Preliminary Studies of Quench Protection for MQXE & MQXF

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Introduction:

The study was aimed to calculate the hot spot temperature in case of quench for the:

- *MQXE-HQ (aperture diameter 120 mm)*
- *MQXF-old design (aperture diameter 140 mm)*
- *MQXF-new design (aperture diameter 150 mm)*

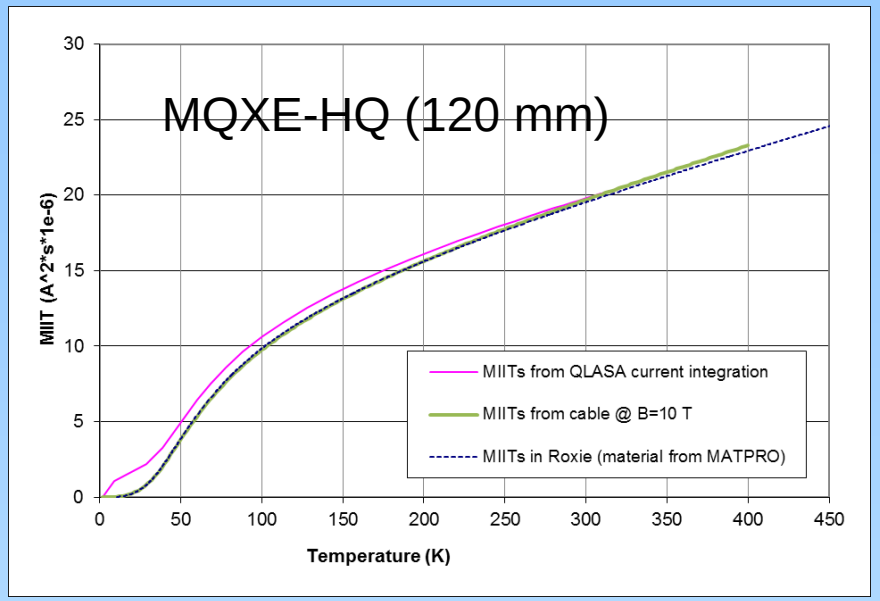
*The calculations have been performed with **QLASA** (analytical code, with analytical evaluation for quench velocity) and with **ROXIE** (FE calculation of heat diffusion)*

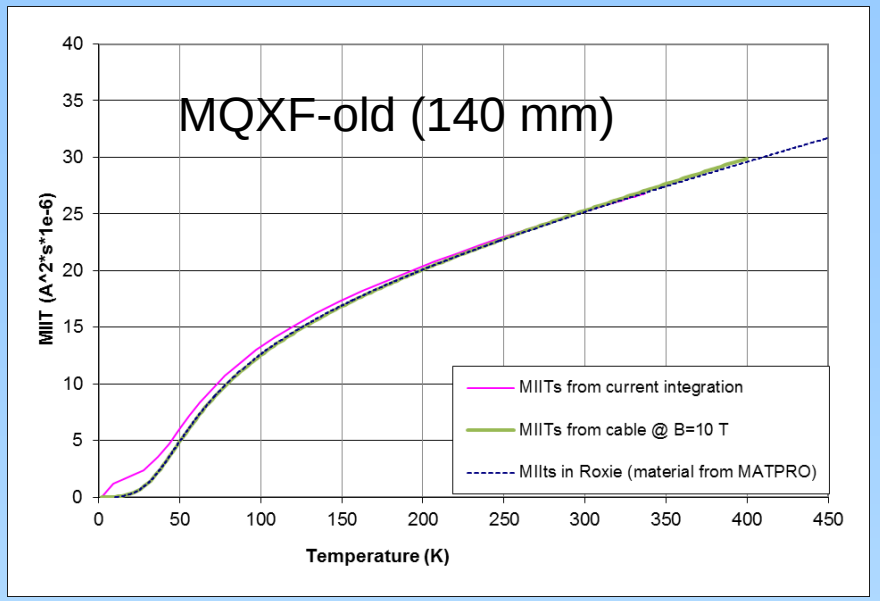
*In both the codes the material properties of **MATPRO** (material library of LASA) have been used.*

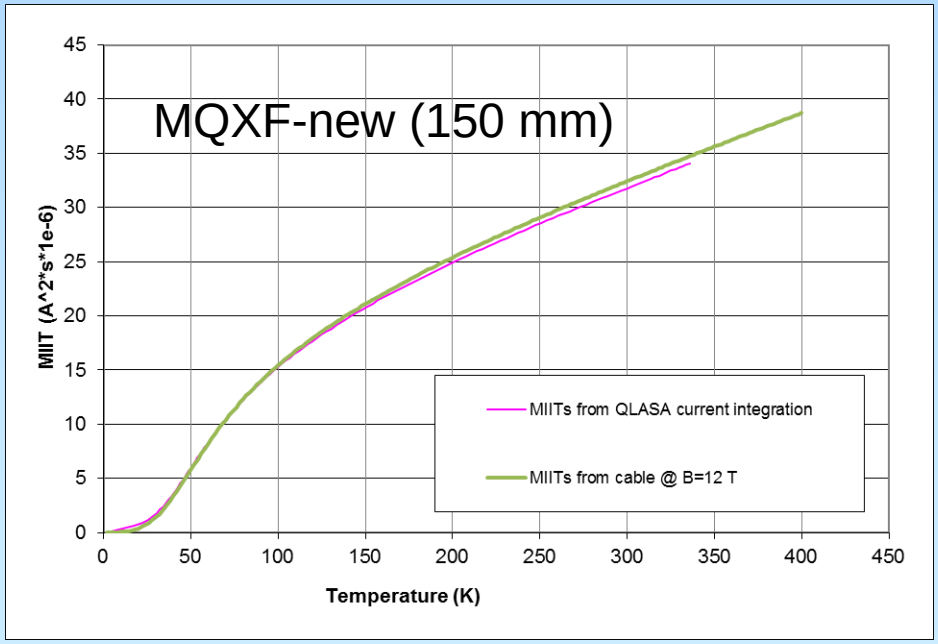
The agreement of the results for both the codes is very good.

Magnets main parameters

	MQXE (HQ)	MQXF-140 mm	MQXF-150 mm
Coil aperture diameter	120	140	150
Magnet max-length (m)	7.19	7.70	8.50
Operating current (A)	14720	15440	17300
Stored energy (MJ)	6.3	9.9	12.3
Peak voltage (V)	1000	1000	1000
Dumping resistance (mΩ)	68	65	58
Inductance/length (mH/m)	8.13	10.8	9.6
Strand number	35	40	40
Bare cond. cross section (mm^2)	21.8	24.9	29.2
Copper/non-copper ratio	1.17	1.13	1.13
MIITs (T=2K-300K @ B=10 T)	20	25	32
Magnet energy/cond.volume (MJ/m^3)	108	91	102


MQXE-HQ (120 mm)
MIIT (A^2*s*1e-6)
Temperature (K)
MIITs from QLASA current integration
MIITs from cable @ B=10 T
MIITs in Roxie (material from MATPRO)


MQXF-old (140 mm)
MIIT (A^2*s*1e-6)
Temperature (K)
MIITs from current integration
MIITs from cable @ B=10 T
MIIts in Roxie (material from MATPRO)

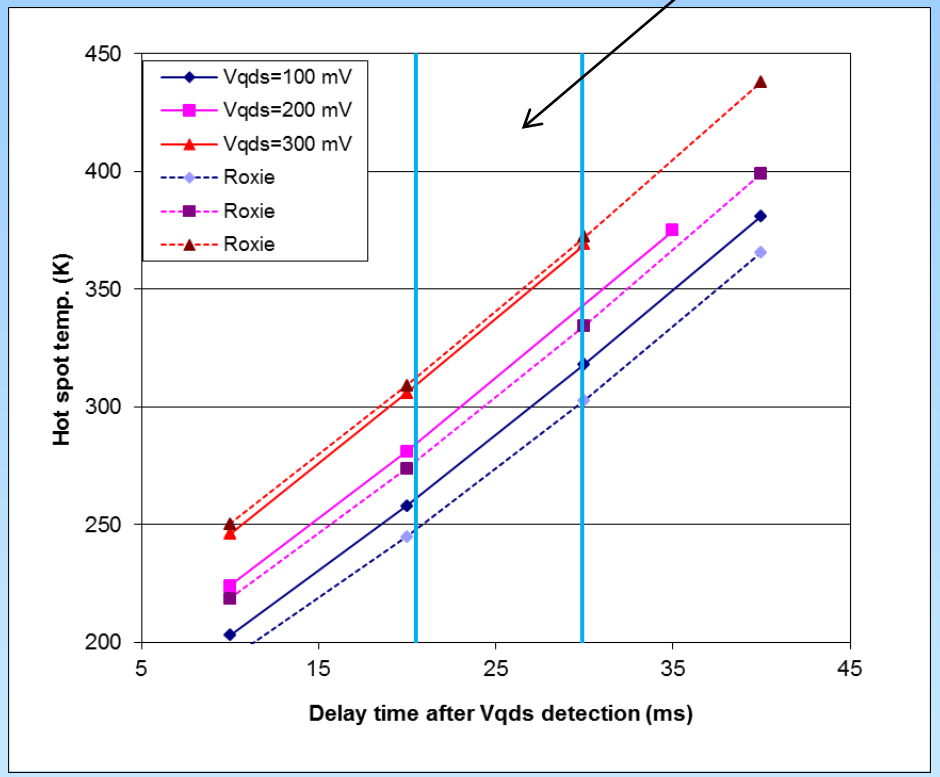

MQXF-new (150 mm)
MIIT (A^2*s*1e-6)
Temperature (K)
MIITs from QLASA current integration
MIITs from cable @ B=12 T

The hot spot temperature calculation has been performed assuming:

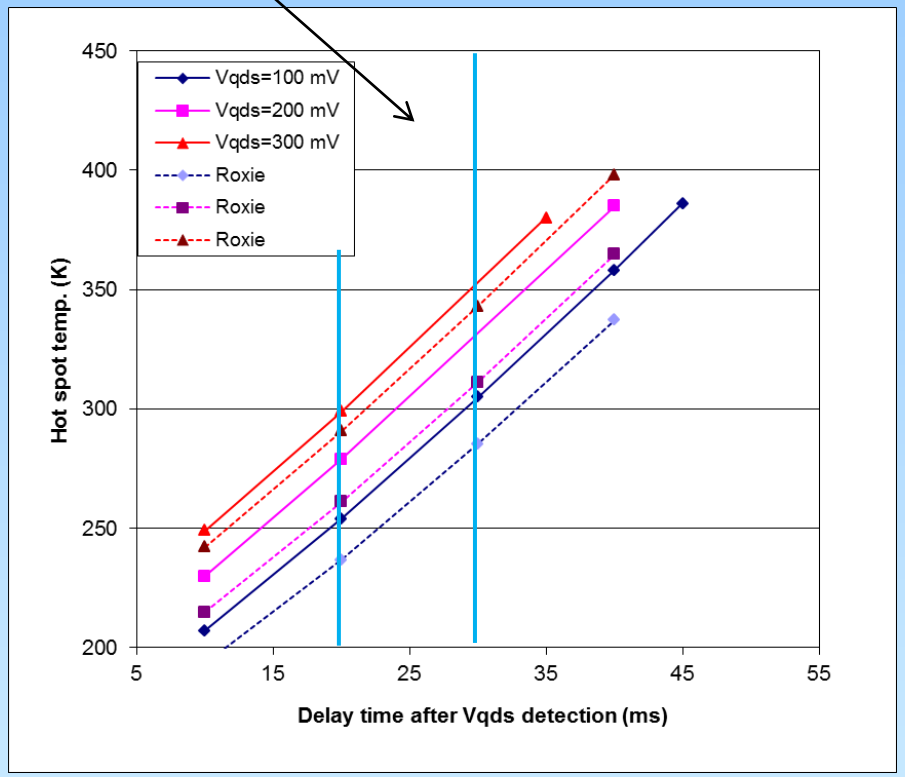
1. The magnet is considered as standing alone, i.e. not in serie with other magnet.
2. At time=0 a quench start in the high field conductor region.
3. The QDS detects the quench as soon as the resistive voltage reaches the threshold voltage Vqds (Vqds = 100 ÷ 300 mV).
4. The protection system activates the heaters and the aperture of the power supply switch. Both these two operations becomes effective with a same delay time (t_d = 10 ÷ 40 ms).
5. The heaters cover all the magnet length and both the layers.
6. In the conductor enthalpy, also the contribution of insulation is considered (the insulated conductor MIITs are sensible larger than bare conductor MIITs)
7. A parametric study has been performed, varying the **Vqds** and **t_d**.

Hot spot temperature calculation

Tipical working range

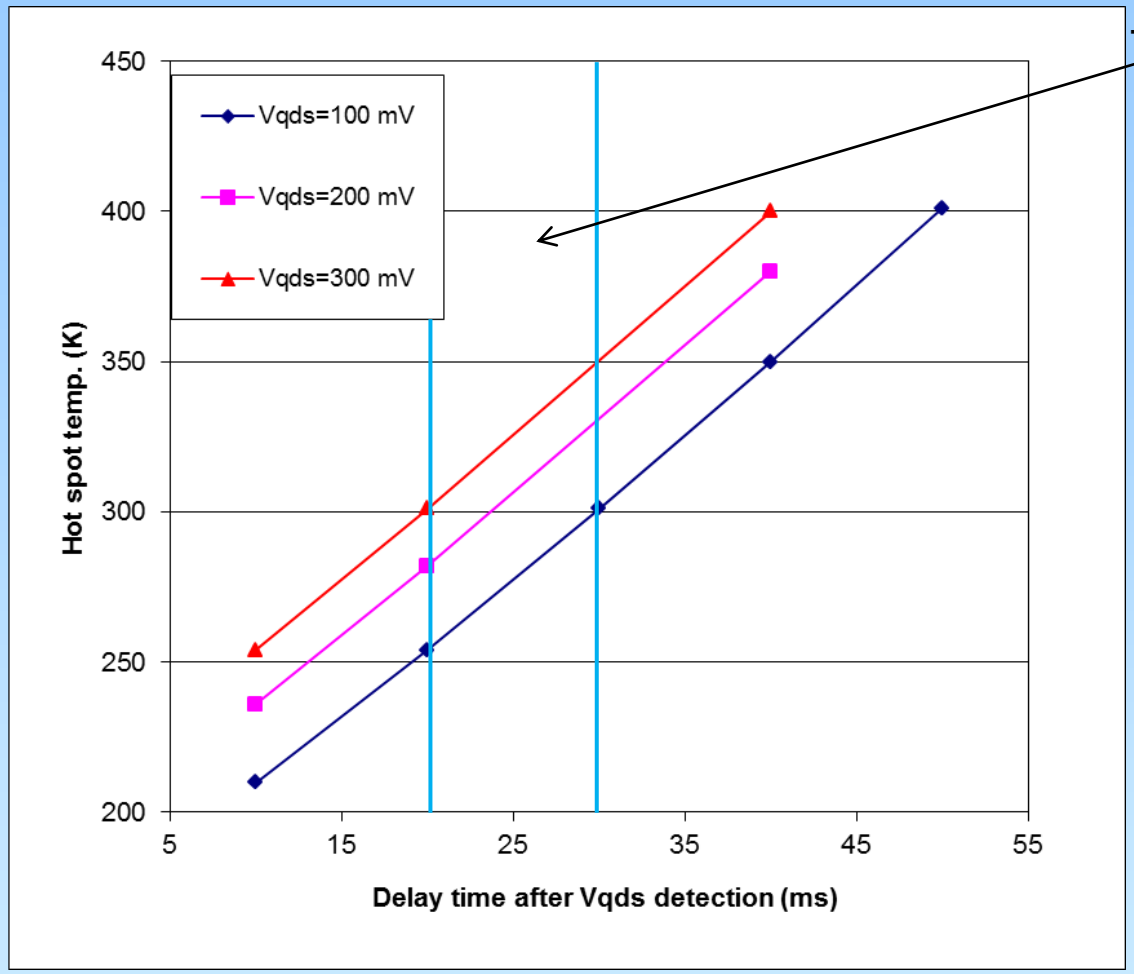


MQXE-HQ (120 mm)



MQXF-old (140 mm)

Hot spot temperature calculation



MQXF-new (150 mm)

Conclusion

- The agreement between ROXIE and QLASA regarding the hot spot temperature prediction is reasonably good.
- The MQXF-old design (140 mm) and MQXF-new design (150 mm) presents about the same behavior of the hot spot temperature vs. the delay time & Vqds threshold voltage.
- The MQXE-HQ magnet presents a slight larger value of hot spot temperature: this is main due to the double effect of lower value of MIITs and larger value of magnetic-energy/conductor-volume
- The hot spot temperature of MQXF-new design (150 mm) can be considered save ($T < 300$ K) with a delay of 20-25 ms for the effectiveness of quench heater and with Vqds of 100-200 mV: both these values are feasible if compared to the experience.
- If the magnets are connected in serie with the same power supply, the calculation has to be re-execute, and by-pass diodes per each magnet are necessary.