

Fault Current Limiter Requirements for 2G Wire

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High Temperature Superconducting Fault Current Limiters: The Drivers

- System fault current level rising with added generators and loads
 - Fault current level exceeds 60 kA in some systems!
- Solutions?
 - Circuit breaker technology near 80 kA upper limit
 - Explosive fault limiting fuses require service call to replace, limited to distribution level
 - Series reactors lossy, bulky, contribute to grid instability
 - Power electronic systems costly, mostly for distribution voltages
- HTS fault current limiters (FCLs) offer:
 - Reduction of fault currents by a factor of 3-10
 - Single shot protection for 5-10 cycles plus automatic resetting after a recovery time of seconds to minutes
 - Distribution and transmission voltages up to ~138 kV

HTS FCLs – an attractive solution to a critical utility problem

Types of HTS FCLs

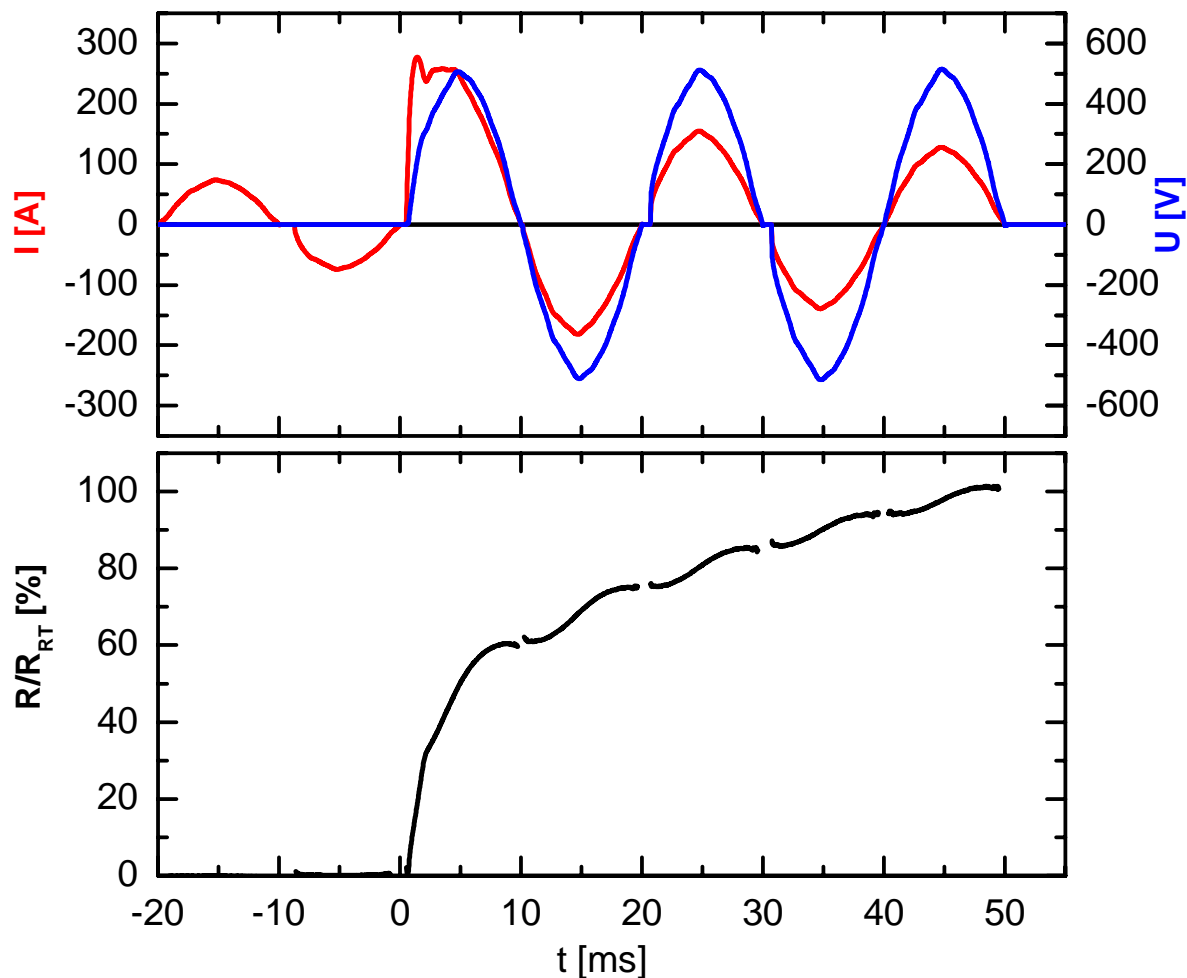
- Many types of HTS FCLs studied during last decade:
 - Bridge FCL
 - Uses power electronics, requires active control
 - Inductive FCL – limits by coil inductance change
 - Bulky, hard to scale, costly
 - “Resistive” FCL – limits by resistance change when I_{fault} exceeds critical current I_c
 - Bulk HTS rods or first generation (1G) HTS wire
 - Successful lab demos, but hard to scale, costly
 - Second generation (2G) HTS wire – coated conductor
 - An attractive new option

Resistive HTS FCLs most viable using 2G HTS Wire

FCL-measurements on AMSC 2G conductor

Bifilar coil made of 2G YBCO wire, L: 9 m, w: 4 mm, I_c : ~ 70 A

Test parameters: U_o : 350 V_{rms}, I_{sc} : 4 kA_{rms}, I_{nom} : 50 A_{rms}, P_{nom} : 17.5 kVA



Requirements of 2G Conductor for FCL Applications



- 1st peak limitation
- Quick response time
- Quench current magnitude close to I_c
- High life expectancy (J/cm)
- High Voltage drop across element (V/cm)
- Uniform quench when tapes are fitted in parallel
- Recovery under load
- 2G element design retrofittable to designs based on BSCCO elements

Tentative Requirements of Coated Conductors for FCL application

The conductor should withstand without degradation of I_c :

Axial tension (4.4 mm wire width)	≥ 10 N
Bending diameter	≤ 50 mm
Number of bending actions at ambient temperature	≥ 10
Number of thermal cycles without load	≥ 10
Maximum temperature during current limitation	150 ... 200°C
Number of limitation cycles within “useful economic life”	≥ 100

Parameters desired for economic feasibility:

Voltage per length (for RABITS sub. with SS stab.)	$\geq 0.7 V_{\text{rms}}/\text{cm}$
Critical current per width	250 ... 300 A_{DC}/cm
Critical current per tape	500 ... 1000 A_{DC}
Specific conductor price	≤ 30 EUR/ kA_{DC}/m



FCL Market Segmentation

Specification	Bus Tie Application		Feeder Breaker Applications			Transformer Applications	
	Basic	Power Quality	Basic	Underground	Industrial	Basic	Underground
Steady-state Current (kA)	0.6-1.2	0.6	0.6	0.6	1.2	2.5	1
Fault Current (kA)	1.8-5.0	1.8	3	3	<20	7.5	3
Hold Time (m-sec)	100	100	400	400	400	600	100
Re-closing Requirement	No	No	Yes	No	No	Yes	Yes
Instant Recovery	No	No	Yes	No	No	Yes	No

- Key parameters affecting the FCL design are;
 - Steady-state current
 - Limiting current during a fault
 - Fault duration (hold-time)
 - Re-closing of the circuit immediately after a fault is cleared (instant recovery)
- Difficult to satisfy all these requirements in a given device

Need modular system to address such a variety of parameters cost-effectively

Summary

- Resistive HTS FCL can address critical utility issues cost-effectively
- 2G HTS wire is optimum vehicle for a practical resistive FCL
 - Requires special geometries with high resistance, low cost stabilizer
 - Significant proof of principle achieved in AMSC/Siemens collaboration