Quench energy in ITER conductors for different magnetic field perturbations with JackPot and THEA combined models

T. Bagni[1,2], A Devred[3] and A. Nijhuis[1]

[1] *University of Twente, Enschede, the Netherlands,* [2] *Ghent University, Ghent, Belgium,* [3] *ITER International Organization, Saint-Paul-lez-Durance, France*

Introduction

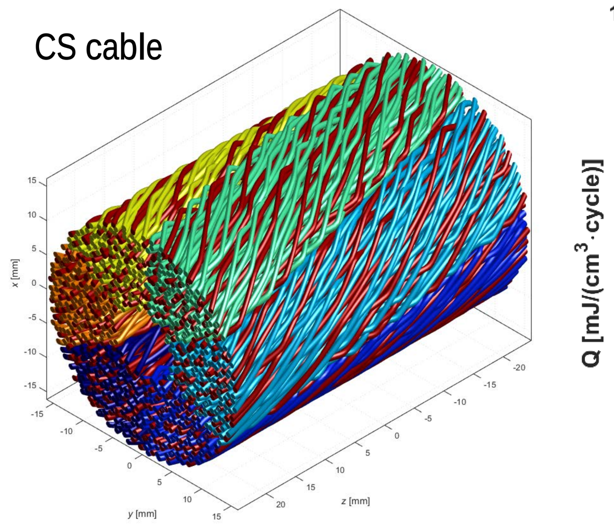
The electromagnetic-thermal model for Cable-in-Conduit Conductors JackPot-ACDC and THEA (Thermal, Hydraulic and Electric Analysis of superconducting cables) are combined for prediction of the stability of ITER Central Solenoid conductors. The combination of both models allows to predict the effect of any type of magnetic field perturbation in time relevant for the magnet coils during the plasma operation scenario of the reactor. At present there is no experiment to test the stability of the ITER Nb3Sn conductors under such conditions. Only limited experimental data on Minimum Quench Energy (MQE) defining the conductor stability are available but the time and magnetic field amplitude settings are quite different from the actual ITER operating conditions. Nevertheless such tests are useful as a basis to calibrate and benchmark the codes. JackPot+THEA allows to determine the MQE for any magnetic field change in time and to fully describe the involved electromagnetic phenomena on strand level detail in terms of local power dissipation and (peak) electric field. Thermally the computation is still on a global scale identifying the quench initiation and propagation. The predictions from the combined codes are in good agreement with the experiments and provide a solid basis for extrapolative scaling of CICC's stability under plasma operating conditions.

JackPot AC/DC

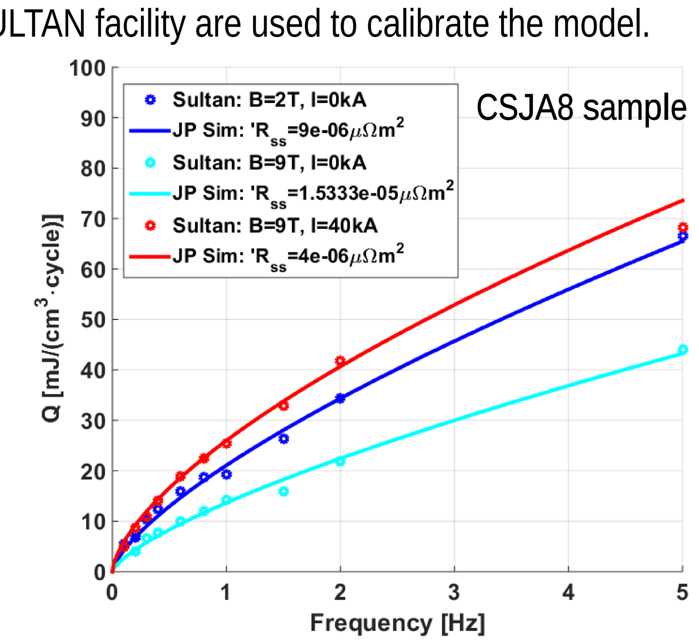
The code Jack-Pot AC/DC is able to reproduce the complete geometry of a full Cable-In-Conduit-Conductor (CICC) and it calculates the trajectories of all the strands (>1000). JackPot creates a network of superconducting and resistive elements, whereby it calculates mutual inductances, contact resistances and coupling with the background field and self-field; all the quantities are obtained from the geometry and the experiments thus there are no free parameters in the model.

AC losses measurements from the SULTAN facility are used to calibrate the model.

CS cable



CSJA8 sample



THEA

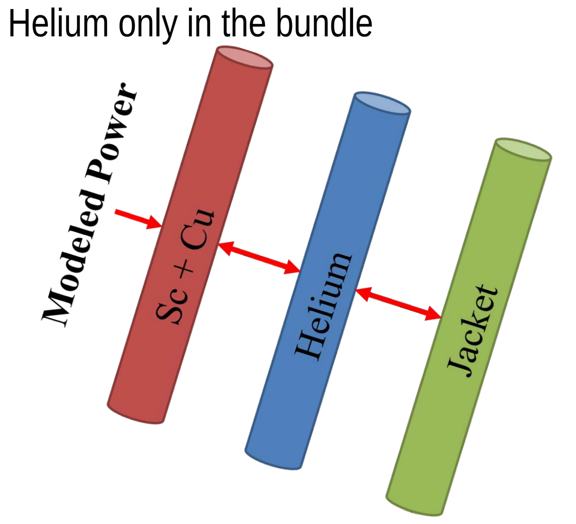
Thermal, Hydraulic and Electric Analysis of Superconducting Cables (THEA) is a 1-D model; it computes the evolution of temperature, coolant flow and current distribution during fast transient like stability perturbations.

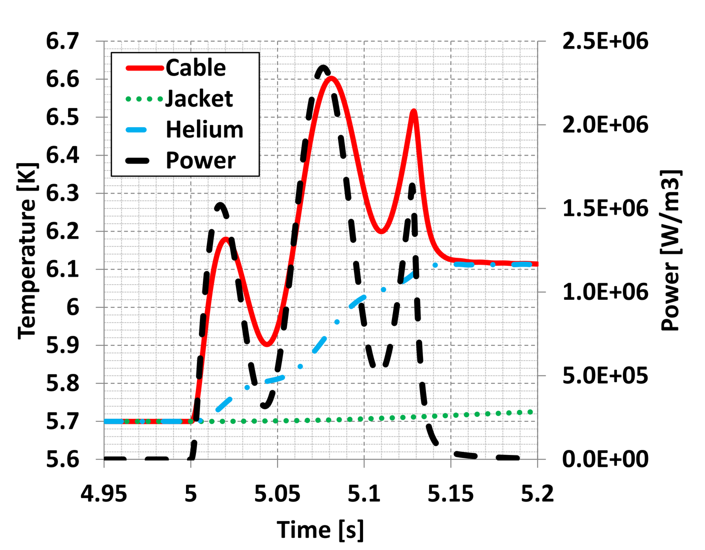
Material components:

- Superconductor (NbTi or Nb3Sn) + Conductor (Cu)
- Jacket: stain-less steel

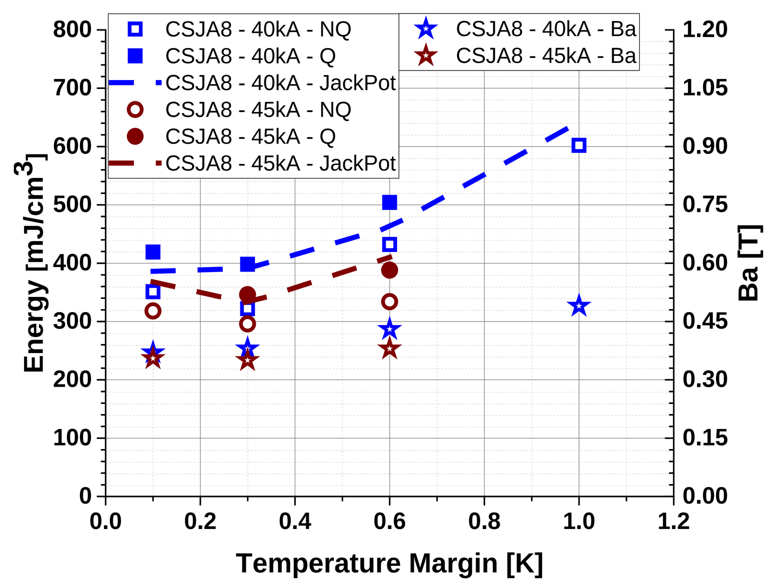
Hydraulics:

- No Helium channel (Sultan sample)
- Helium only in the bundle



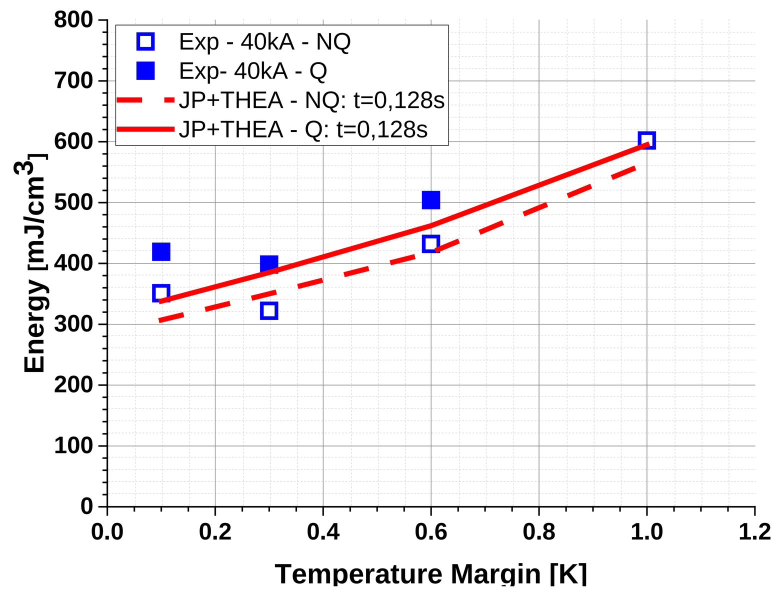


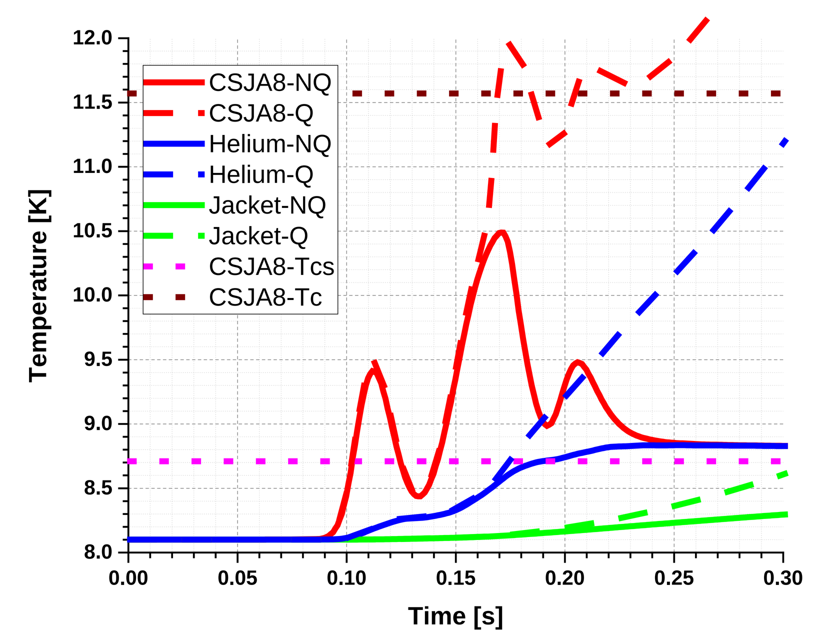
JackPot+THEA simulations compared with SULTAN stability tests



Minimum Quench Energy (MQE) of CS conductor computed by JackPot as a function of the temperature margin. The markers represent the experimental data from the SULTAN tests (open dots indicate recovery, full dots quench) and the dashed lines are the JackPot simulations of the SULTAN test in recovery conditions. On the right the experimental magnetic field pulse amplitude used for JackPor calculation.

MQE of CS conductor as a function of the temperature margin. The square markers represent the experimental data from the SULTAN tests, the red lines are the JackPot+THEA simulation results. The sinewave pulse period is 0.128 s.

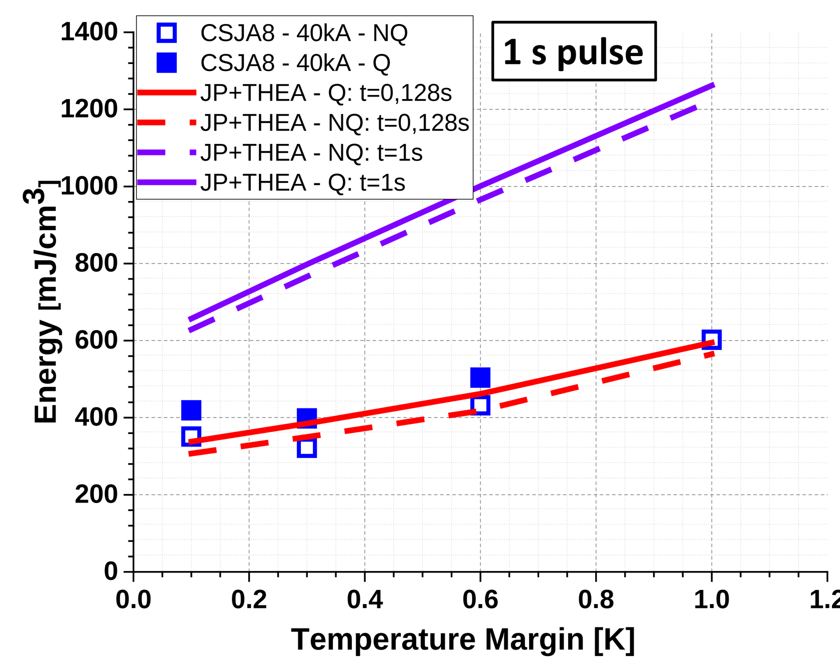


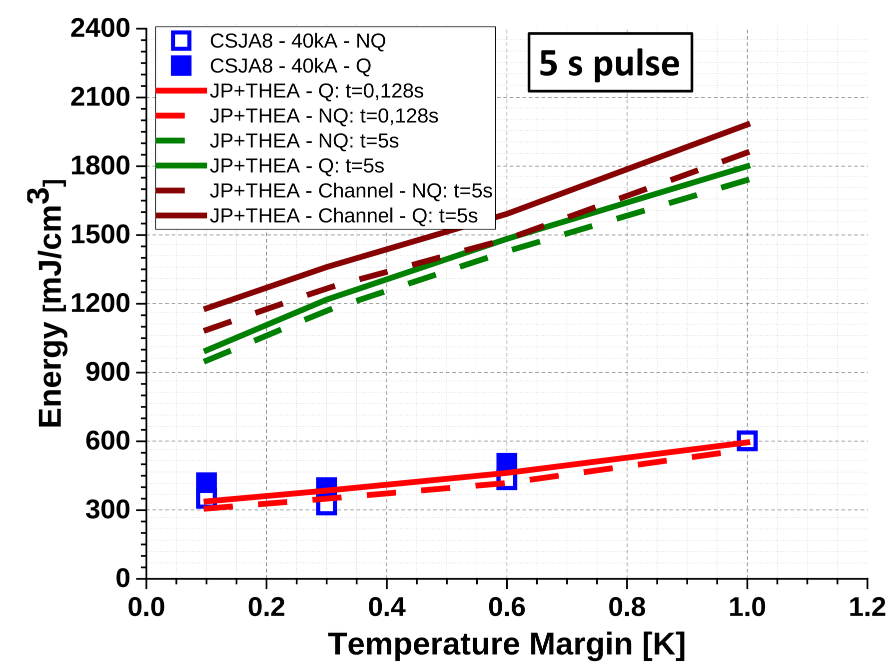


CS temperature profile during JackPot+THEA stability simulations at margin $\Delta T = 0.6\,K$. The solid lines represent the conductor recover, while the dash lines represent the temperature behavior during a quench. The horizontal dash lines are the T_{cs} and the T_c of the CS sample

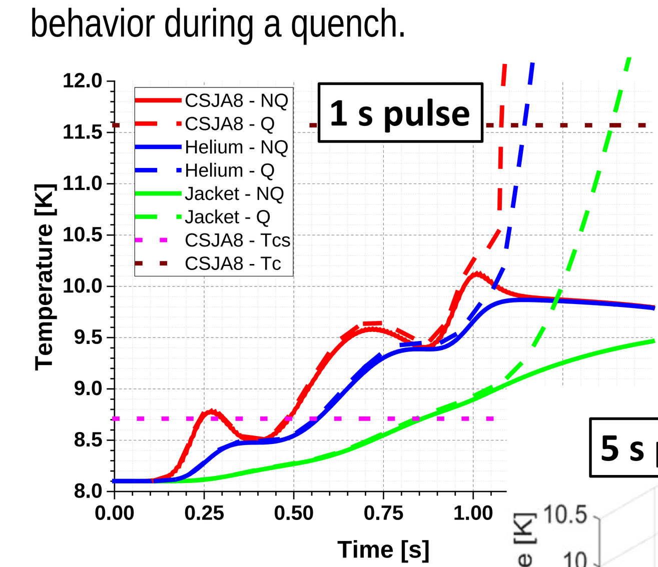
JackPot+THEA stability prediction for the CSJA8 conductor

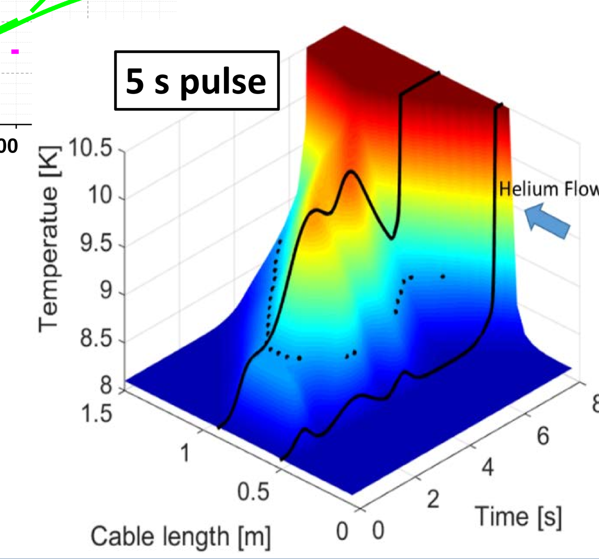
After the successful validation of the model, the stability simulation can be extended to different pulse duration, in order to evaluate the MQE for longer magnetic field disturbances. Two different pulse duration, of 1 s and 5 s, are used for the stability simulations of the CSJA8 conductor as function of the temperature margin between the T_{cs} and the operating temperature of the test. The blue points are the experimental data from SULTAN, the red symbols are the energy values calculated with JackPot+THEA.

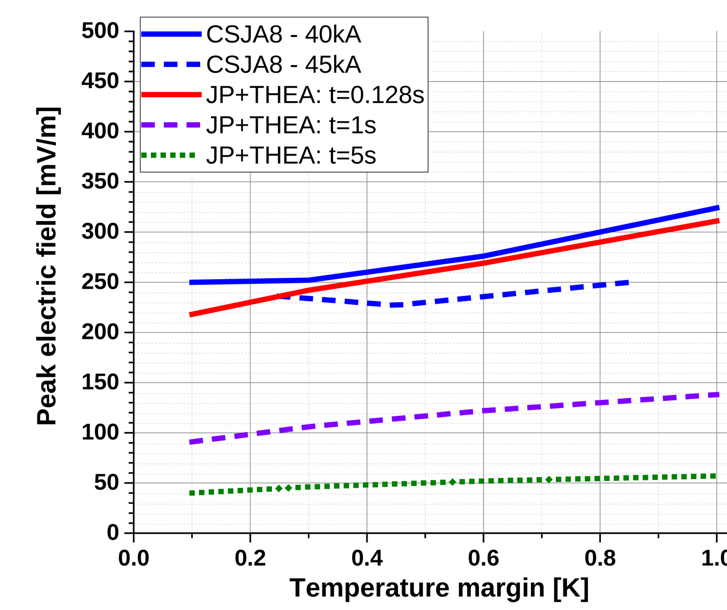




Temperature profiles during stability simulations with t_{pulse} = 1 s and t_{pulse} = 5 s sinewave pulse period, the solid lines represent the conductor recover, while the dash lines represent the temperature behavior during a quench.







Peak electric fields, simulated with JackPot for the CS sample, are compared with JacPot+THEA simulation of the CSJA8 with different pulse period.

Conclusions

•JackPot as stand-alone is capable to estimate the MQE of NbTi CICC conductors. And JackPot+THEA is able to predict the SULTAN MQE experiment for CSJA8 with excellent agreement.

• JackPot+THEA has successfully extrapolated the stability test for the CS conductor at 1 s and 5 s single sinusoidal magnetic field pulses, starting from the SULTAN experimental measurements for fast transient pulse.

•The 5 s slow pulse allows to understand the influence of the central channel for stability purpose. The central channel increase the MQE margin of about 10 %, compared with the simulation without it.

Contacts

Tommaso Bagni

Mail: t.bagni@utwente.nl

Wed-Af-Po3.11-15[180]

MT25
25th International Conference on Magnet Technology
RAI - Amsterdam
August 27 - September 1, 2017