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Transmission Level HTS Fault Current Limiter

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SFCL program overview

Partners

AEP American Electric Power

EPRI

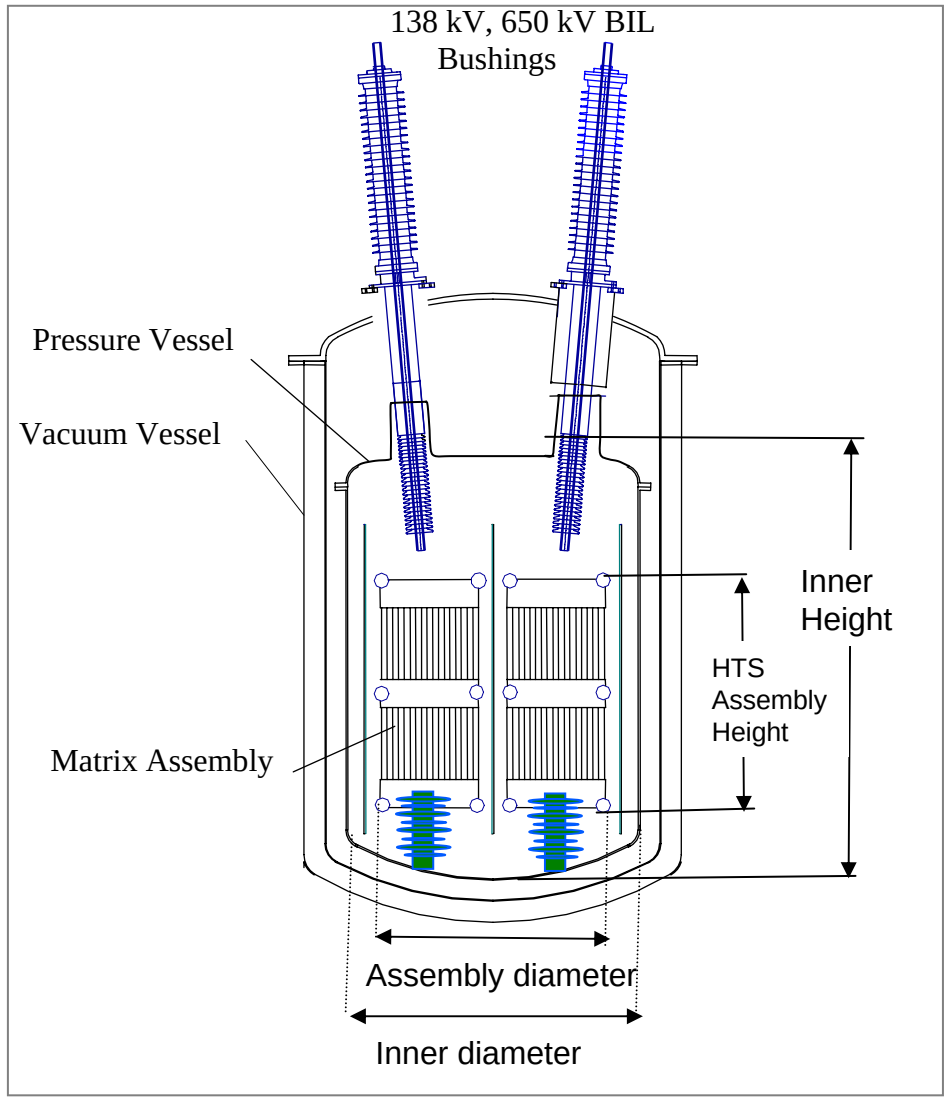
Los Alamos National Laboratory

Oak Ridge National Laboratory

Sumitomo Electric

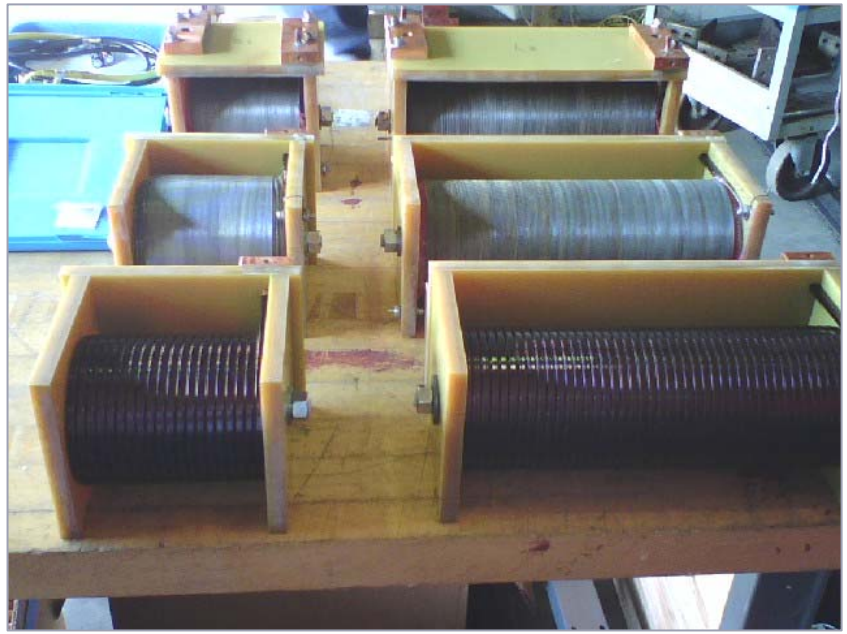
Specifications

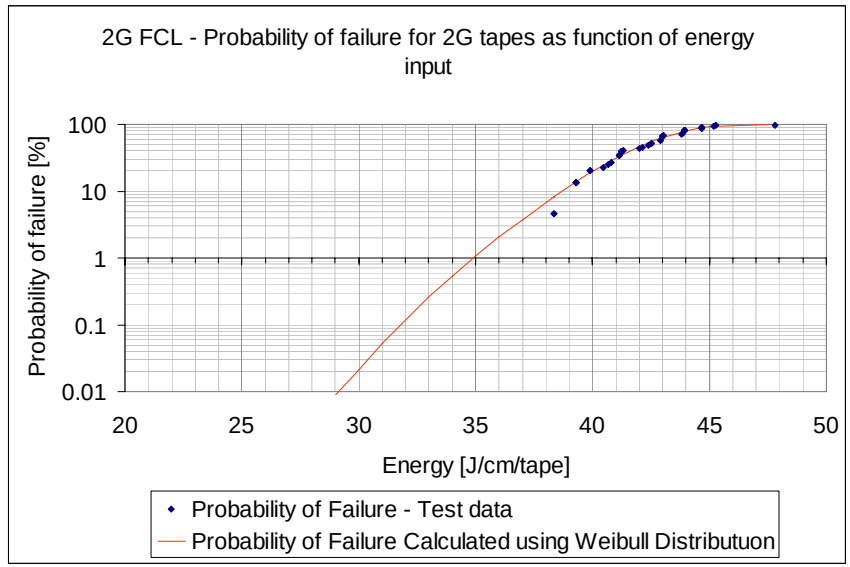
- YBCO based, resistive type FCL
- 138 kV class device
- Fault Current – 13.8 kA
- Load Current – 1,200 A_{rms}
- Design fault current – 37 kA
- Design device response – Recover to superconducting state after a fault carrying full load current



Prior accomplishments

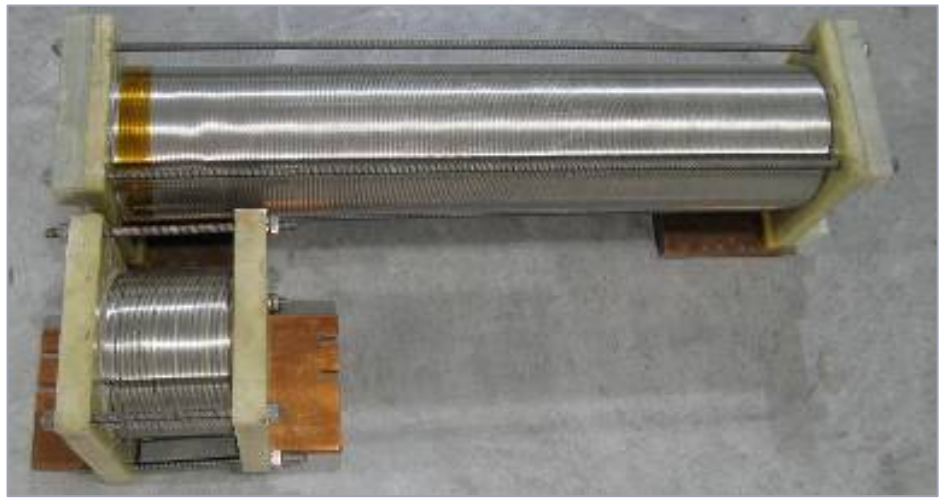
- Proof-of-Concept demonstrated
  - MCP 2212 (2004)
  - 2G YBCO (2006)
- Beta device testing specifications established
- Completed design and testing of HV bushings (SEI)
- Investigated several ‘engineered’ 2G architectures for improved RUL
- Design and laboratory testing of shunt coils to withstand high fault transient loads
- Thermal simulation of RUL process
- Weibull plots of ‘standard’ 2G failures
- Conceptual CRS & vessel design
- Investigated LN_2 dielectric properties



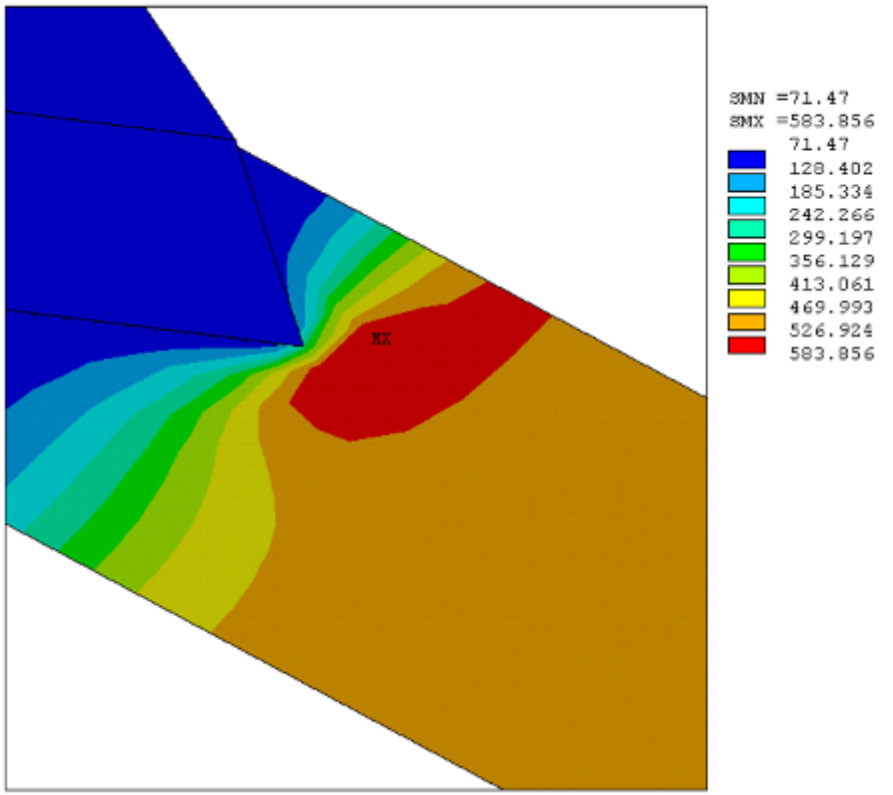


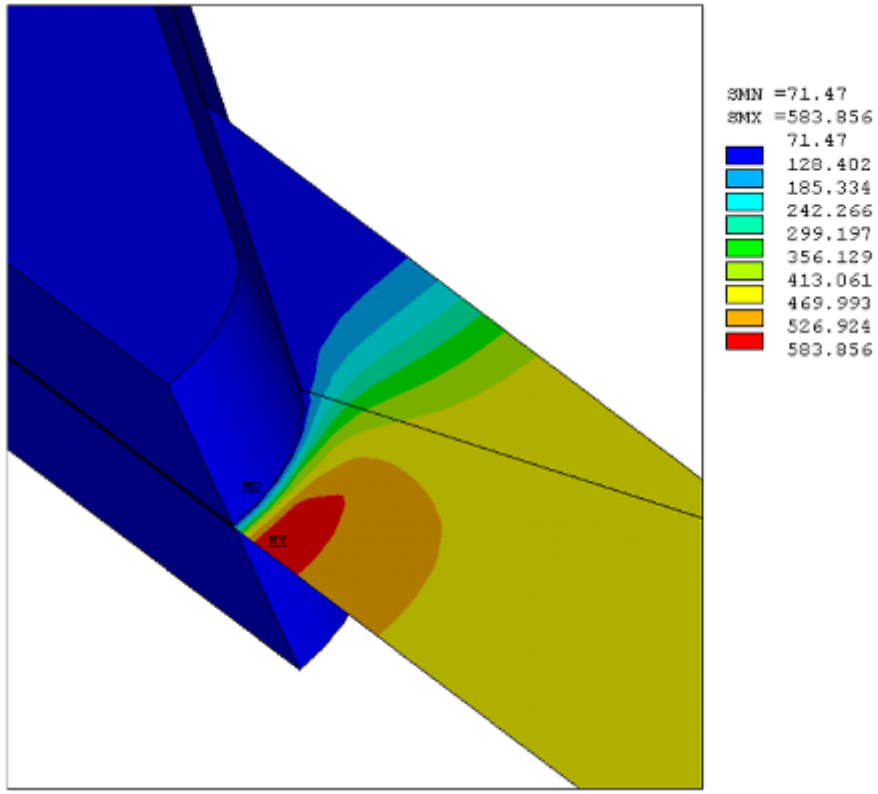
Improvements to shunt coil and contact design

- Shunt coil improvements:
  - Manufacturing improvements (easier assembly, more robust coil)
  - Mechanical strength
  - Multi-Layer winding (size reduction)
- Connector improvements:
  - Shape optimization to avoid contact hotspots
  - Improvement in RUL Time
  - Improvement in RUL Current
  - Improvement in consistency of contact resistance

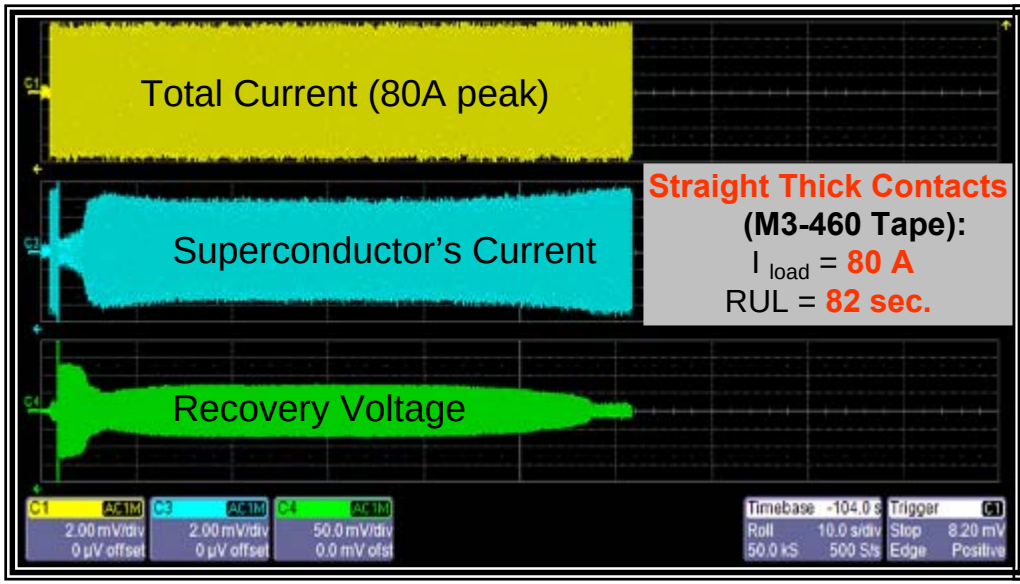


Tape heating near contact during fault impacts RUL

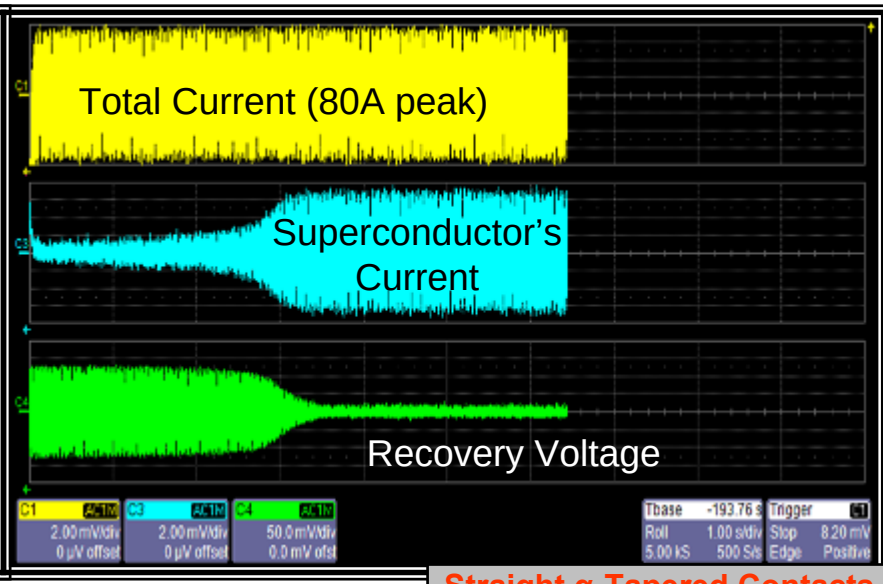




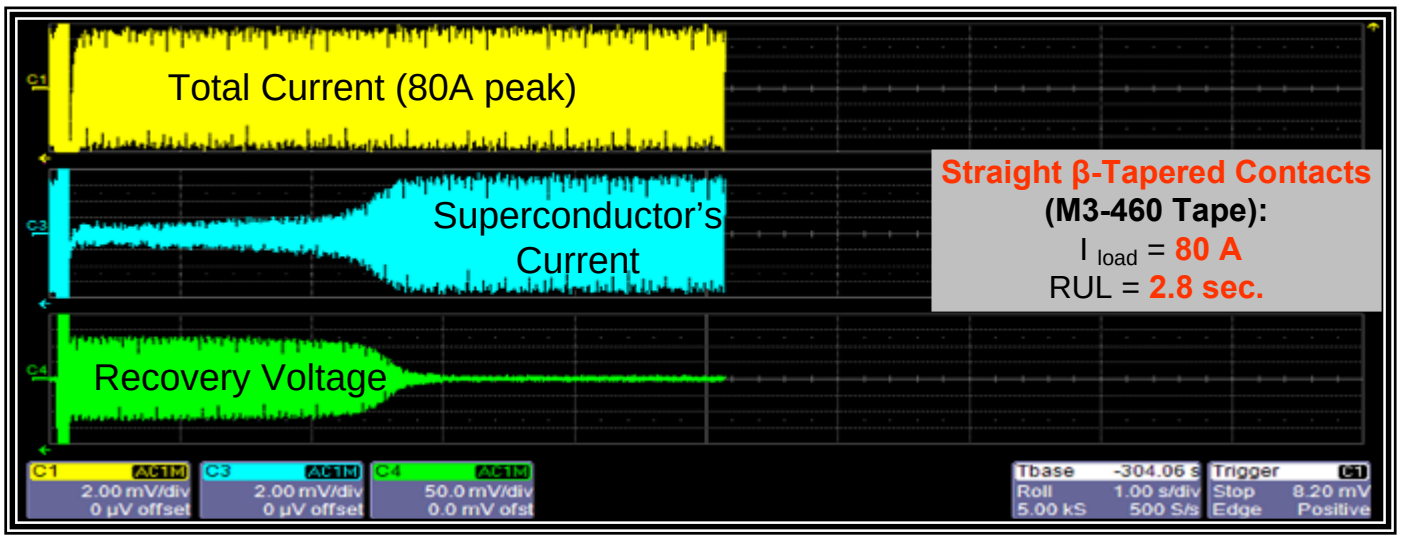
Correlation between different contact geometries



Straight Thick Contacts
(M3-460 Tape):
I_{load} = **80 A**
RUL = **82 sec.**



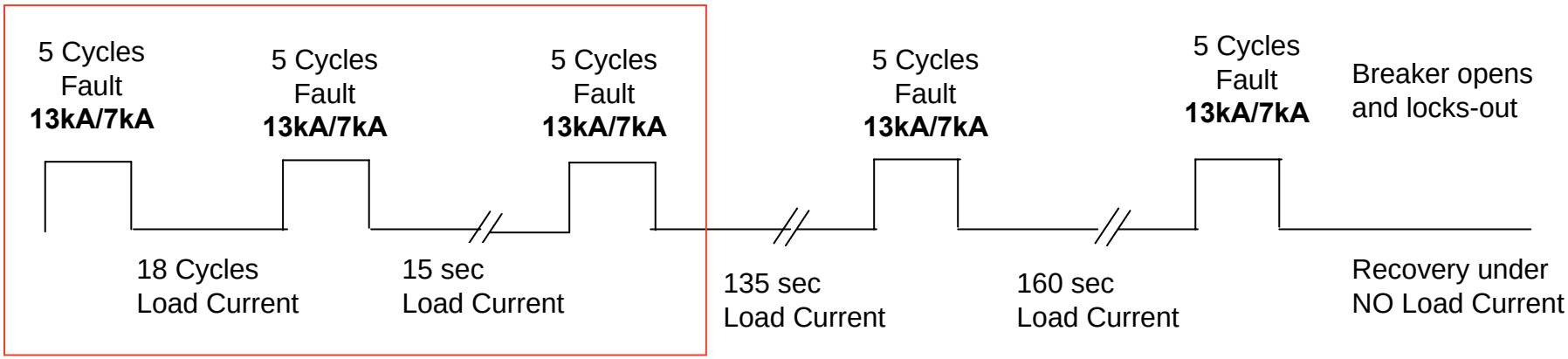
Straight α-Tapered Contacts
(M3-460 Tape):
I_{load} = **80 A**
RUL = **3.5 sec.**



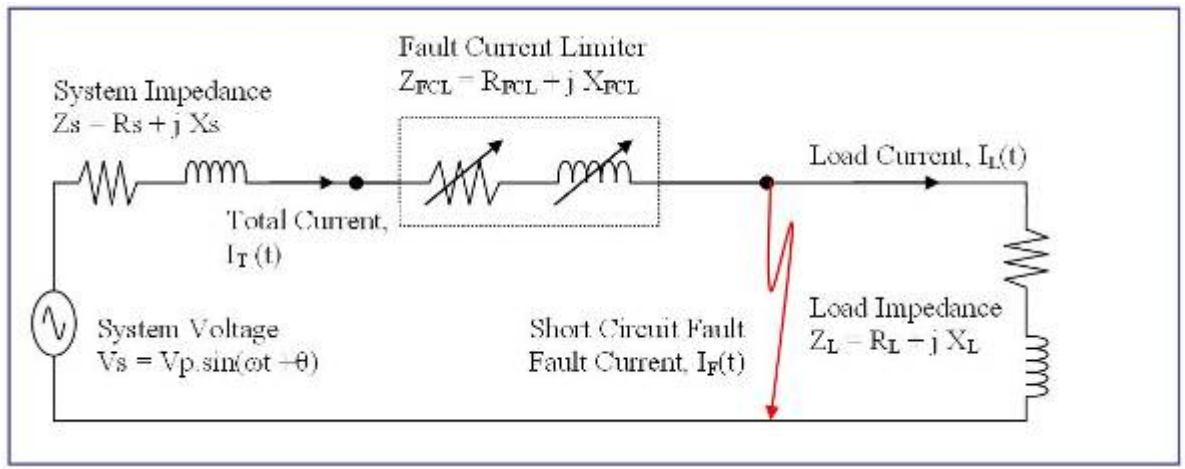
Straight β-Tapered Contacts
(M3-460 Tape):
I_{load} = **80 A**
RUL = **2.8 sec.**

Recent KEMA tests

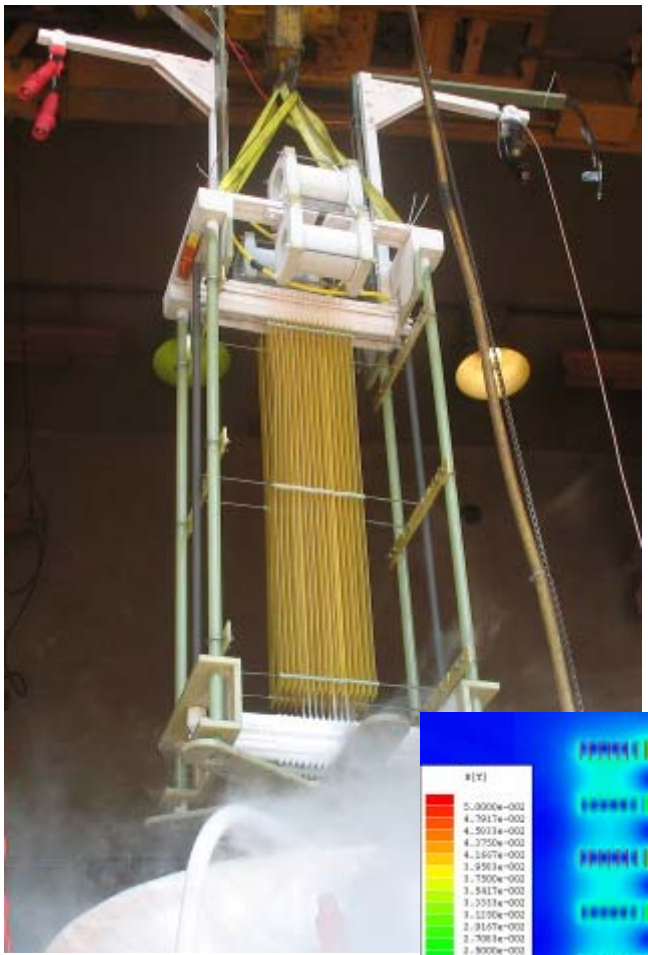
- Recent rounds of KEMA testing focused on critical AEP reclosure sequence on an HTS element



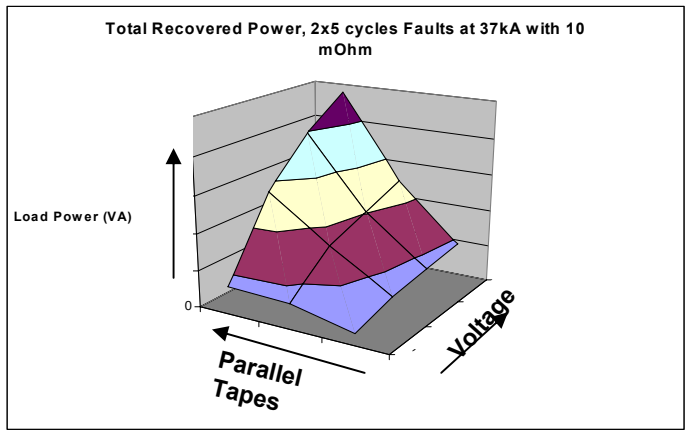
- Straight elements were used
- Improved connector designs were used
- “Standard”, pre-qualified tapes were used
- Test Dates: May 2008, July 2008

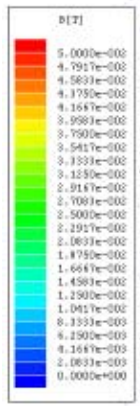


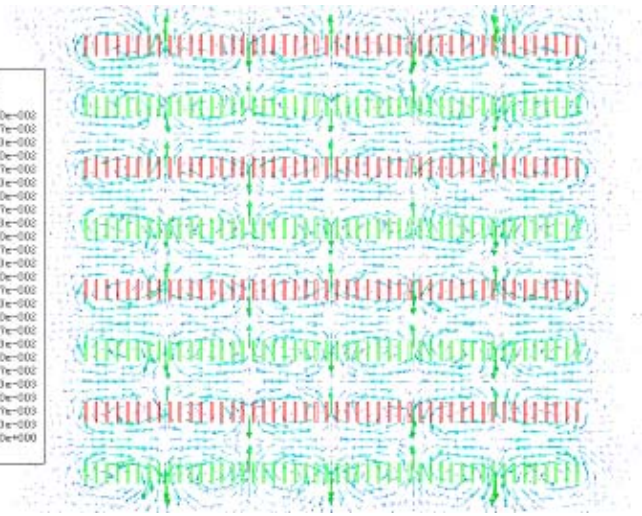
2G RUL capabilities tested at KEMA



- ‘Standard’ SC12100 2G wire used
- Test conditions
  - 37 kA fault
  - follows AEP sequence
- Test variables
  - Shunt impedance
  - Number of parallel tapes
  - System voltage (v/cm/tape)
  - Load Current

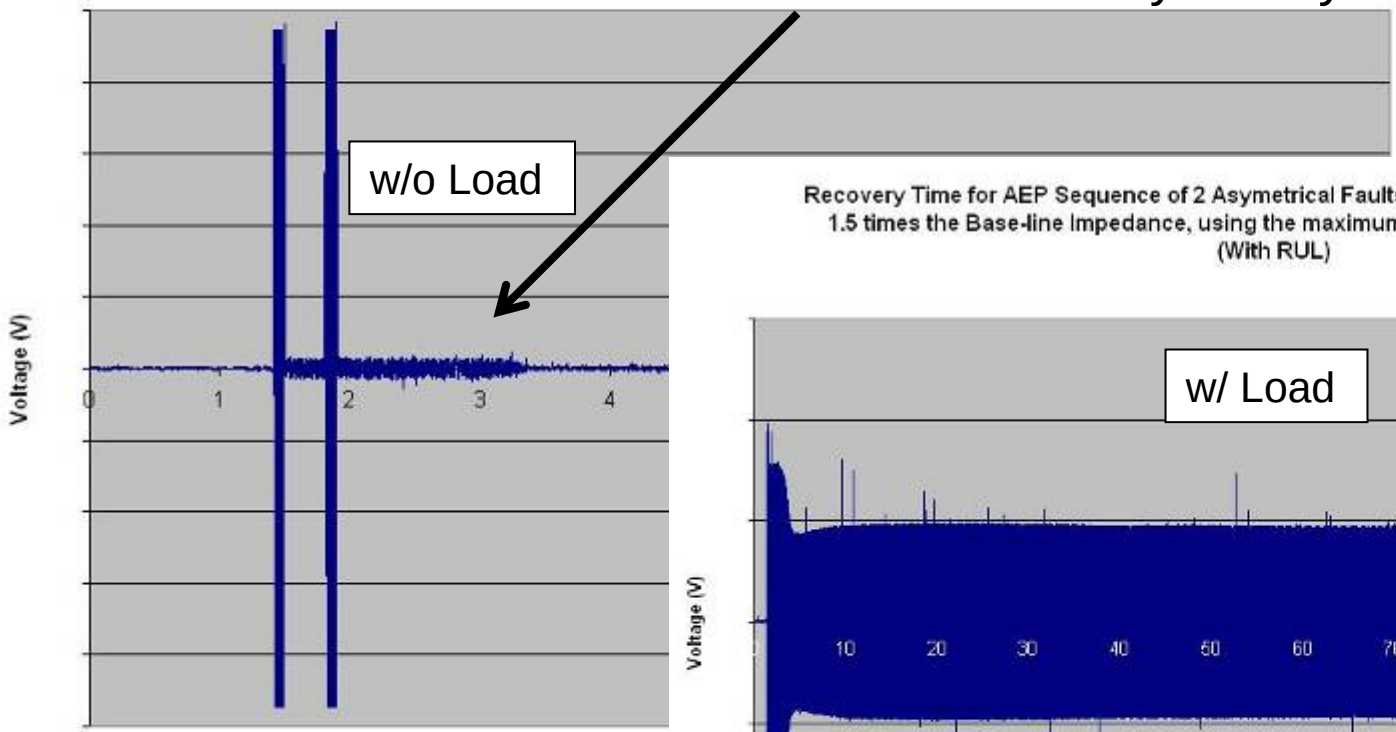


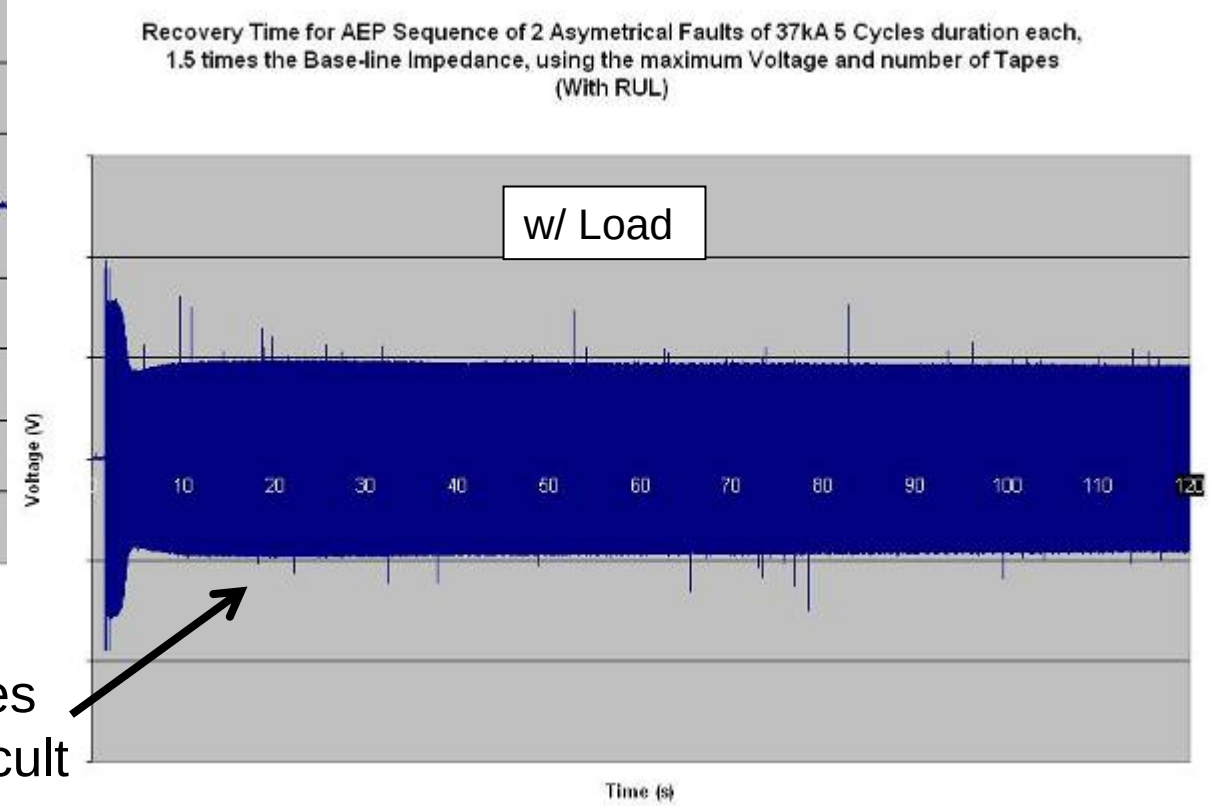




Achieving RUL is a difficult task

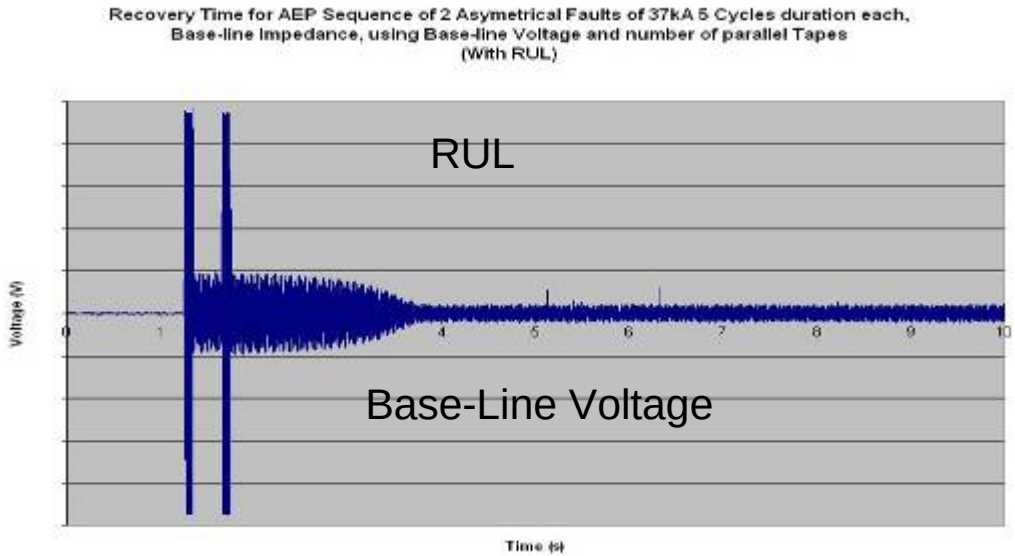
Without load current recovery is very fast



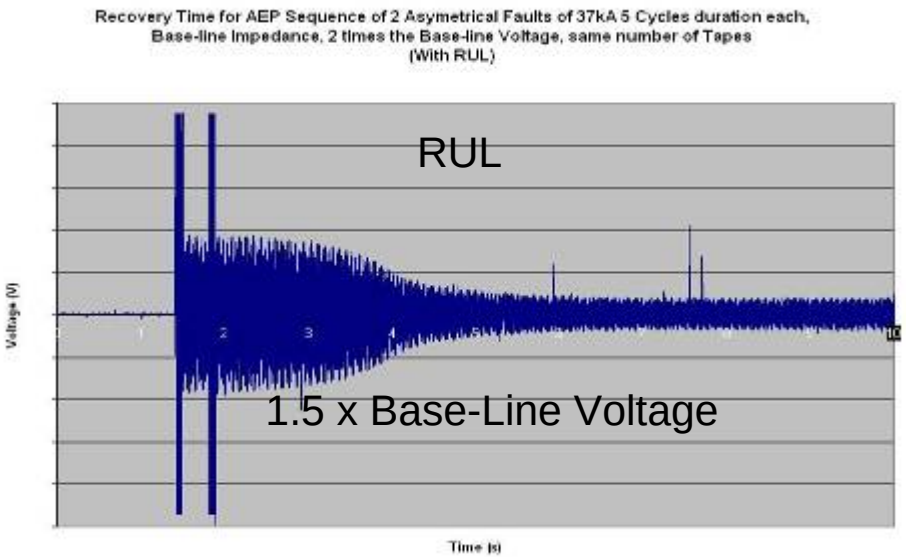


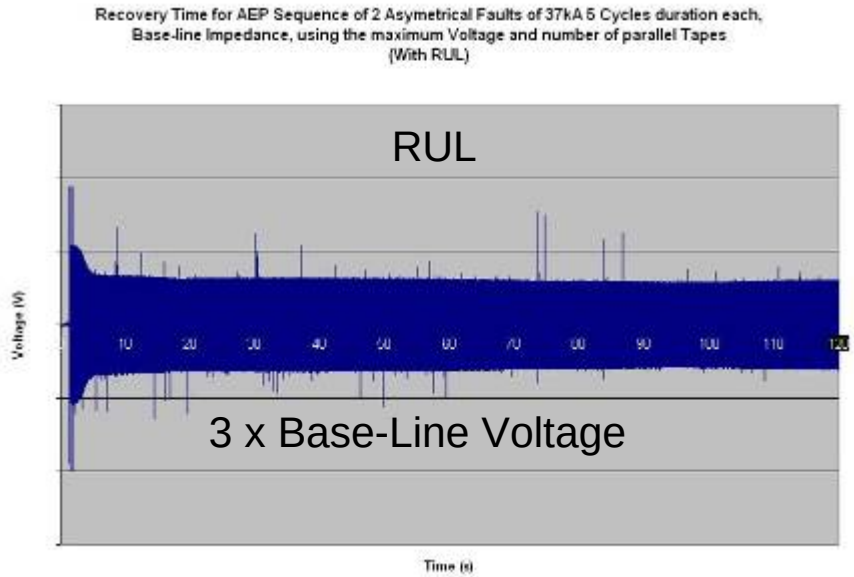
Adding load current makes recovery much more difficult

Electrical stress on the tapes can limit RUL

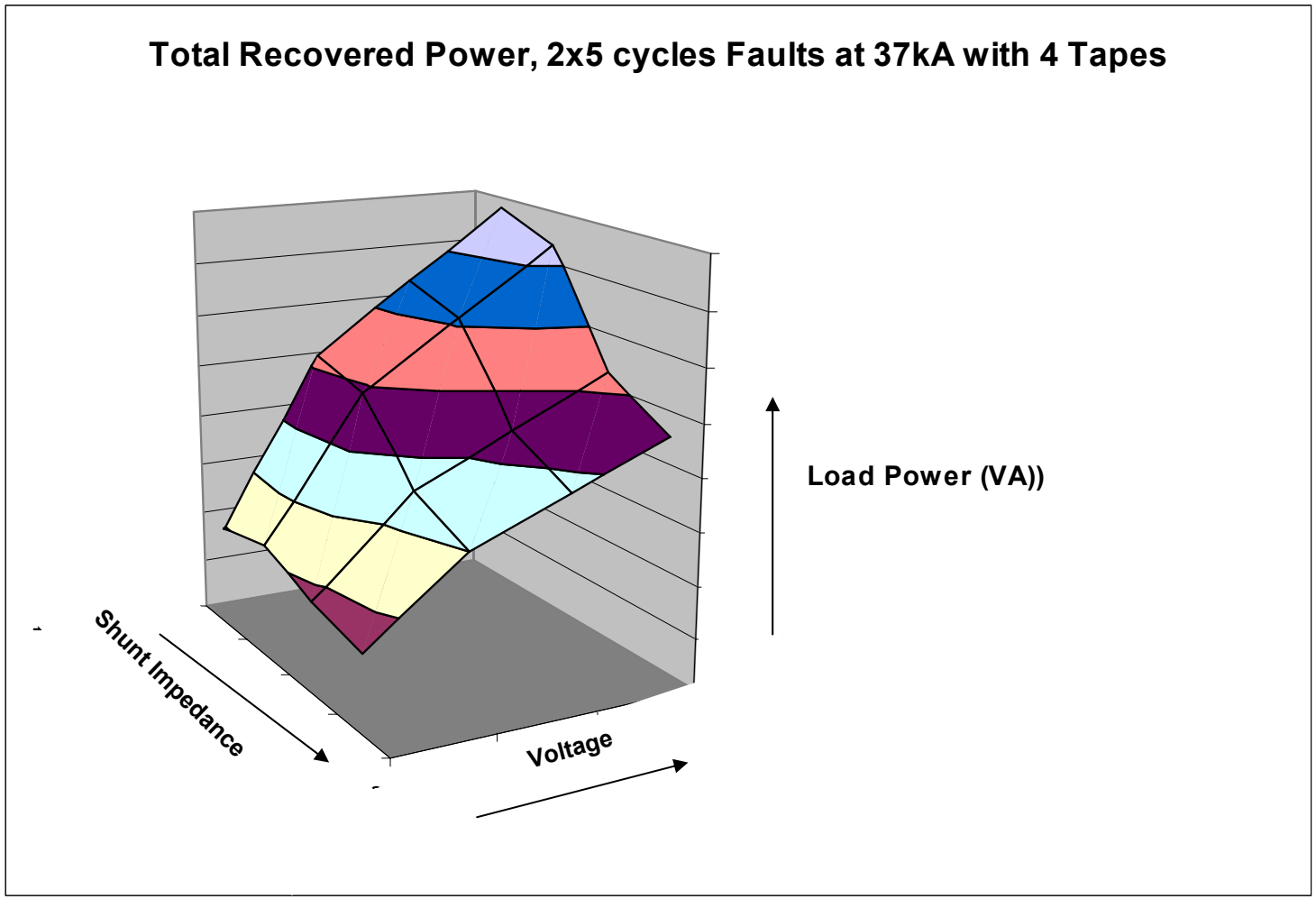


- RUL time can affected by increasing the V/cm on the tape
- Limits of the design optimization are understood





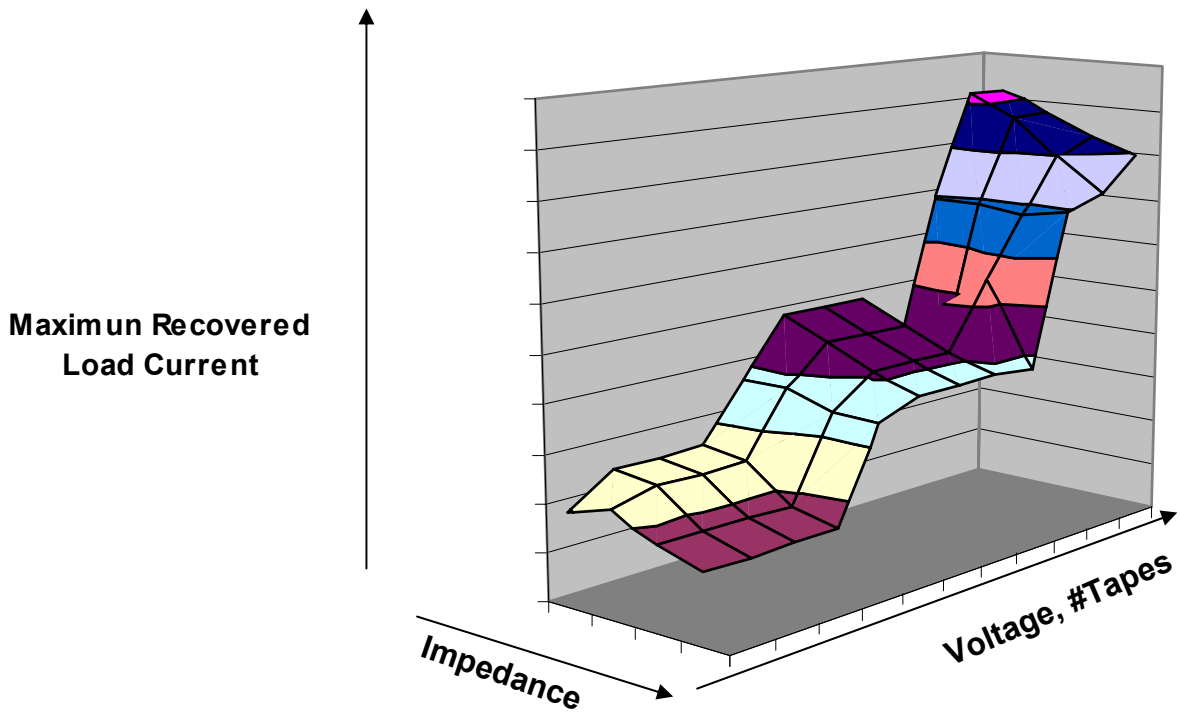
Factors impacting RUL defined by test results



Sample surface plot of RUL conditions

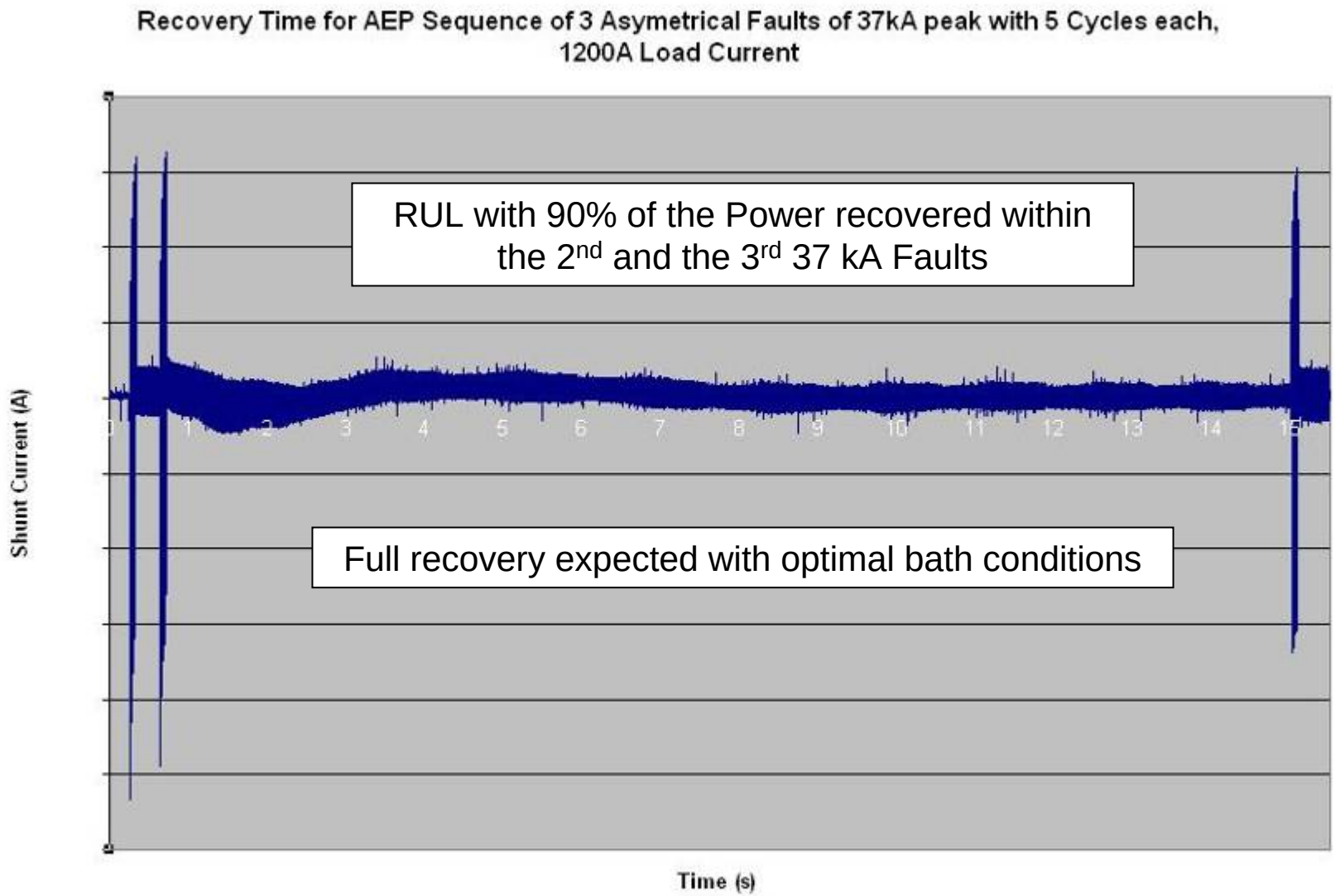
Ability to predict RUL over wide design space

Maximum Load Current as a function of shunt impedance, operating voltage & number of tapes



Recovered Current with 2 Asymmetrical 37kA Faults, 5 cycles each

Worst case conditions at Tidd can achieve RUL



Thank You for your attention!

For more information:

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or

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