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Power management in ITER for NTM control, the path from the commissioning phase to the demonstration baseline

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Neoclassical Tearing Modes (NTMs) are expected to be metastable in the high beta ITER discharges, and can be triggered by transients like ELMs and sawtooth crashes. Consequently, it is imperative to develop NTM control schemes in order to optimize ITER performance. This work examines the application of ECCD for control of NTMs in ITER plasmas at half-field and full field and taking into account - for the first time in a time-dependent simulation - the time scales of the response of the ITER EC system [1] with respect to the mode evolution. In order to do this, an Extended Rutherford Equation (RE) [2] has been implemented in TRANSP and coupled to a controller for the EC [3]. The extended RE evolves the frequency and the width of the island and it includes the effects of the alignment of the EC deposition with the rational surface. Simulations indicate that the stabilization of the (2,1) mode is particularly challenging, because the mode can grow to a size detectable by the ECE diagnostics and lock on time scales shorter than the response of the power switch between launchers. The contribution of the alignment is therefore critical for assessing the evolution of the (2,1) NTM at its early stages, when the ECCD can be destabilizing if deposited close to the island separatrix. At these early stages, turbulence fluctuations can even help stabilization. When the RE is solved self-consistently by taking into account the nonlinearity of the evolution of the magnetic equilibrium, current and pressure profiles, as they are modified by the ECCD, and tolerance on the alignment with the rational surfaces, simulations indicate that pre-emptive stabilization is the best compromise between minimization of power requirements and optimization of performance and confinement and that up to 5-7 MW of power are needed to sustain an island below locking size. Relaxing the beam width up to 6cm by selection of waveguides might be required for the stabilization of the (2,1) mode in deuterium and D-T plasmas at half-field. In these plasmas, the neutral beam energy sources provide an additional knob to the design of discharges with improved stability, by shortening the sawtooth period up to a factor two and by modifying the NTM island threshold size by 50%. These discharges are therefore well suited for demonstrating NTM control with ECCD at reduced magnetic field and β_N, and to improve robustness of the control schemes, while moving along the path to the demonstration baseline discharge.

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