Tools for the calculation & simulation of electro-thermal behavior of magnets and circuits

Status and plans

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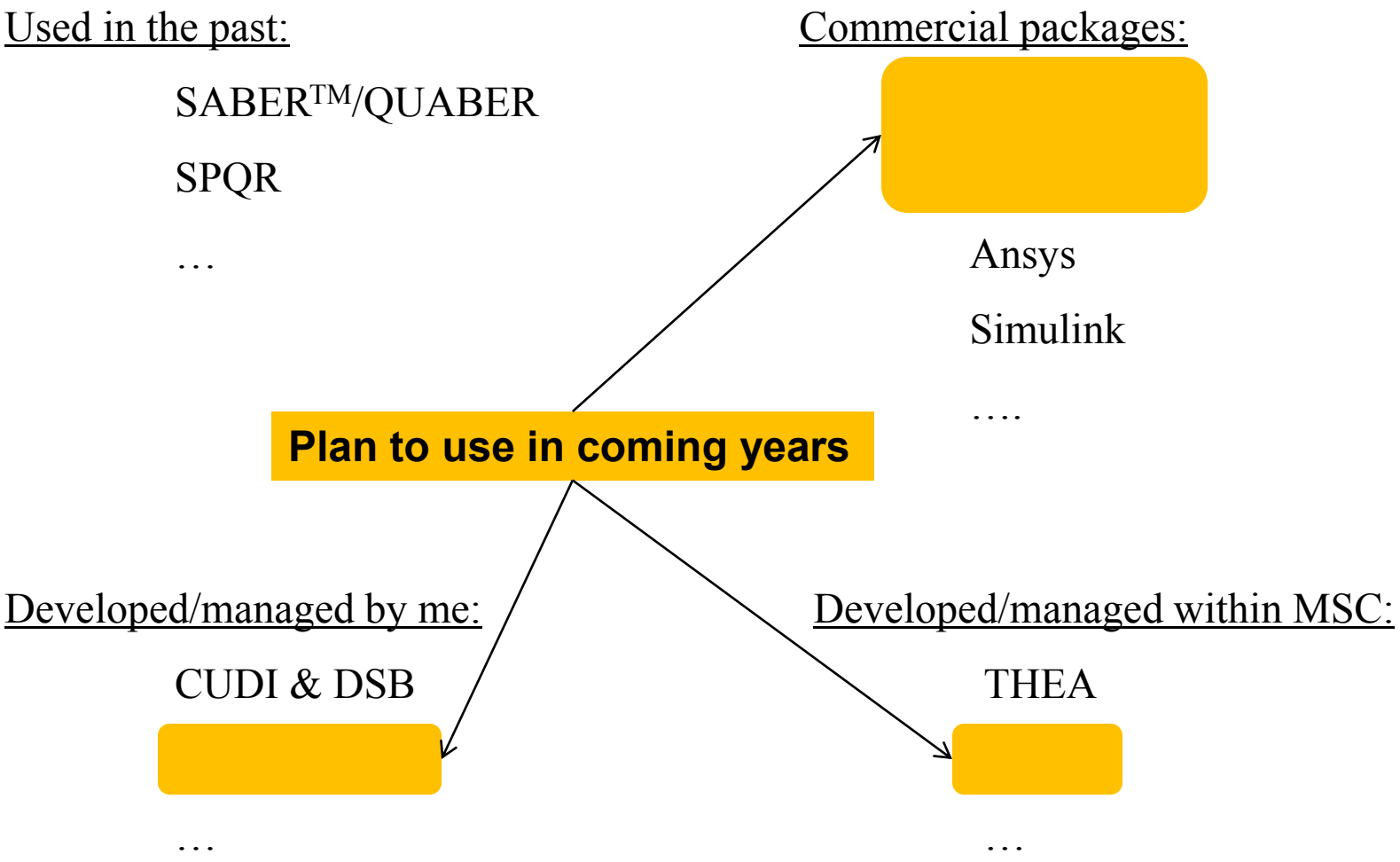
Tools


Used in the past:
SABER™/QUABER
SPQR
…
Commercial packages:
Ansys
Simulink
….
Plan to use in coming years
Developed/managed by me:
CUDI & DSB
…
Developed/managed within MSC:
THEA
…

ROXIE

- Useful for us for field maps and quench analysis of coils (MIIts, temperature distribution, thresholds, effect of heaters).

- Models for all LHC magnets are available (except D1 and D2).

- Output used as input in QP3/ PSpice/ Comsol.

- We never run the program ourselves, but the Roxie guru's are always willing to help us.

QP3

- In principle 1D, but some 2D features included (transverse cooling, shunts)

- Useful for us for simulating:
  - longitudinal and turn-to-turn propagation
  - quench behavior (e.g.: 13 kA interconnects with/without shunts, including SM18 and FRESCA tests and safe operating current for the LHC)
  - modifications of QPS thresholds
  - initial V(t) curve during quench ($\Rightarrow$ rough estimate of quench localisation)
  - BLM thresholds
  - thermal amplifier

- User-friendly input, but no user manual yet, and output is not graphical (just csv-type files).

PSpice

- Some effective thermal modeling can be included (e.g. resistive built-up of a quenching magnet) but needs input from other programs.

- Available at CERN (CMF→Cadence).

- RB, RQ, and RQ4 models are (almost) ready.

Comsol

- Interesting for us for the thermo-electrical modeling of specific parts of circuits, that require a 3-D approach, such as the shunt on the 13 kA joints, the bolted ‘half-moon’ connection to the diode, ‘praying hands’ 6 kA joints etc.

- License available in MCS group.

- Preliminary model of 13 kA joint is ready.

Some remarks

Main problem (and hence uncertainty) is often that we do not know the exact input parameters (material properties, geometry and insulation, heat transfer, phase transitions, R, C, local heating, …). The devil is in the details!!

Model validation is important, but is often only possible on the 'standard' case.

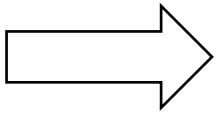
Adiabatic conditions are easier to simulate and usually sufficient for design & protection issues. Including helium cooling is however necessary to understand reality.

A recurrent problem is the transfer of codes once the author/user leaves CERN. Better documentation could help, as well as using only a small number of well-known commercial tools.

Towards 7 TeV

Towards 6-7 TeV electro-thermal transients will become much more important:

- Currents ↑
- Voltages ↑
- Ramp rates during FPA's ↑
- Radiation levels ↑
- Quench margins ↓



- Conductor movements ↑
- Local heat dissipations ↑
- Quenches and trips ↑
- Quench propagation ↑
- Temperature and pressure excursions after a quench ↑
- Cross-talk between circuits ↑
- Collective quenching ↑
- Risk of short-circuits ↑

We should have the tools ready to understand these future events

Plans

PSpice

1) Model all different circuits in the LHC and document (to ensure use in the future).
2) Validate (as much as possible) using available PM data.
3) To be used in case of non-understood events in the machine, but also to estimate possible error scenario's (short circuit, …).

Requires about 2 persons for next 2 years

Tbd: Does it make sense to re-animate the previously used Saber/Quaber?

Comsol:

Technical student foreseen for 1/3/2011-1/3/2012. Finalising 13 kA shunted joint will require a few months. Rest of the time for new singularities (pointed out by Splice Task Force or others).

Tbd: Should we try to model the thermal behavior of a quenching magnet in a cryocell environment (or leave it to CRG)?

Plans

QP3

- Needs continuous support because each problem has unique features.

- Calculate updated BLM thresholds for several magnets for various beam loss distributions and pulse durations between 10 μs and 100 s.

- Make graphical interface for output

- Write user manual

- Supplement the 'PSpice documentation per circuit' with additional quench and protection info (T_{hot} vs. MIIts curves for different parts of all circuits, V(t) slope at the start of a quench, …).

- Needs additional boost if thermal amplifier test is pursued.

Requires 1-2 persons for next 2 years