Quench Detection Performance of the Magnet Safety System for the inductively coupled KATRIN Source Magnets

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Introduction to KATRIN

KATRIN: Karlsruhe Tritium Neutrino experiment [1]

A. Electrical simulation for a typical quench at M6 (L6M)

- Short time interval of \(t_{QV}\) between QD6 and GD3: \(dt < 80\) ms (Fig. 5a)
- Absolute voltages \(V_{th}\): 10 mV to 1250 mV
- Auto-balancing function
- 41 detectors

B. Programmable Logic Controller (PLC)

PLC validates a quench with GD#, QD, and a time interval (\(t_{QV}\)) and triggers interlocks according to the rules in Table 1.

Table 1. Main logical rules of the MSS

<table>
<thead>
<tr>
<th>No.</th>
<th>Cases</th>
<th>QD combination</th>
<th>GD</th>
<th>(t_{QV})</th>
<th>Protection level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>M(n=1-3) - X - X</td>
<td>(M_{n} N_{n})</td>
<td>(&lt; 150) ms</td>
<td>(X)</td>
<td>(X)</td>
</tr>
<tr>
<td>1b</td>
<td>M(n=4-7) - X - X</td>
<td>(M_{n} N_{n})</td>
<td>(80) ms (&lt; t_{QV} \leq 1.5) s</td>
<td>(X)</td>
<td>(M)</td>
</tr>
<tr>
<td>2a</td>
<td>DPS-M1 - GD4 - GD5</td>
<td>(bd_{1})</td>
<td>(60) ms (&lt; t_{QV} \leq 1.5) s</td>
<td>(X)</td>
<td>(X)</td>
</tr>
<tr>
<td>2b</td>
<td>MPS-M1 - GD6 - GD7</td>
<td>(bd_{1})</td>
<td>(60) ms (&lt; t_{QV} \leq 1.5) s</td>
<td>(X)</td>
<td>(X)</td>
</tr>
</tbody>
</table>

A. Quench Detection System (QDS):

- Bridge voltages
- Absolute voltages
- \(V_{th}\): 10 mV to 1250 mV
- Sampling rate: 100 kHz
- Auto-balancing function
- 41 detectors

Fig. 2. Operation mode: Driven-mode (DM)

Fig. 3. Quench validation by QD6, GD3 (a) and differential voltages of M6 during the quench (b), and slow discharge of the WGTs magnets by breaker-opening (BO) (c) after 1.5 s from the quench validation by the MSS. dt is 480 ms.

Discussion

A. Electrical simulation for a typical quench at M6 (L6M)

- \(K_{ij}\) between M6 and DPS-M1 0.005
- \(\Delta T\) on 10 K shield!

B. Electrical simulation for the quench at DPS-M1

- Long time interval of \(t_{QV}\) between QD6 and GD3: \(dt > 80\) ms (Fig. 6a)
- Negative differential voltages at M6 (L6M, L6AB) (Fig. 6b)

Conclusion

- The MSS of KATRIN-WGTS successfully operated during the first operation of the complete KATRIN magnets.
- The MSS of the WGTs is able to validate quenches of the inductively coupled neighbouring magnets and trigger the corresponding interlocks.

References