

# the ITER plasma current termination phase: physics constraints on control

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Following recent characterization of the plasma termination phase from a multi-machine database [1], the ITER termination phase is being analyzed, to define uncertainties due to physics assumptions and to deficiencies in the modeling. Considerable modelling and development has been done on ITER termination scenarios, focussing on specific aspects: magnetic control with transport assumptions [2], or particle exhaust control with assumptions on magnetic control [3].

Because of the high nonlinearity in the plasma response, only time-dependent self-consistent simulations can show whether the proposed termination scheme is robust. None of the available time-dependent equilibrium and transport solvers has a complete and extensive physics scope.

However, taken together, these codes offer a wide range of complementary physics models that can be used to identify robust operational ranges for the ITER plasma termination phase.

We know from experiments and from extensive vertical stability analysis with DINA that the plasma cross-section and elongation on ITER need to be reduced with current, while at the same time guiding the plasma downward [2].

However, when physics-based models are used for the heating and current drive sources, it is found that the reduction rate of the plasma cross-section in H-mode and the vertical displacement are constrained by the ability of maintaining RF core heating for impurity control and tracking the  $q=2$  surface for NTM control. Based on these preliminary results, the joint modeling activity is looking into (a) level of impurities and their dynamics (b) impurity seeding (c) density decay rate (d) external power stepping-down. The latter, in particular, needs to be

adjusted taking into account fast ion stability, fast ion acceleration by IC waves, core heating for impurity control and stabilization of NTMs in H-mode, stabilization of ELMs. The goal is to define new limits on the ramp-down schemes that combine long-term known magnetic control constraints for ITER with new constraints imposed by physics-based models, whose availability in time-dependent simulations is progressively becoming available.

[1] P.C. de Vries et al, (2018) Nucl. Fusion 58 026019

[2] Y. Gribov et al, Nucl. Fusion 55 (2015) 073021

[3] F. Koechl et al, Nucl. Fusion 57 (2017) 086023

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