Design of a Mutual Inductance Based Quench Detector for the Corrector Magnets of the SIS100*

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The corrector magnets of the SIS100 employ a multi-strand superconducting wire known as Nuclotron [1] which is made out of up to 28 insulated strands rolled in parallel along a CuNi tube filled with liquid Helium. Due to this special construction of the Nuclotron cable, resistive bridge-based quench detectors will not be able to detect a symmetric quench (quench occurring at the same time in two or more strands) in these magnets. A novel quench detector based on the mutual inductance effect was developed in order to be able to detect all quench situations in the corrector magnets of SIS100.

Mutual Inductance Concept

The detectors based on this concept monitor two voltages: one is the voltage across the magnet and the other is the induced voltage in a secondary coil formed by one of the superconducting strands (see Figure 1).

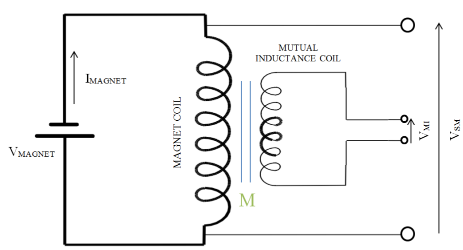

Figure 1: Diagram of the magnet and the acquired signals for the mutual inductance quench detection. V$_{SM}$: voltage across a single magnet coil, V$_{MI}$: voltage across the mutual inductance coil and M: Mutual inductance coefficient.

$$V_{SM} = L \cdot \frac{di(t)}{dt} + i(t) \cdot R_Q \quad (1)$$

$$V_{MI} = M \cdot \frac{di(t)}{dt} \quad (2)$$

In (1), the first term corresponds to the voltage across the coil of the magnet with inductance L. The second term corresponds to the quench voltage. In (2), the mutual inductance coefficient is proportional to the inductance L ($L = k \cdot M$). If we multiply (2) by k and we subtract it from (1), we obtain the quench voltage:

$$V_Q = V_{SM} - k \cdot V_{MI} = i(t) \cdot R_Q \quad (3)$$

If we define V_{TH} as the quench detection threshold, we can have two conditions:

- a) $V_Q \leq V_{TH}$: the coil is in superconducting state, $R_Q \approx 0\Omega$.
- b) $V_Q \geq V_{TH}$: the coil quenches, R_Q will rise and the quench protection system should be activated.

Mutual Inductance Quench Detector

A mutual inductance quench (MIQ) detector based on galvanic analog isolation barrier has been developed. This detector has been successfully tested in the lab with signal generators simulating the theoretical signals of the magnet during normal operating and quench conditions.

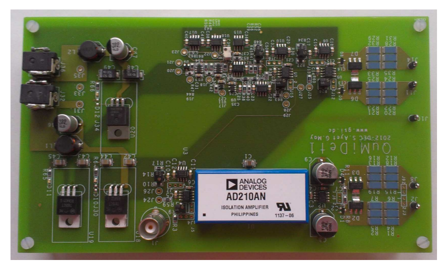

Figure 2: First version of the MIQ detector.

Outlook

After acquiring the signals (ramp up voltages, mutual inductance voltage...) of a real magnet (delivery expected on Q2-2014) and checking that the parameters (mutual inductance, impedances...) assumed during the development of this detector are correct, a second version of the detector with the following features is foreseen:

- Adjustment of quench detection parameters to the real SIS-100 magnets.
- Remote display of signals and voltages and remote control of all quench detector variables: signal processing parameters, thresholds, timing...
- Digital isolation based detector.

References

[1] Hamlet G. Khodzhibagiyan et al., “Design and Test of a Hollow Superconducting Cable Based on Keystoned NbTi Composite Wires”, IEEE Transactions on Applied Superconductivity, Vol. 15, No. 2, June 2005

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