Optimization of plasma heating efficiency in fusion systems through suppression of energetic particle instabilities

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This study is dedicated to the analysis of the Alfven Eigenmode (AE) stability in nuclear fusion devices, particularly the optimization of the plasma heating efficiency. On that aim, linear and nonlinear simulations are performed with the gyro-fluid FAR3d code that solves a reduced MHD model for the thermal plasma coupled with a gyrofluid model for the energetic particles (EP) species [1]. The AE stability is analyzed in several nuclear fusion devices including the Tokamaks DIII-D, EAST, JT60SA, ITER and CFETR as well as the Stellarators LHD, TJ-II, Heliotron J, CFQS and QPS, identifying the dominant and sub-dominant modes destabilized along the discharges, modeling results validated by comparing simulations and experimental data. Parametric studies are performed to identify the optimal operational regime of the neutral beam injectors (NBI), thermal plasma parameters and magnetic configurations to maximize the AE stability. The simulations identify configurations with improved AE stability if the electron heating closes off the TAE/GAM gap, the beam voltage generates EP causing a weak resonance, the q-profile enhances the continuum damping, the NBI deposition region generates a peak of the EP density profile gradient away from gap locations, between other examples. In addition, the effect of multiple EP populations in reactor relevant plasma is studied, as well as the effect of external actuators on the AE stability as the current drive induced by the NBI, the electron cyclotron current drive (ECCD) and the electron cyclotron heating (ECH). Next, the role of the resonance overlapping, generation of shear flows and zonal currents, transitions from stable to bursting AE activity, AE destabilization by nonlinear energy transfer and feedback effects with pressure gradient driven modes are discussed in the AE saturation phase.

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References

[1] J. Varela et al Nucl. Fusion, **57**, 046018 (2017)