Self-consistent interaction of Runaway Electrons and Magneto-hydrodynamic instabilities

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Post-disruption relativistic runaway electrons pose one of the foremost risks to the safe operation of fusion-grade tokamaks and has attracted substantial research efforts in the recent years. The co-evolution of REs and the background plasma MHD is a strongly non-linear process, which can potentially determine the nature of the eventual termination of the RE beam. This work focuses on understanding plasma dynamics in the presence of REs, using analytical approaches and numerical simulations via the non-linear MHD code JOREK. At high RE energies, axisymmetric equilibrium has unique properties different from the force-free equilibrium of a cold thermal plasma. Self-consistent formulations of equilibrium in the presence of REs and the effects of REs on MHD stability will be discussed. On this basis, an RE fluid model has been developed and implemented in JOREK. The model is applied to study several problems of key interest to fusion research and ITER. Three-dimensional simulations of an RE beam termination experiment in JET will be discussed. Our studies reveal that non-linear MHD activity triggered by an unstable n=1 double-tearing mode, can cause global magnetic stochastization leading to fast loss of REs. Dynamics in the simulation are in good agreement with experimental data and the observed RE deposition profiles partly explain the reason for no first-wall damage. Various aspects including the mechanism that causes the shrinking of the non-stochastic plasma core (observed in the experiment) will be discussed. Recent state-of-the-art RE fluid model extensions in JOREK, and ITER benchmarks of vertical displacement events (VDEs) will also be presented.

References

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