Electrical integrity and its protection for reliable operation of superconducting machines

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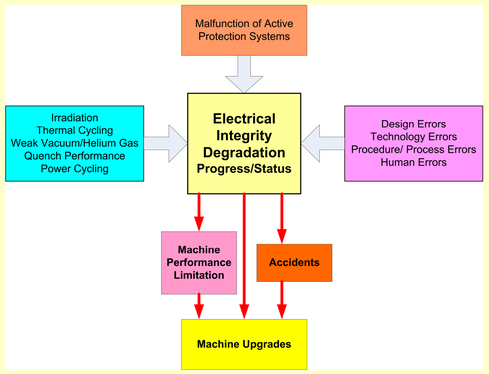
Introduction

The SIS100 synchrotron is the core accelerator of the FAIR project. The long term operation of such an advanced superconducting machine requires adequate Electrical Integrity (EI). Issues related to EI shall be taken into account at the design, production and commissioning stage respectively. In order to assure the safe and reliable operation of superconducting magnets at cryogenic conditions, the facility shall be equipped with active protection systems. When using superconducting technology, quench detection and magnet protection are the most essential. Their design has a strong influence on the coordination of electrical insulation. The case of SIS100 synchrotron is considered here as an example.



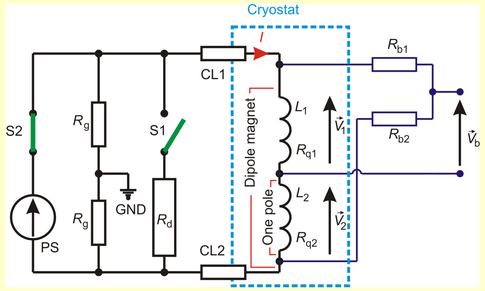
Objectives

- ❑ Definition of operating and maximum voltages:
  - standalone magnet case,
  - ring case (!).
- ❑ Defining requirements for the passive protection:
  - electrical insulation,
  - creepage distance and clearance,
  - superconducting joints quality.
- ❑ Defining requirements for active protection (quench detection and protection systems).

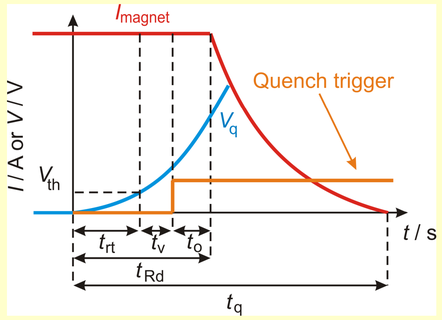
Conclusion

- ❑ The magnet construction, production and machine commissioning provide the reference level of the electrical integrity. The main goal of tests during the production and commissioning is elimination of electrically faulty components.
- ❑ Selected testing methods and acceptance criteria must be proved during testing of samples, prototypes and First of Series (FoS) components.
- ❑ Correlation between maximum voltages and quench protection/detection (QP) system are considered. The test voltage is provided (3 kV).
- ❑ The active protection systems are mandatory to preserve electrical integrity during operation at cryogenic conditions.

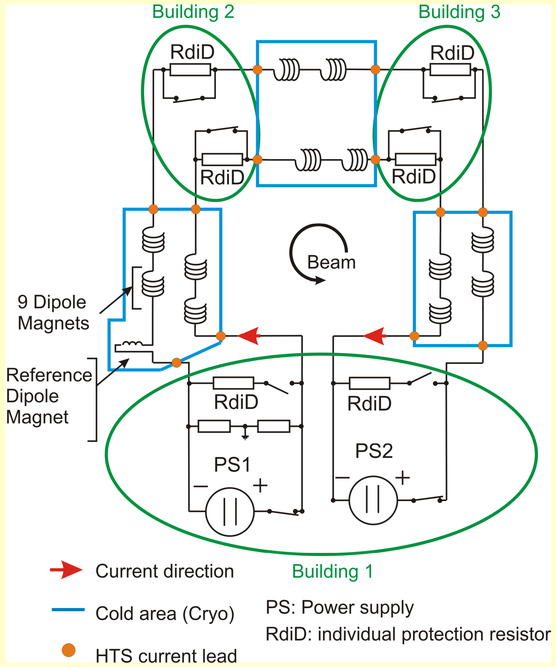
Active Protection: Quench Protection and Detection Systems



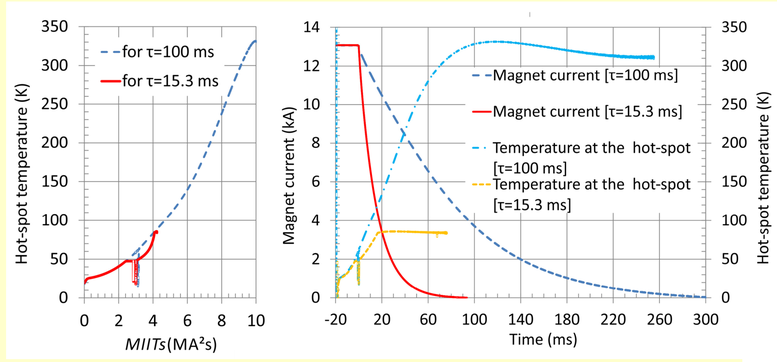
Standalone Magnet



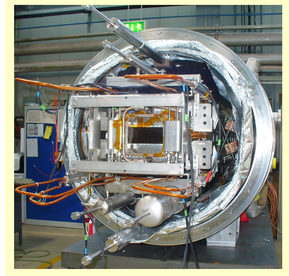
Quench detection – time sequence



Dipole ring of the SIS100 machine



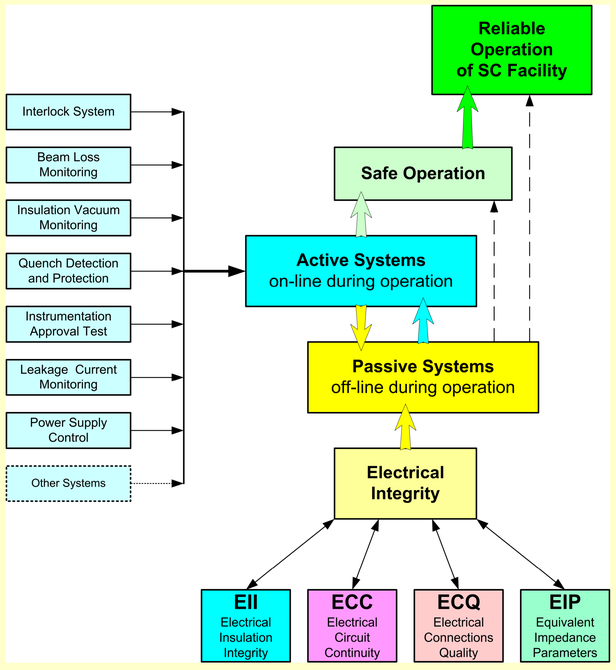
Measurements on *MIITs* and hot-spot temp. at different τ



FoS dipole magnet

$$MIITs(t) = \int_{t=0}^{t=\infty} I_{mag}^2(t) \cdot dt$$

Passive and Active Protection



1 mag. vs. ring

Correlation: Vmax and QP

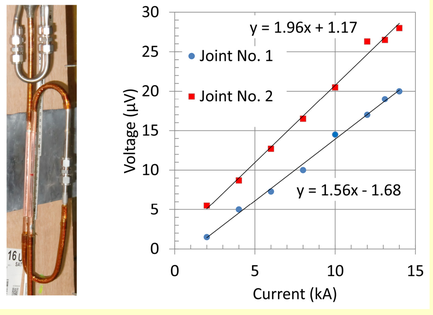
$$\tau_1 = \frac{L}{R_d} = \frac{0.55\ mH}{36\ m\Omega} = 15.3\ \text{ms} \rightarrow R_{di} = \frac{109 \cdot L}{\tau}/6 = 653\ \text{m}\Omega$$

$$\rightarrow V_{max} = R_{di} \cdot I_n = 653\ \text{m}\Omega \cdot 13.1\ \text{kA} = 8.6\ \text{kV}$$

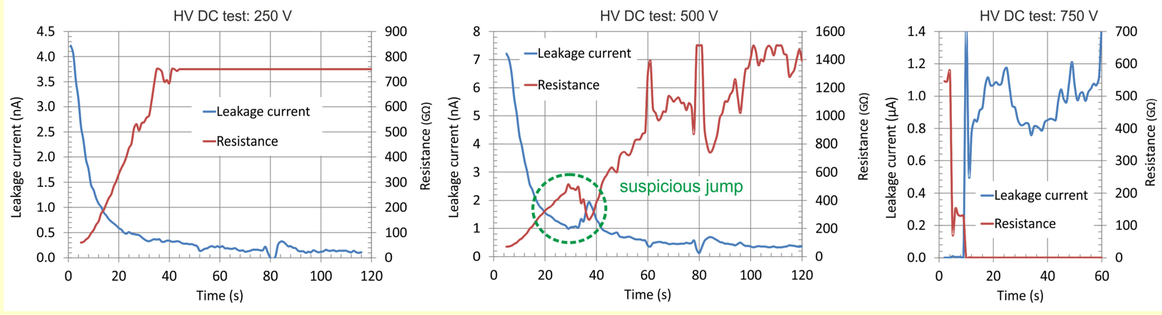
$$\tau_2 = \frac{L}{R_d} = \frac{0.55\ mH}{5.4\ m\Omega} = 100\ \text{ms} \rightarrow R_{di} = \frac{109 \cdot L}{\tau}/6 = 100\ \text{m}\Omega$$

$$\rightarrow V_{max} = R_{di} \cdot I_n = 100\ \text{m}\Omega \cdot 13.1\ \text{kA} = 1.3\ \text{kV}$$

Passive Protection



SC joints measurements



Insulation tests