QuickField Analysis for Fault Current Limiters

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**QuickField analysis for
Superconducting Fault Current Limiters**

Topics

- Fault Current Limiter (FCL) concepts
- Specifying Superconductors in QuickField
- AC FCL Simulations
- Time Harmonic FCL Simulations
- FCL Models with x-y and r-z symmetry

FCL Simulations

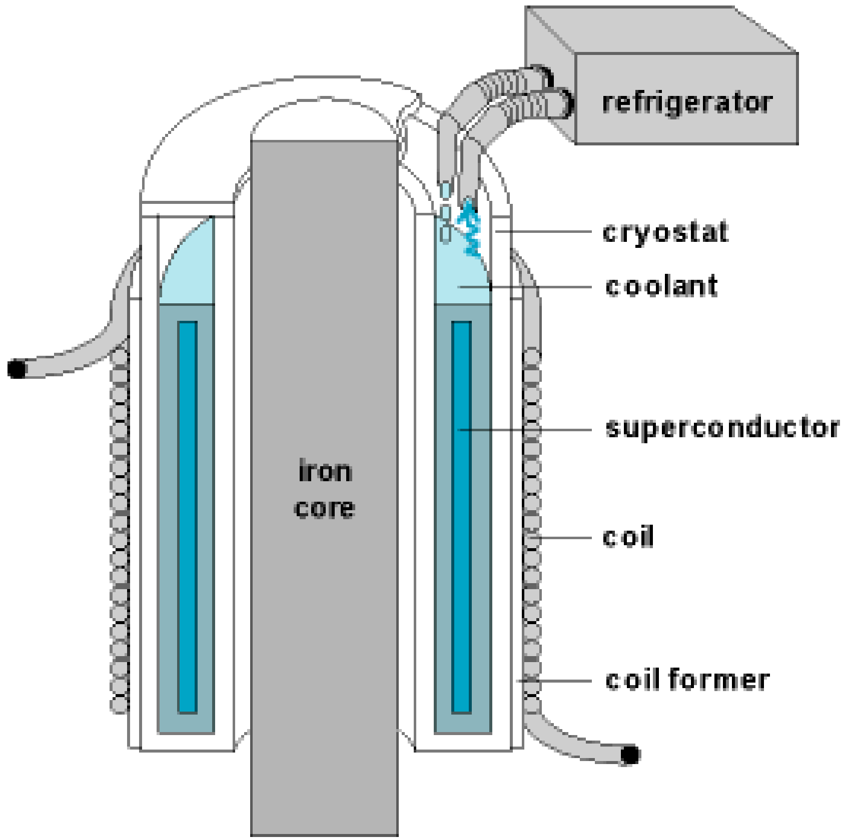
- Inductive FCL (superconductors)
- FCL based on core saturation
- Resistive FCL

QuickField Features Used in FCL Simulations

- AC Magnetics
- Transient Magnetics
- AC Conduction
- Transient Electrics
- Nonlinear B-H and J-E characteristics
- Coupled Electric Circuit
- Coupled Heat Transfer
- FCL with x-y and r-z symmetry

Fault Current Limiters

- Inductive



Industry (CRIEPI) has developed the inductive limiter shown in Fig. 4.11 (Ichikawa and Okazaki 1995). This approach, similar to those of ABB and Siemens-Hydro Quebec, uses a cylinder of bulk BSCCO-2212 or BSCCO-2223 to separate a normal copper coil from an iron core. In normal operation, the field from the copper coil does not penetrate the superconductor; under fault conditions, however, the current induced in the superconductor is sufficient to drive it normal, and the magnetic field links the iron yoke. This greatly increases the inductance of the copper coil, thus providing current limiting. CRIEPI work has focused on ac magnetic shielding performance of bulk superconductors and their responses to fault currents. In addition, introduction of a "control ring" in the system to absorb some of the energy deposited during a fault has reduced the cooldown time of the shield following a faulted state.

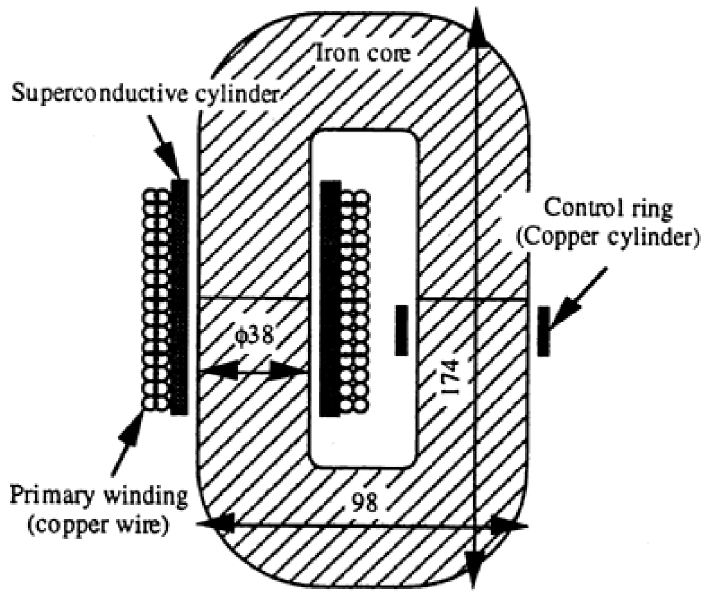


Fig. 4.11. Schematic diagram of the CRIEPI inductive FCL (Ichikawa and Okazaki 1995).

The most extensive FCL program in Japan has been the collaboration between TEPCO and Toshiba. The long-term goal of this program is the development of a 500 kV limiter with a rated current of 8,000 A. Initial development has been focused on a distribution-level limiter designed for 6.6 kV.

Superconducting Tubes for Current Limiters

Characteristic

Formula: Bi1.8Pb0.26Sr2Ca2Cu3O10+x (2223 phase)
Density: > 5.0 g/cm^3
Critical temperature: 108 K

Superconducting BiPbSrCaCuO (Bi–2223 phase) ceramic tubes and rings are suitable for inductive fault current limiters developed for power transmission networks.

Product range – Superconducting Tubes for Current Limiters

Self-field critical current density (77 K)	300 A/cm^2 - 800 A/cm^2
Inner diameter	10 mm - 60 mm
Length	10 mm - 120 mm

Specifying Superconducting Regions

- Simply Connected (e.g. superconducting disk)
  - –zero normal B boundary condition
  - –extremely small μ
- Multiply Connected (e.g. superconducting tube)
  - – zero vector potential on boundary
- Type II Superconductors (nonlinear B-H characteristics)

Fault Current Controllers

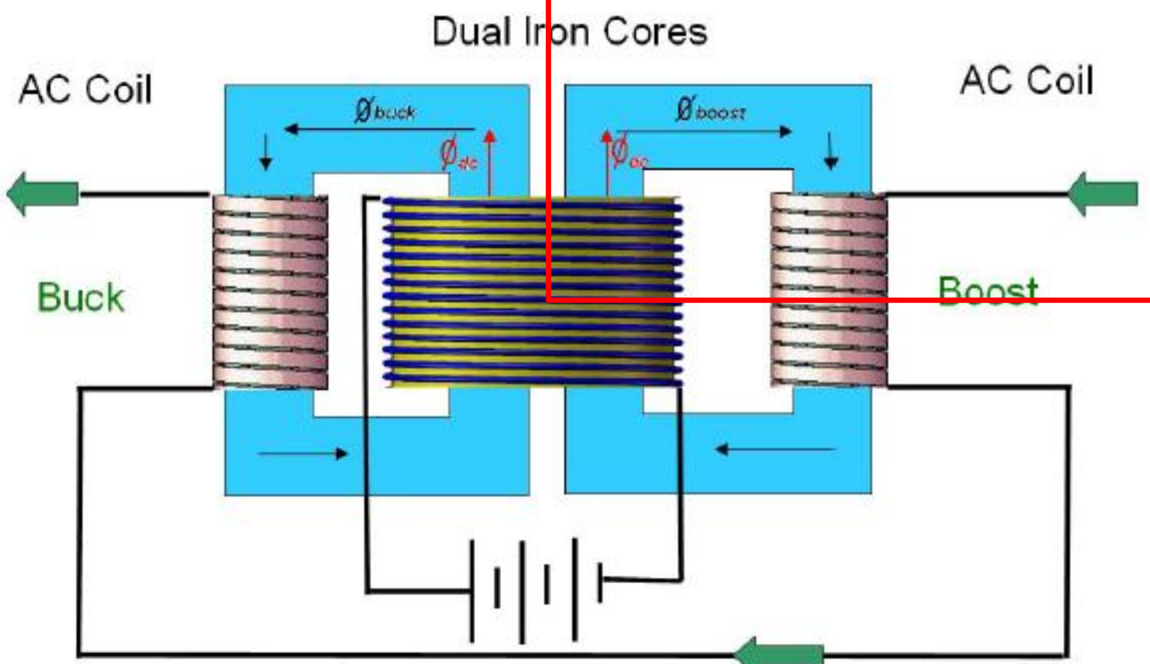
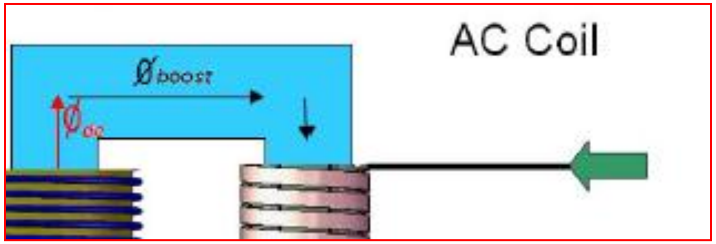


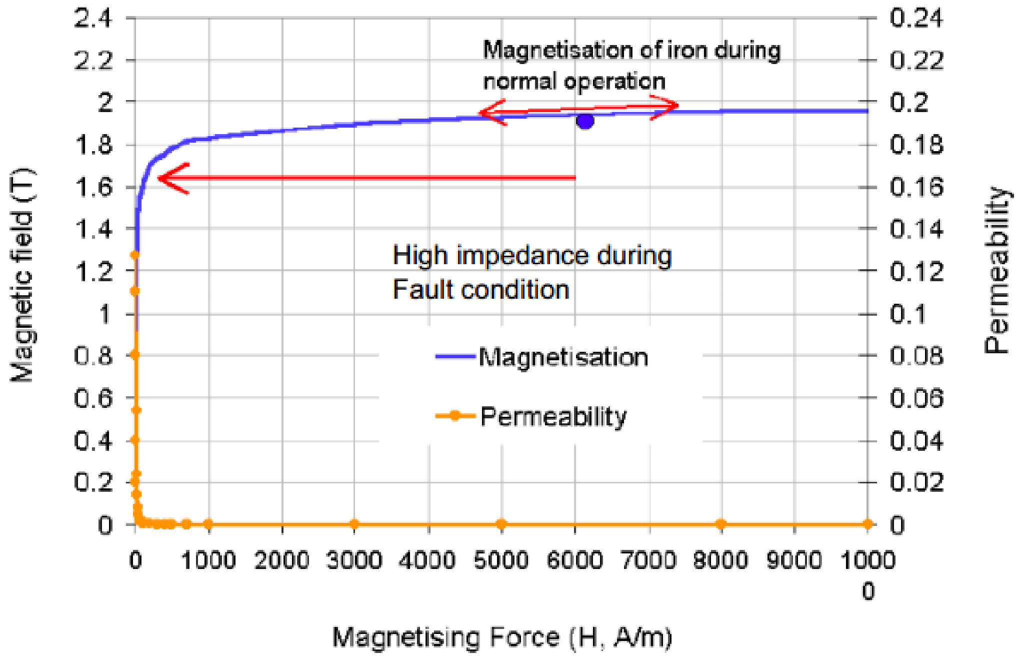
Fig. 1. Dual iron cores saturated by an HTS DC coil in a single-phase FCL

Modeling and Test Validation of a 15kV 24MVA Superconducting Fault Current Limiter

Franco Moriconi, Nick Koshnick, Francisco De La Rosa, *Senior Member, IEEE* and Amandeep Singh, *Member, IEEE*



Zenergy Approach

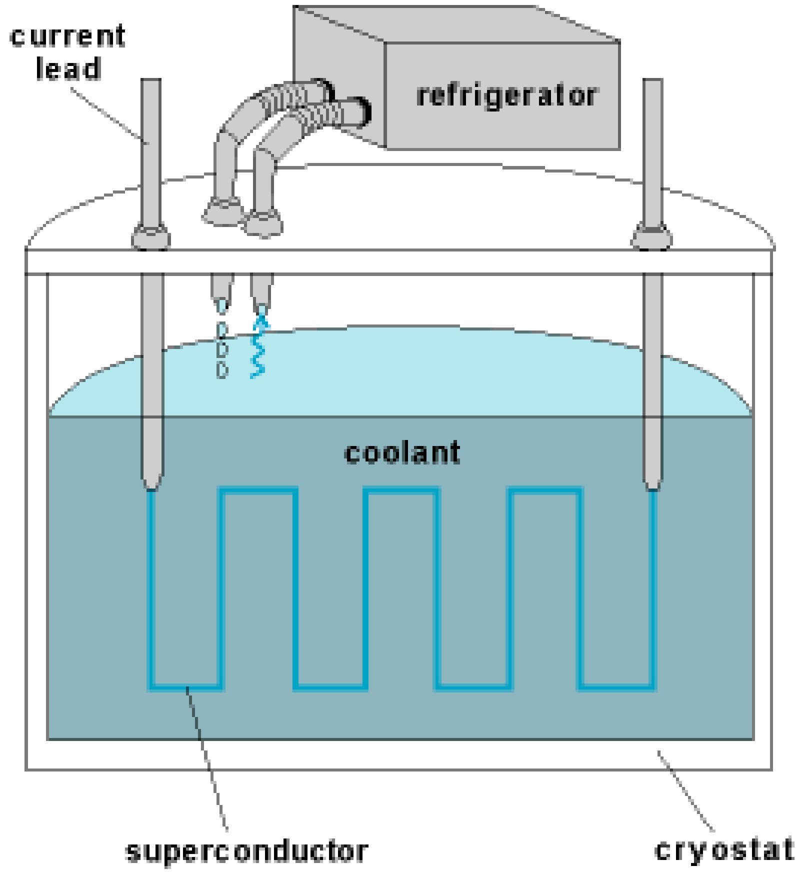


- Normal operation: DC bias saturates the magnet to provide low impedance.
- Fault condition: the fault current pushes the core out of saturation yielding high impedance.

ZENERGY POWER

Resistive FCL

- Resistive



Current Leads | Magnetic shields | Tubes for Current Limiters | Levitation Disks | Targets | Demonstration Kits

Current Leads

Characteristic

Material: Bi1.8Pb0.26Sr2Ca2Cu3O10+x (2223 phase)

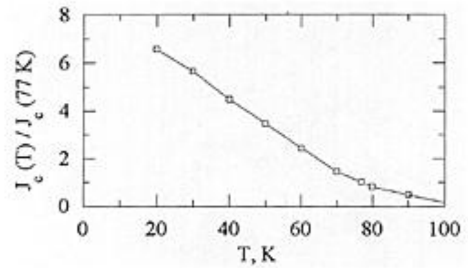
Density: > 5.0 g/cm^3

Critical temperature: 108 K

Superconducting tubes of BiPbSrCaCuO (Bi-2223 phase) ceramics with silver covered ends of a low contact resistance are suitable for current leads effectively reducing heat leak into superconducting magnets. The leads may also be used as resistive current limiters.

On a special request we can encase any current lead into a protective tube.

Temperature dependence of self-field critical current density Jc(T) normalized to Jc(77 K) for CAN Bi-2223 tube.



Conclusion

- Inductive FCLs are modeled under normal and fault conditions using ideal superconducting boundary conditions
- Models include nonlinear B-H characteristics of type-II superconductors and ferrites
- FEM models are coupled to electrical circuit components
- Resistive FCLs are modeled using transient electric and AC magnetic modules
- Coupled heat flow analysis was demonstrated