MHD stability of magnetically confined plasmas in presence of superthermal particles

Synthesis

Axisymmetric modes in elongated plasmas are normally associated with a well-known ideal instability resulting in a vertical shift of the whole plasma column. This vertical instability is stabilized by means of passive feedback consisting of eddy currents induced by the plasma motion in a nearby wall and/or in plasma-facing components. When a thin resistive wall is considered, the n=0 mode dispersion relation can be studied analytically with reduced ideal Magneto Hydrodynamic (MHD) models and is cubic. Under relevant conditions, two roots are oscillatory and weakly damped. These oscillatory modes present Alfvénic frequency and are dependent on plasma elongation and on the relative position of the plasma boundary and of the wall. The third root is unstable and represents the so-called resistive wall mode (RWM). We focus on the two oscillatory modes, dubbed Vertical Displacement Oscillatory Modes (VDOM), that can be driven unstable due to their resonant interaction with energetic ions.
The fast ion drive, involving MeV ions in present days tokamak experiments such as JET, may overcome dissipative and resistive wall damping, setting an instability threshold. The effects of energetic particles are added within the framework of the hybrid kinetic-MHD model. An energetic ion distribution function with $\partial F/\partial E > 0$ is required to drive the instability, achievable with pitch angle anisotropy or with an isotropic distribution in velocity space with regions of positive slope as a function of energy. The latter situation can be achieved by considering losses of fast ions or due to fast ion source modulation. The theory presented here is partly motivated by the observation of saturated n=0 fluctuations in the Joint European Torus (JET), which were initially interpreted in terms of a saturated n=0 Global Alfvén Eigenmode (GAE). Modeling of recent JET discharges using the NIMROD extended-MHD code will be presented, focusing on mode structure and frequency dependence. It is early for us to conclude whether the mode observed at JET is a VDOM rather than a GAE, nevertheless, we discuss the main points of distinction between GAE and VDOM that may facilitate their experimental identification.