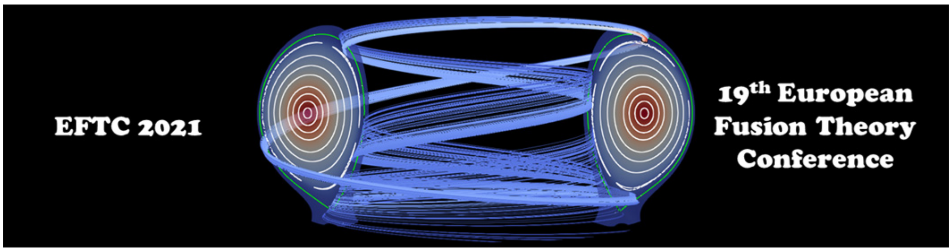

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Fast particles resonance with axisymmetric modes in shaped plasmas

Content

Axisymmetric modes (i.e. with toroidal mode number n=0) destabilized by fast ions have been observed in recent JET experiments [1]. Motivated by these experimental results, we have reconsidered the dispersion relation of macroscopic n=0 vertical displacements in shaped tokamak plasmas. Vertical displacements are normally stable thanks to a combination of passive and active feedback stabilization. Passive feedback stabilization, consisting of currents flowing along the wall and/or in plasma facing components, is required in order to stabilize the ideal instability. Considering the presence of a nearby resistive wall, the n=0 mode dispersion relation is cubic. Under relevant conditions two roots are oscillatory and weakly damped with $\omega \sim e_0^{1/2}\omega_A$, where ω_A is the poloidal Alfvén frequency and the ellipticity $e_0 = (b^2 - a^2)/(b^2 + a^2)$, with b and a major and minor semi-axis of the ellipse describing the plasma boundary. Since $e_0 < 1$, the mode frequency lies below the minimum of the Alfvén continuum, therefore the mode is not affected by continuum damping. The third root is unstable with growth rate related to the wall resistivity. Much work has been done regarding the third unstable root, which can be stabilized with active feedback. However, not enough attention has been given to the two oscillatory roots. In fact, even though these modes are damped by the wall resistivity, due to their oscillatory character they can be driven unstable by resonant interaction with energetic particles. In this work a fully analytic derivation of the cubic dispersion relation for the n=0 modes forms within the so-called reduced ideal MHD model is presented. Thereafter, effects of energetic particles are considered on the basis of the hybrid kinetic-MHD model, where thermal plasma is treated using ideal-MHD, while fast particles are described in terms of the collisionless drift-kinetic equation. The mode-particle resonant condition for these modes is $\omega = p\omega_{b/t}$, where p is an integer number labelling harmonics over particle orbit periodicity and $\omega_{b/t}$ is the bounce (or transit) frequency of magnetically confined fast particles. In order to drive the mode unstable a fast particles distribution function with $\partial F_h/\partial E > 0$ is necessary. It is possible to show that such a distribution function can be obtained considering fast particles losses or a modulation of their source [2-3]. Both trapped and passing particles can resonate. In particular for typical values of for JET and fast particles energy of the order of the MeV, the largest contributions to the mode resonance involve the first harmonic ($p = \pm 1$) for transit particles and the second harmonic ($p = \pm 2$) for trapped particles. The growth rate introduced by the resonant interaction can overcome the damping introduced by wall resistivity. This theory presents a possible explanation to the observed n=0 modes in presence of fast particles, alternative to the one proposed in [1], which involves global Alfvén eigenmodes (GAEs).

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