Fault Limiting Technology Trials in Distribution Networks

Applied Superconductor Ltd. was incorporated in November 2004 in Blyth (Northeast of England) at NaREC (New and Renewable Energy Centre)

Klaus, D. W. et al – United Kingdom
Collaboration Agreement for 1 pilot installation each with ScottishPower, Electricity North West and CE Electric UK

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Melt Cast Processed BSCCO 2212 Bulk Parts

Nexans Bulk Parts are:
- Inorganic ceramics (Bi-Sr-Ca-Cu-O)
- Available in a large variety of shapes and sizes
- Ready for assembling in electrical devices, system components or magnets

Characteristics:
- Rigid el. conductors
- Easy machining
- High current carrying capacities (100A - 12kA)
- Low thermal conductivity

Annealing at 750 - 840°C
Melt in rotating mould
Form parts from NSC being used in commercially available industrial magnet systems

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Production of BSCCO-Tubes

Nexans SuperConductors

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The innovation process

IFI & RPZ – Targeted incentives for DNOs

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Fault Levels need to be kept low because of:

DNOs commitment to \( \leq 250 \text{MVA@11kV} = 13.1 \text{kA} \)

Ageing network assets, limited fault capacity

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Fault Levels tend to rise with:

- Increasing Load
- New Generation
- Interconnecting

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Fault Levels ideally are:

High when the system is healthy – low impedance improves power quality, stability

Low during faults – high impedance limits fault current

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Fault Levels can be controlled by:

**Splitting the network**
- Feeder fault leads to more customers interrupted
- Requires special precautions to prevent fault levels from being exceeded
- Non-compliance with design regulations

**Fitting high impedance transformers or series reactors**
- Increases system losses and impedance, degrading power quality
- Reduces symmetrical fault current more than peak
- Air-cored reactors produce electromagnetic radiation

**Using single operation current limiting devices**
- Complex sensing, decision-making and actuation chain
- Does not fail to safety (no fault limitation)
- Uses pyrotechnic (exploding link) to divert fault
- Long outage time after fault
Air-cored Reactor

Iron-cored Reactor

G&W (USA) CLiP Fault Limiter

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- 1.2 MVA 3-phase inductive 1996 (ABB)
- 1.2 MVA 3-phase resistive (Siemens)
- 6.4 MVA 1-phase resistive (ABB)
- 10 MVA 3-phase resistive 2003 (Curl10)
Bi$_2$ Sr$_2$ Ca$_1$ Cu$_2$ O$_x$

BSCCO 2212, a layered copper oxide ceramic, was found to be a superconductor in 1988. It has a $T_c$ of 95K which is well above the boiling point of liquid nitrogen, 77K. Nitrogen is much more widely available than most other gases and therefore less costly and considerably less cooling power is required at 77K than at lower temperatures e.g. 4K for Helium.

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HS Elements Nexans SuperConductors Cologne

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Superconductors remain in the superconducting state as long as the current, temperature and flux density remain below the critical values.

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The superconductor adds resistance to the circuit once the critical current is exceeded. In the normal state, the resistivity of BSCCO is many times that of copper.

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Prague, 8-11 June 2009

Sample 4, 73 K test 16, 120 ms

Voltage [Vx100]
Ua [V/cm]
Ub [V/cm]
Uc [V/cm]
current [kA]

6.5 kAp
380 Vp
0.8 V/cm

Iprosp. = 11 kAp
Prague, 8-11 June 2009

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Overcurrent Relay
Current Transformer

SFCL

Voltage Transformer

Voltage Comparator

Series Circuit-breaker
CB Trip Command

Voltage Transformer

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PILOT 1 Operational Characteristics

Transformers upgraded to 11.5/23MVA
Fault contribution (rms) 4.2kA each
Fault contribution (peak) 11kA each

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Busbar fault level = 8.4kArms / 22kA peak
Old Switchgear was 150MVA @ 11kV

Breaking capacity    7.87kA
Making capacity      19.7kA
Upgrade switchgear!

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SOLUTION
Split Network

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SOLUTION
Fit SFCL
Limit current so that T1 contribution + limited T2 contribution < 95% Old Switchgear Rating (7.5kA rms, 18.7kA peak)
Limited rms current = 7.5 – 4.2 = 3.3kA
Limited peak current = 18.7 – 11 = 7.7kA
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Prospective Current (SFCL short-circuited)

55.9kA peak in phase 1
20.1kA rms symmetrical

Recovery voltage across series circuit-breaker

Trip pulse to series circuit-breaker

Station X/R = 60

Transient peak = 20.6kV

Note restrike

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**Limited Current**

- 6.68kA peak in phase 2
- 0.89kA rms symmetrical

*Voltage across SFCL*

*Current and voltage in phase*

*Circuit mainly resistive*

*Recovery voltage across series circuit-breaker*

*No ringing or transient overvoltage*

*Trip pulse to series circuit-breaker*

Peak during limiting = 19.5kV

Note absence of transient part of recovery voltage

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Lower Electromagnetic Forces on Conductors

\[ F \propto I^2 \]

Less Heating in Conductors

\[ \Delta T \propto I^2t \]

Less Arc Energy where

\[ E = IV_{arc}t \]

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Lower X/R ratio

\[ \frac{X}{R} = \tan \phi \]

Lower restriking voltage

\[ V_r \propto V_{pk} \sin \phi \]
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