NEW TECHNIQUES

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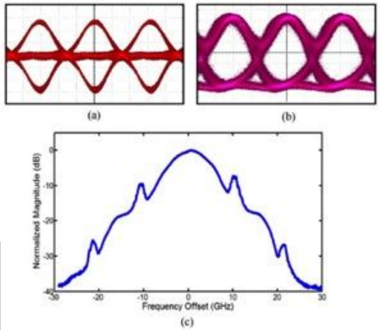
Outline

- Present day techniques (kicking in open doors):
  - Quench Detection
  - Quench Triggering



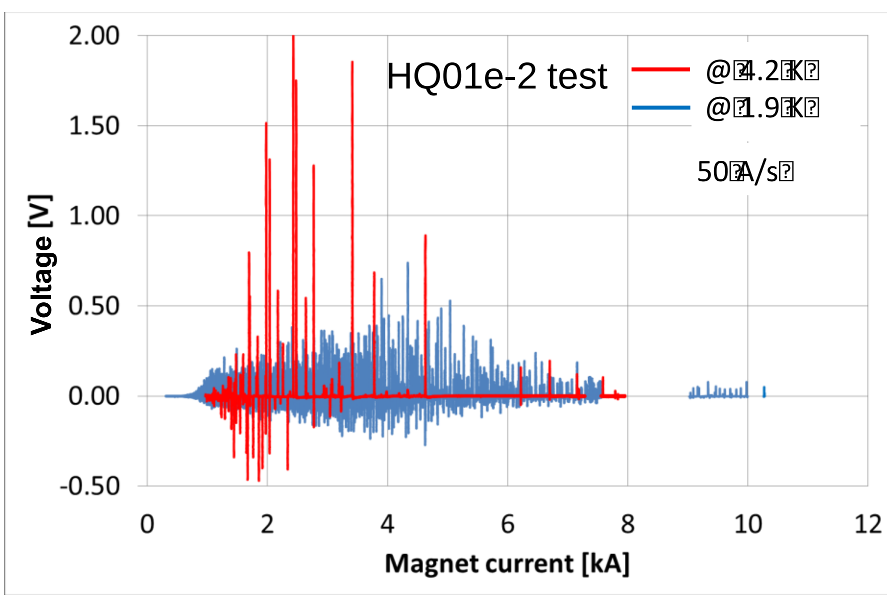
- Requirements for detection and triggering

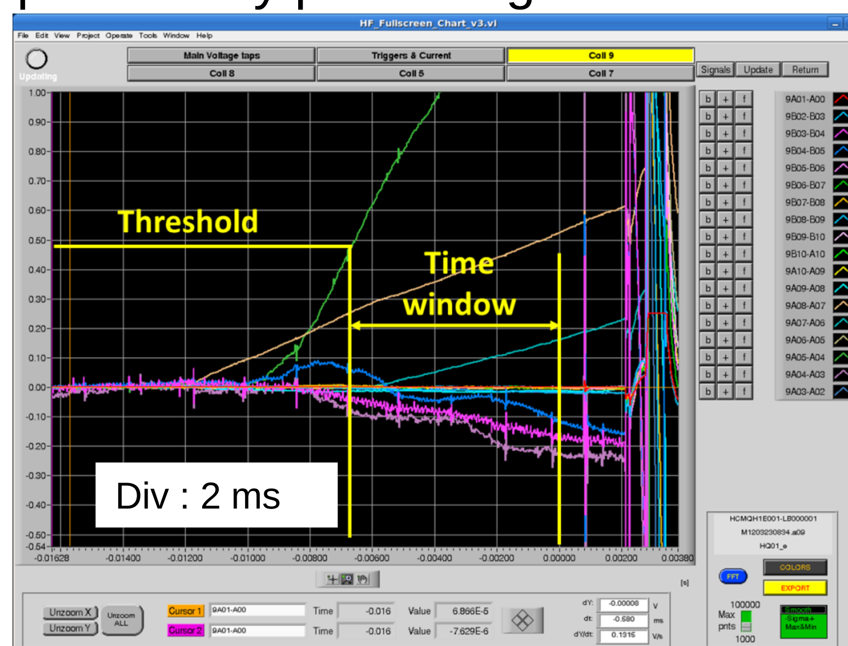
- New detection techniques

- New triggering techniques

Quench Detection

- Quench detection up to now practically only via voltage measurement
  - Time scale : ms
  - Voltage scale : 0.05 V – 1 V domain
  - Needed:
    - quench propagation speed of a few m/s
    - Clean em environment : flux jumps are very perturbing





Quench triggering

- Quench triggering is mostly done with quench heaters
  - Time scale : 10 ms – 100 ms domain (lowering for high field)
  - Need to up above Tc :   larger T margin in low B regions of the coil
  - In HTS the T margin can be >10 K
  - Often thin sheets subjected to the coil pre-stress: very fragile
  - Heaters are up to now not compatible with heat treatment
  - The 'heater proximity to cable' requirement is contradictory to the 'good insulation' requirement

Requirements for detection and triggering

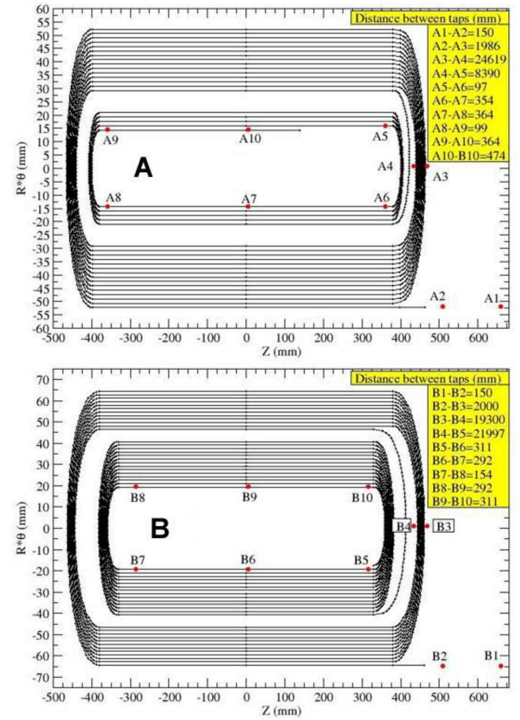
- The heat generated during the time given by: the quench detection time + the delay for triggering the quench + the dump trigger time + the dump time; should lead to a hot spot temperature that the coil can survive
- Remarks:
  - What is the hot spot temperature that the coil can survive ?
    - Depends on the conductor type, the insulation scheme and the mechanical support structure
  - The minimum required detection time delay is thus a function of the whole protection system
    - $t_{detection}$ typically for Nb-Ti and Nb_3Sn from a few to 20 ms
    - What is $t_{detection}$ for HTS ?
  - The quench trigger time has to be adapted to the detection time (if the detection is slow we might have to trigger fast !) => a thermal quench trigger is then not ideal

New detection techniques

- in order of less and less conventional
  - Voltage taps per coil
  - Voltage taps per coil segment
  - Co wound voltage taps to compensate inductive effects
  - Voltage taps inside the conductor
  - Quench antenna
  - Optical fibers for temperature detection
  - Pressure or flow detection of He
  - Co-wound superconducting wires
  - Microwave detection of He liquid to gas transition
  - Acoustic emission

New detection techniques (2)

- Voltage taps per coil
  - In (nearly) all accelerator magnets
- Voltage taps per coil segment
  - Used is many model magnets and prototypes
- Co wound voltage taps to compensate inductive effects
  - For fast ramped magnets e.g. Tokamaks LLNL
- Voltage taps inside the conductor
  - Used for cable in conduit for eg. Tokamaks
- Quench antenna
  - Used extensively for quench localization (LHC, LARP) but for detection ?



New detection techniques (3)

- Optical fibers for temperature detection
  - J. Schwartz et al., MIT, other R&D ongoing elsewhere; HTS coils, Toroids
- Pressure or flow detection of He
  - solenoids, toroids with cable in conduit
- Co-wound superconducting wires
  - Mostly applied in solenoids
- Microwave detection of He liquid to gas transition
  - Some attempts in cable in conduit
- Acoustic emission
  - Since long looked at: See presentation of M. Marchevsky

New triggering techniques

- in order of les and less conventional
  - quench heaters on each coil
  - Quench heaters on coil segments
  - Quenchback
    - Inductive coupling
    - Hot gas or resistor heat
  - bake-able quench heaters in between coil layers
  - Overpowering of magnet
  - Oscillating power on magnet
  - Inductive heating
  - RF heating
  - Laser heating
  - Millimeter wave phonon disruption

New triggering techniques (2)

- quench heaters on each coil
  - Most existing accelerator magnets
- Quench heaters on coil segments
  - LHC dipoles
- Quenchback
  - Inductive coupling
    - In most magnets this is one of the passive mechanisms which is very helpful to protect the magnet: designed into the magnet
  - Hot gas or resistor heat
    - Used for high field solenoids
- bake-able quench heaters in between coil layers
  - On the wish-list for the 11 T dipole FNAL-CERN (M. Karppinen), development to start soon.

New triggering techniques (3)

- Overpowering of magnet
  - At a quench trigger start a fast ramp-up,   not used for accelerator magnets
- Oscillating power on magnet
  - Presently being tested on MQXC (see G. Kirby talk on MQXC)
- Inductive heating
  - Large detector solenoids
- RF heating
  – Ideas
- Laser heating
  – Used for spot heating (thesis of E. Takala)
- Millimeter wave phonon disruption
  – An idea for a sc. switch (J-M. Triscone et al. UNIGE), is this applicable for quenching long conductor coils ?

Instead of conclusions: Open questions

- What is the hot spot temperature that a coil can survive ?
- What is $t_{detection}$ for HTS ?
- How to induce a (fast) quench in a ‘super’ cooled Nb-Ti coil ?
- How to quench a Nb_3Sn coil in areas with large T margin ?
- How to quench a Nb_3Sn coil fast (ms) and entirely ?
- How to quench a HTS coil ?
- How to handle coils with $J_{engineering}$ >400 A/mm^2

Grading of the potential

- How do we grade the potential of the new (or unusual) techniques ?
- What has to be pushed ?
- Who will do this work ?

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