



Protection from quench of the model dipole for SIS300

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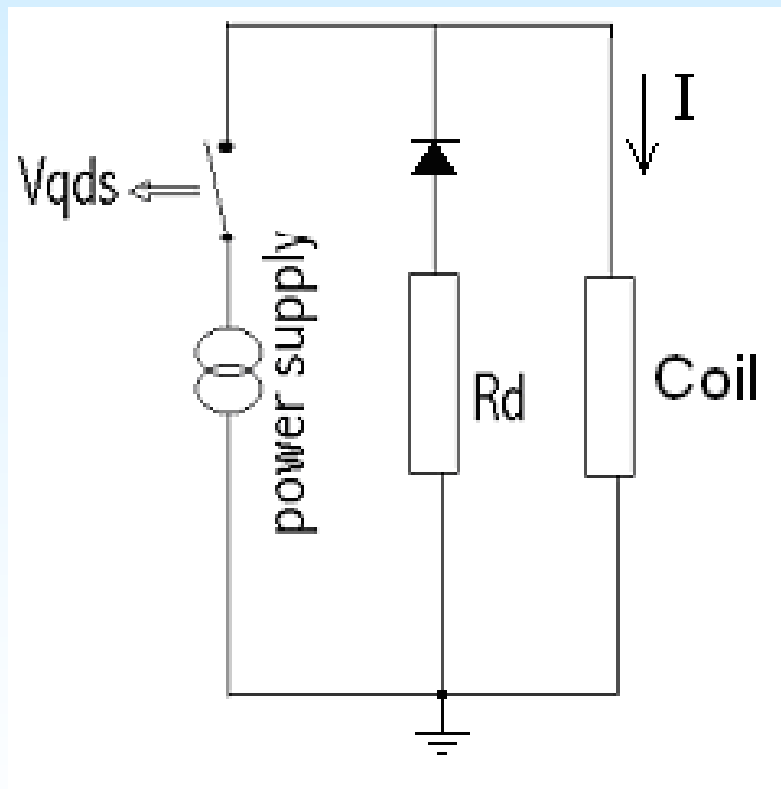
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- The study of quench propagation has been carried out with the code QLASA.

- A classical electrical scheme has been adopted for the electrical circuit
- The diode avoids the current to circulate in R_d during ramp-up
- The opening of main switch is driven by the QDS
- The resistive threshold voltage for QDS could be critical, so has been varied between 0.2-1.0 V



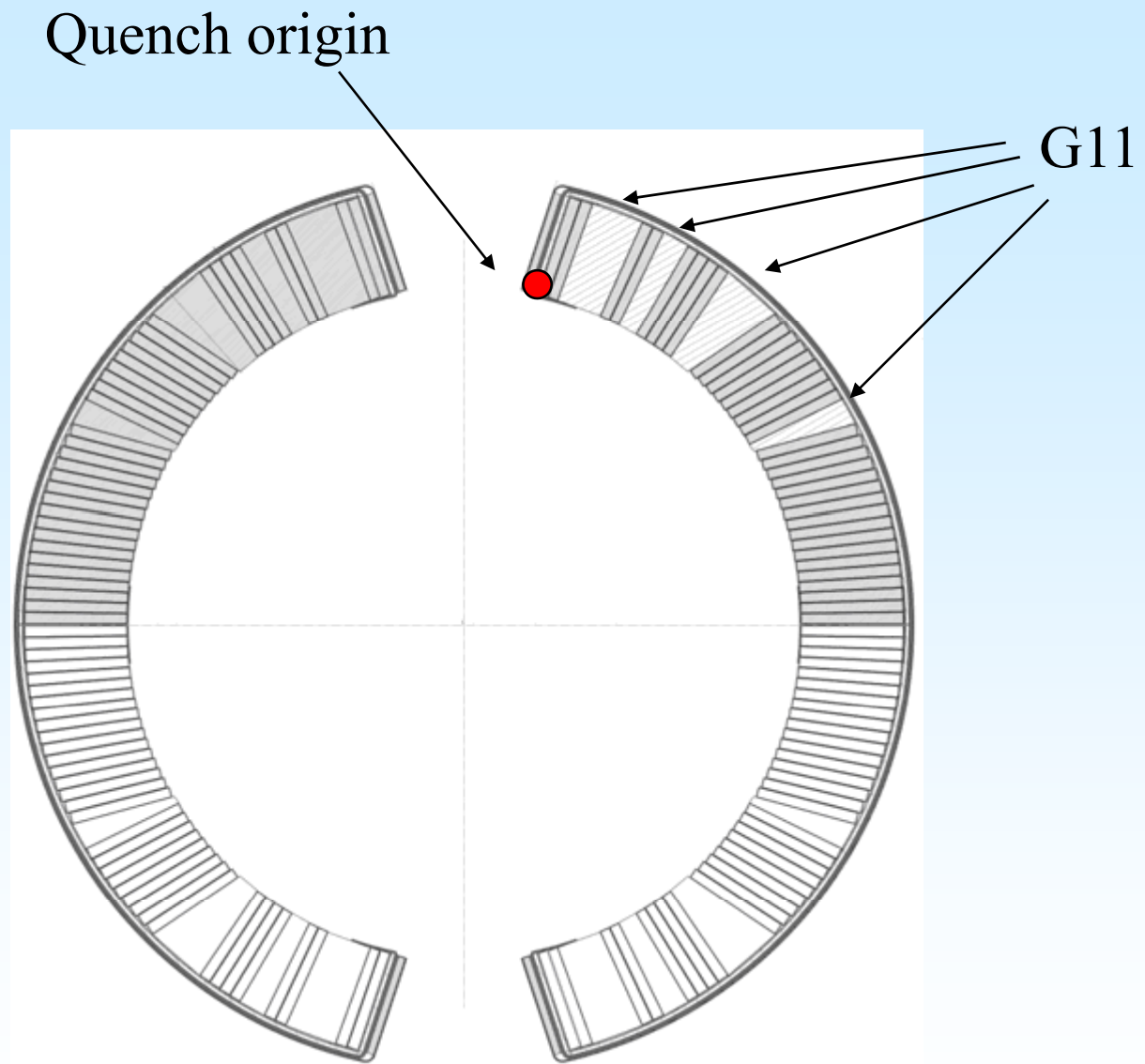
Main parameters for the protection study

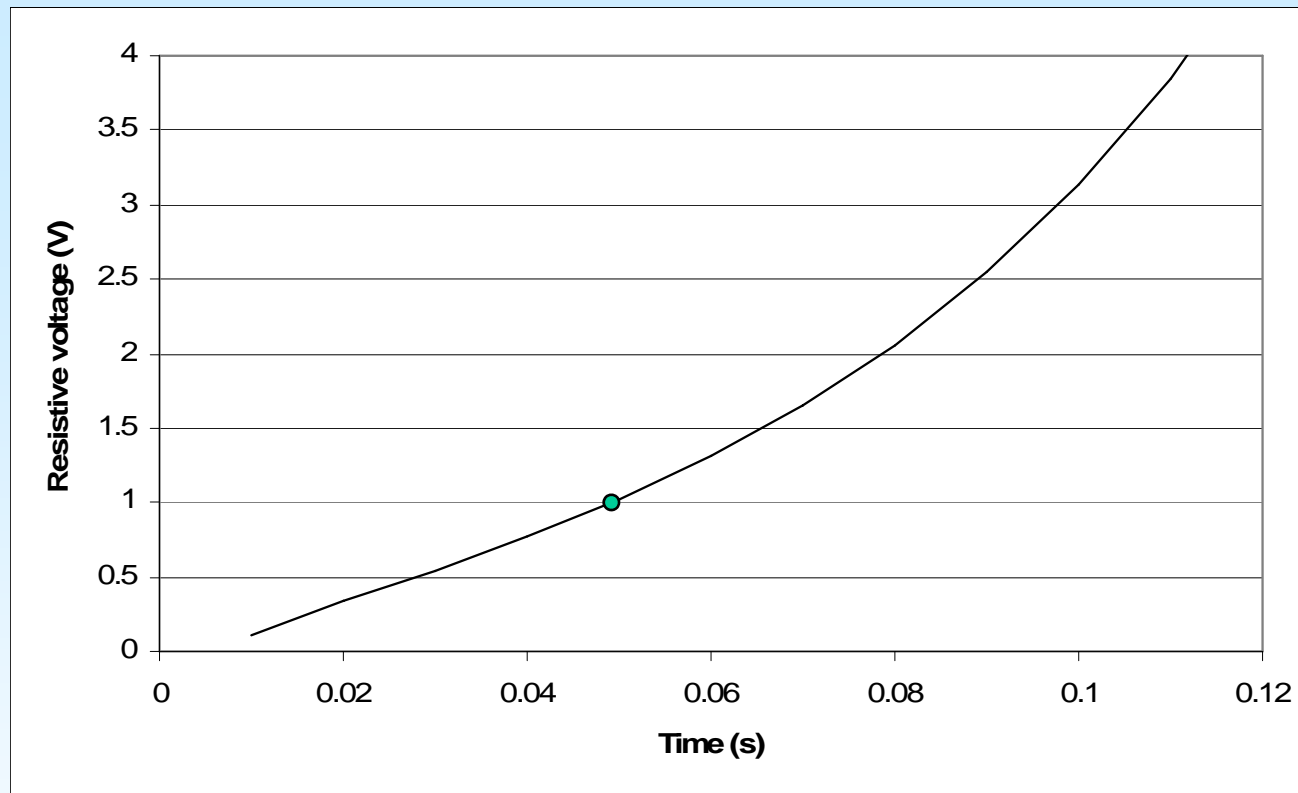
Nominal current	8926 A
Inductance	11.4 mH
Magnetic storage energy	459 kJ
Dumping resistance	44 m Ω
Time constant (L/R_d)	0.26 s
Maximum voltage	400 V

Material volumetric percentage composition of windings.

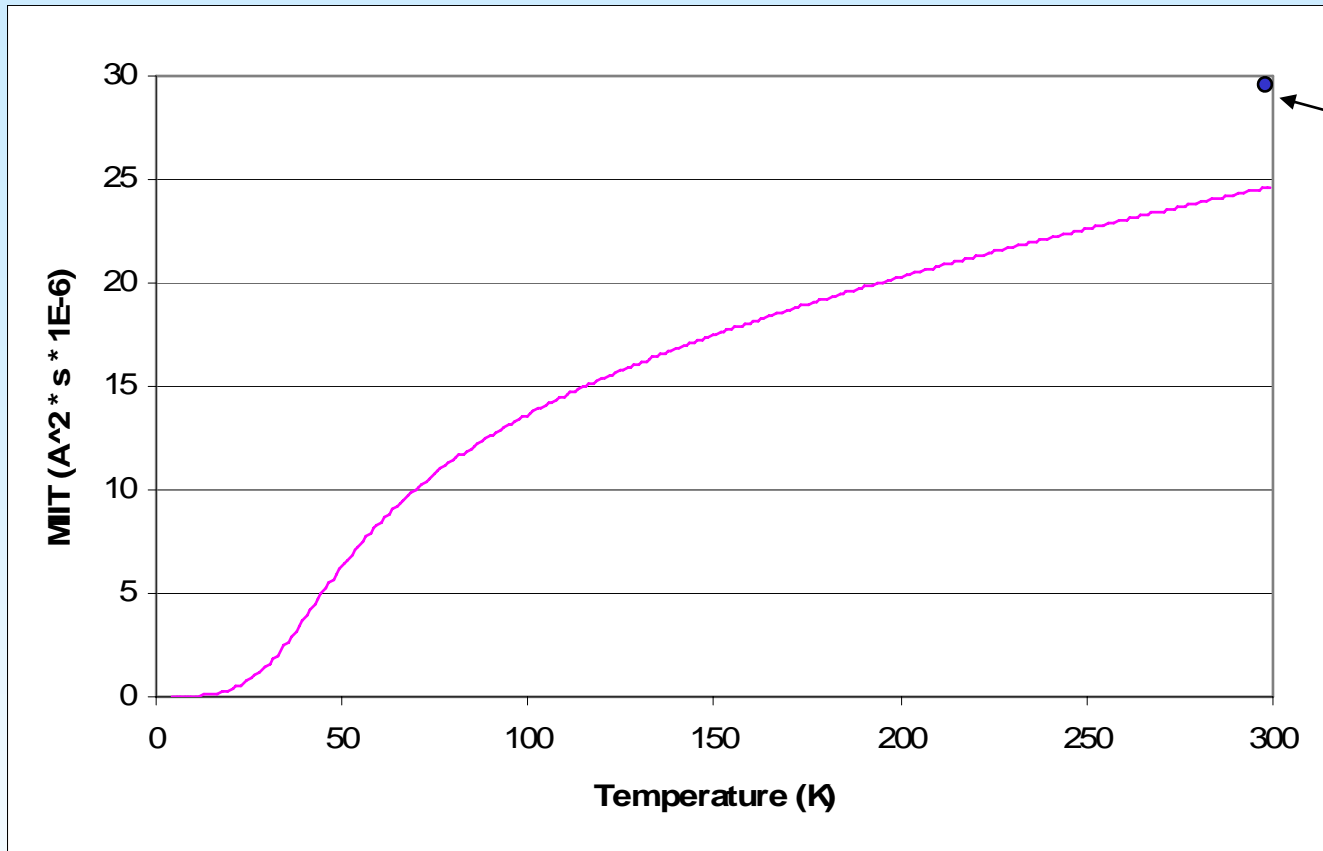
Copper (RRR=100)	35.8 %
NbTi	28.0 %
Copper-Manganese	14.0 %
Cable insulation (kapton)	13.3 %

- The dumping resistance is chosen to limit the V_{max} to 400 V
- The quench is supposed to start in the last block, with only two conductors
- The conductor blocks are considered thermally insulated each others (the discharge process is very fast ~ 1 s)





- The quench longitudinal velocity is 13.2 m/s (a factor 0.5 has been applied to M.Wilson analytical formula, for safety).
- The diffusion time of quench between adjacent conductors is about 1 ms (calculated from M.Wilson analytical formula).



LHC dipole
outer layer:
30 MIIT @300 K

- The lower value of MIIT respect the outer-layer LHC dipole is due to the less percentage of Cu in the strand ($Cu_{LHC}=66\%$; $Cu_{sis300}=46\%$)

- This effect is partially mitigated by the MnCu (18%) resistivity

$$\rho_{MnCu} = 2.5E-8 \Omega m \text{ at } 10K \quad \text{and} \quad \rho_{MnCu} = 3.9E-8 \Omega m \text{ at } 300 K.$$

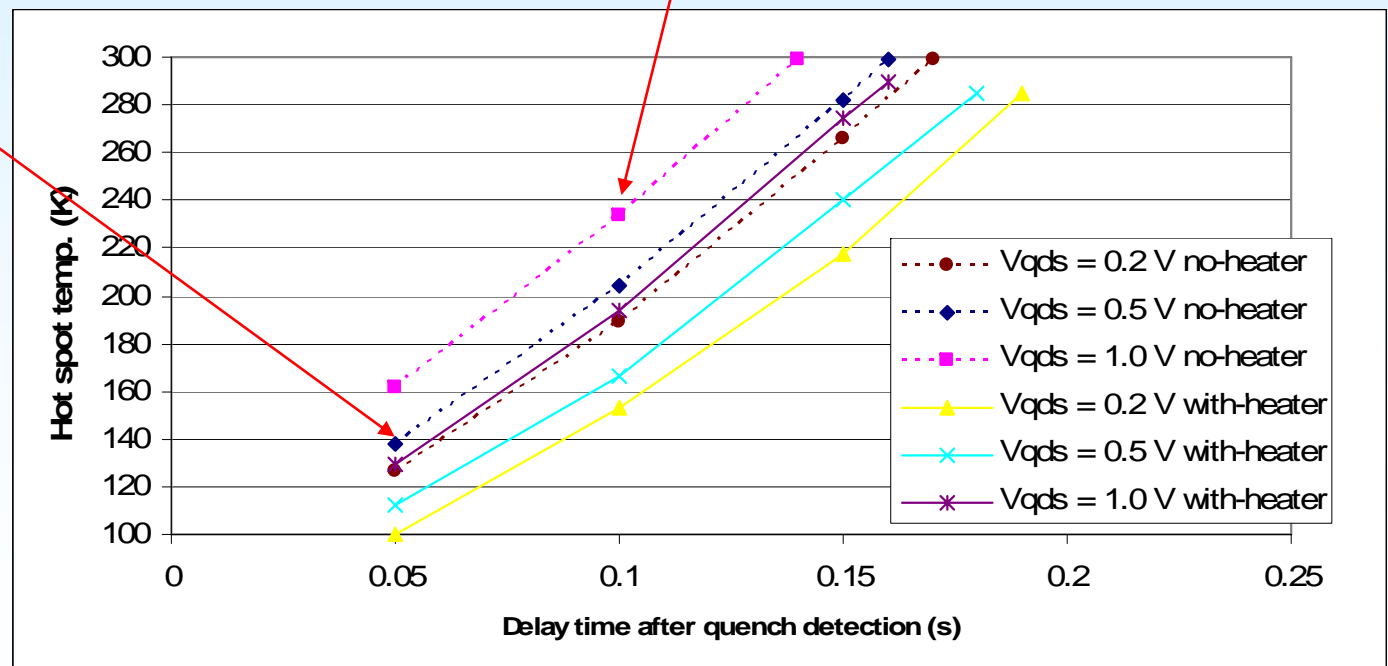
- Because of a very low constant time $\tau=L/R_d=0.26$ s the energy extraction is very efficient (85% of magnetic energy is extracted)
- Consequently the hot spot temperature can be kept below 300 K, even without quench-heaters.

Delay time = (20 +30) ms

$V_{qds} = 0.5$ V

Delay time = 100 ms

$V_{qds} = 1.0$ V



Conclusions of quench calculations:

- The magnet is protected also without using **quench heaters**.
- In case of necessity, threshold voltages up $V_{qds} \approx 1 \text{ V}$ can be used
- The hot spot temperature are reasonably below 300 K (between 140 K – 235 K)
- The spacers between blocks (in G11) drastically reduce the propagation of quench between blocks, but quench-backs are likely produced ($\tau \leq 0.26 \text{ s} \Rightarrow dBo/dt \approx 15 \text{ T/s}$)
- The use of quench heaters is foreseen in anycase as additional protection and to study the protection for **longer magnet** (7.8 m long)
- Quench heaters similar to LHC dipole are envisaged.