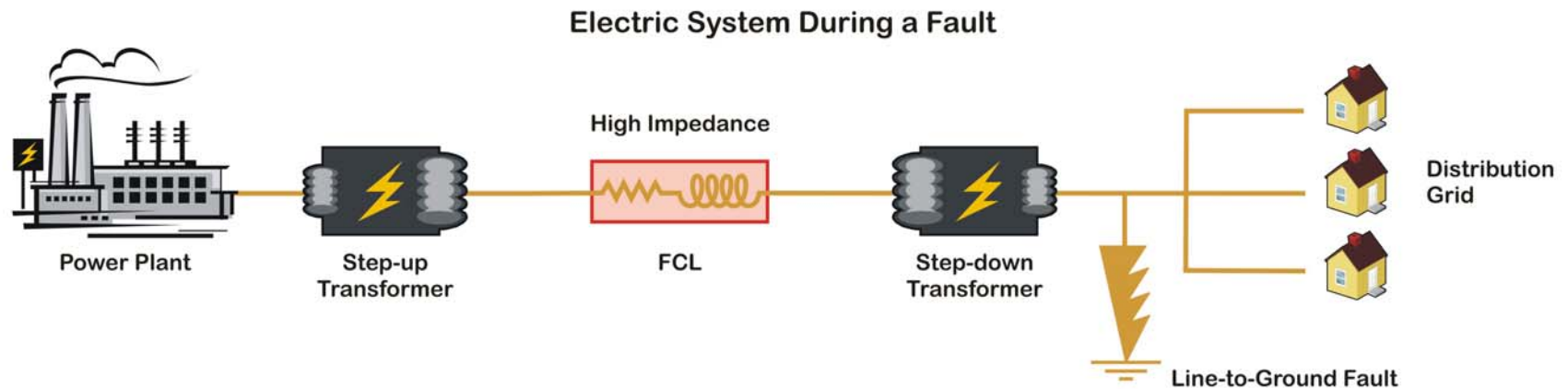
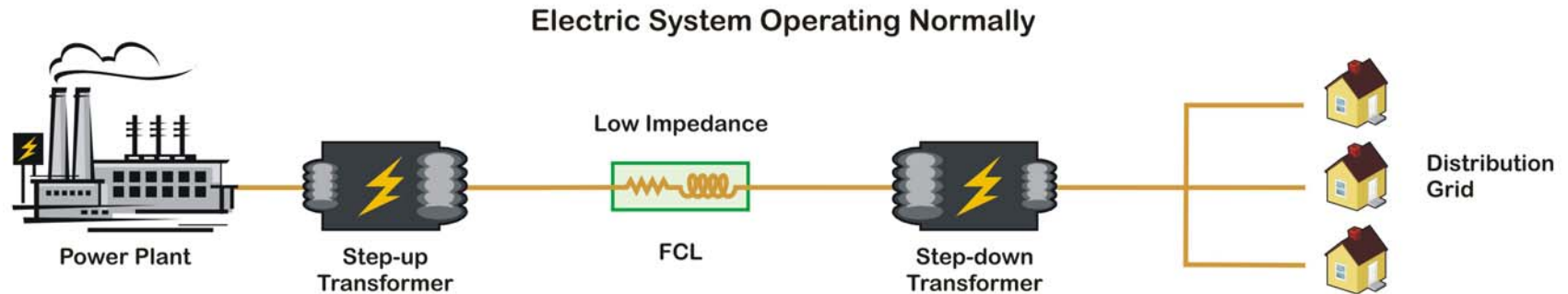


Types of Testing

Category	Description
Research and Development Tests	Electrical and mechanical tests performed in a laboratory and conducted during development.
Long-Term Prequalification Tests	IEC definition – “A test made before supplying of a general commercial basis of a system in order to satisfactory long term performance of the complete system.”
Type Tests	Performed to demonstrate the adequacy of designs and materials of a system. Generally required when there is a significant change in materials or the manufacturing process.
Factory Production Tests	Verify that the device meets specifications before leaving the factory.
Commissioning Tests	Tests performed to detect shipping or installation damage. Also reveals defects in workmanship.
Maintenance Tests	Field tests during the lifetime of a system to detect deterioration.
Special-Purpose Tests	Specialized tests designed to obtain specific information.

Based on Table 3-2, on test categories for underground cable in EPRI Specifying and Testing HTS Power Equipment (Report number TBD)

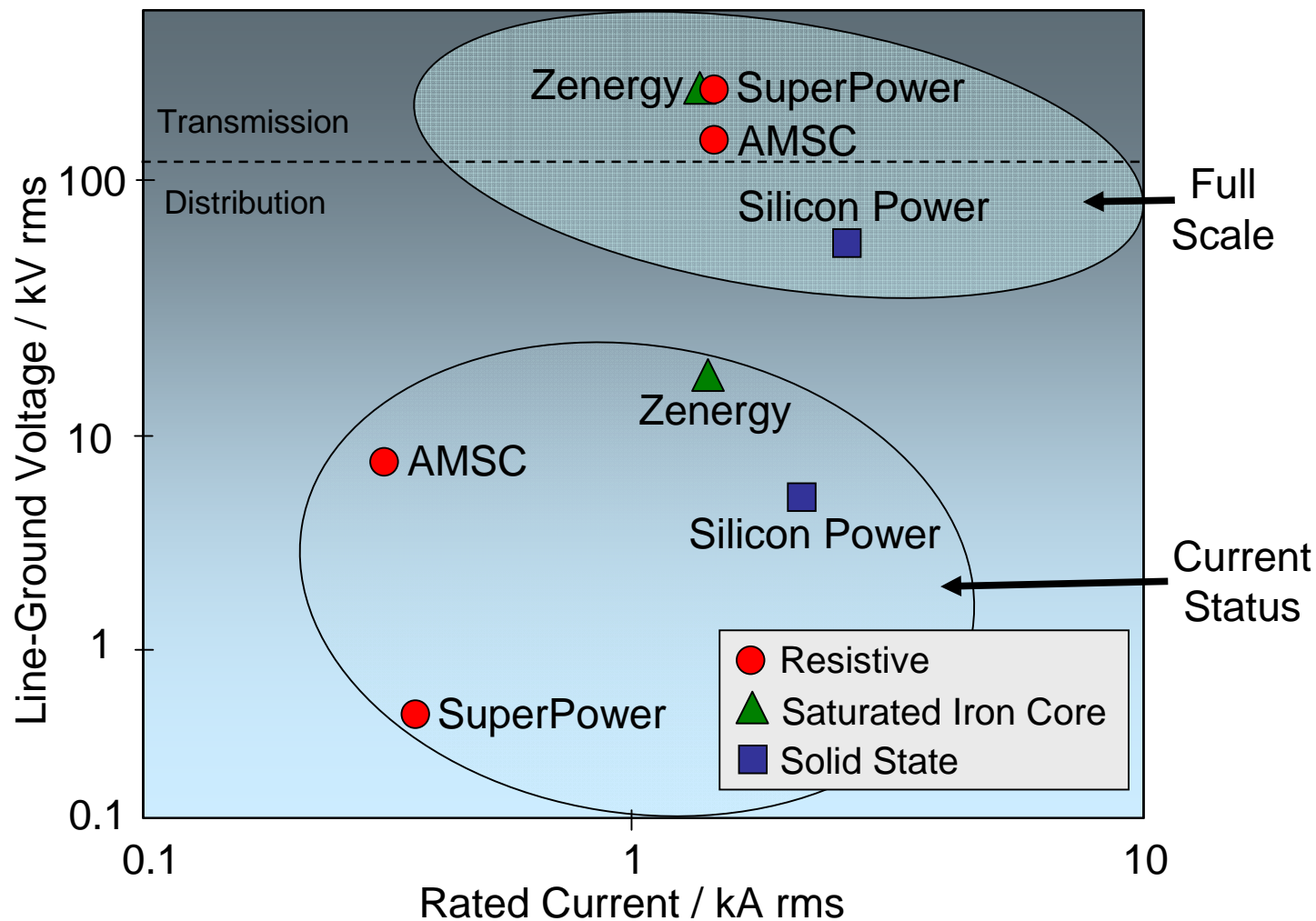
What is a FCL and How Does it Work?



Specifications for DOE's FCL Projects

Specification	AMSC	Silicon Power	SuperPower	Zenergy (Formerly SC Power)
Design	<ul style="list-style-type: none"> • Resistive FCL • 3-phase, high-voltage • Low-inductance bifilar coil switching module technology using 2G wire 	<ul style="list-style-type: none"> • Power electronics-based FCL • 1 phase • Uses high power semiconductors -gate turn-off thyristor (GTO) 	<ul style="list-style-type: none"> • Resistive FCL • Matrix design has parallel, 2G HTS elements and conventional coils 	<ul style="list-style-type: none"> • DC-based iron core • One DC first-generation HTS coil for a three-phase AC FCL • Saturable reactor-type FCL • Suitable for 2G materials, when available
Ratings (final design)	Voltage: 138 kV, 2000 A Class (115 kV, 1200 A at SCE site)	Voltage: 69 kV Amps: 1,000-3,000	Voltage: 138 kV Amps: 1200	Targeting a three-phase transmission-level device at: Voltage: 138 kV Amps: 2,000 to 4,000 steady-state
Fault Current Reduction	20–50% Reduction – 37 % at SCE (63 kA to 40 kA)	TBD	20%–50% reduction	20% to 40% reduction of a 60 kA to 80 kA fault
Testing Protocol Basis	TBD	Circuit Breaker	Transformer, Reactor, and Circuit Breaker	Transformer

Current Status and Future Requirements of FCLs

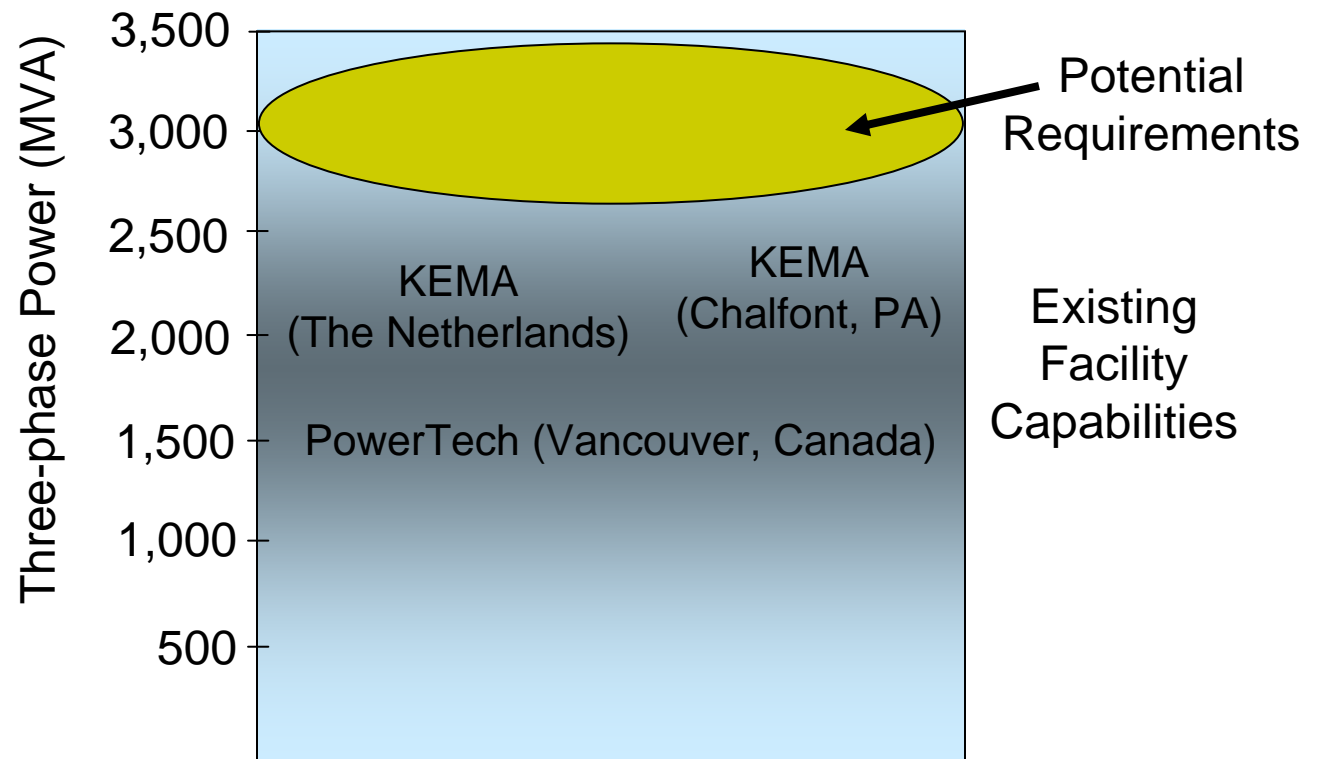


Examples of Test Facilities and their Capabilities

Name	Location	Insulation Test (MV) at “zero” current			Current Test (kA) at “zero” voltage		High-Power Test Maximum (Surge) Power Rating (MVA)	Kind of Source(s) for the Lab	How Can the Facility Be Accessed?	Can the Facility Accommodate Cryogenics Testing?
		AC 50/60 Hz	Lightning Impulse 1/2/50µs	DC	Fault	No-load voltage (kV) /				
KEMA ^[1]	Chalfont, PA	0.55	0.80	0.10	50 for 1 s 63 for 0.5 s.	13.8	2250	Short-circuit generators rated for 1,000 and 2,250 MVA	Private facility -- approx \$10k/day	Yes, but customer provides
KEMA ^[2]	Arnhem, The Netherlands	1.00	2.20	1.00	390 for 0.42 s.	20	8400	4 short-circuit generators, 2,100 MVA each	Private facility	Yes, but customer provides
Power Tech ^[3]	Vancouver, Canada	0.80	3.00	1.00	110 for 3 s.	13.6	1500	Power system grid (12,000 MVA)	Private facility -- approx \$10k/day	Yes, but customer provides
ORNL ^[4]	Oak Ridge, TN	0.2	0.8	0.3	50	0.3 (0.6 with upgrade)	N/A	DC and AC power supplies	Available to DOE funded partners	Yes
LANL	Los Alamos, NM	0.138 (with upgrade)	N/A	0.025	4 (100 for ~1 sec. with upgrade)	TBD	1400	13.4-kV power grid; 1.4 GVA generator	Available to DOE funded partners	Yes
NEETRAC ^[5]	Atlanta, GA	1.00	2.20	1.00	25 for 2s	0.12	N/A	2.2 MV, 220 kJ Impulse generator 1MV Cascade Transformer	University-based Independent test laboratory	Has not tested with cryogenics yet, but could
Florida State University-CAPS ^[6]	Tallahassee, FL	0.1	0.14	0.14	84 13 7	0.385 0.48 4.16	130	60 Hz power system grid fed from 12.47 kV	University-based Independent test laboratory	Yes
					1.7 13 4.8 (DC)	4.16 0.48 1.15 (DC)	N/A	Variable frequency and voltage converter ^[10]		

Testing Facility Gaps

Testing can be done at the distribution level power, but not the transmission level



Major Findings – Part 1

- T&D equipment testing facilities can provide voltage and current to adequately test FCLs at the distribution level
- There is no place that has the capabilities to test FCLs at transmission-level current and voltage levels simultaneously
- While there is a need to conduct high voltage-current tests, there are a number of experts who believe it may be possible to substitute simulation modeling (“synthetic tests”) for actual tests



Zenergy's FCL Testing at PowerTech

Major Findings – Part 2

- Commercial testing facilities are not always conducive for advanced design and prototype testing for R&D projects
- Commercial T&D equipment testing facilities tend to be costly, busy, and difficult to schedule
- There are approximately 90 testing facilities around the world and these are equipped and managed to conduct routine tests of existing or market-ready devices to meet known standards and protocols



AMSC's FCL module testing



Major Findings – Part 3

- Today there are no common guidelines for testing prototype high-temperature superconducting (HTS) and solid-state FCLs and for integrating these devices with the electric system
- Testing procedures have been and will continue to be developed by FCL device manufacturers and their utility R&D partners and will vary depending on the design of the equipment and the application
- This lack of standards complicates the testing process as each trip to the testing facility has unique requirements, protocols, and procedures
- The existence of standards could help expedite and accelerate the testing process

Conclusions

- There is a need for testing facilities that have the flexibility to respond to the special requirements of R&D projects
- Given the unique capabilities of fault current limiters there is an expectation that utilities will allow FCLs to be installed and tested on their own systems, before they have been simultaneously tested for high current and high voltage
- There is a need to continue the discussion on FCL testing recommendations



SuperPower's FCL module testing



Questions?

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