Alfvénic instabilities excited by runaways

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The control of runaway electrons (REs) is a pressing issue for ITER, due to their significant potential for damage. In disruption studies on several tokamaks, it has been observed that the generation of a RE beam only occurs above a threshold toroidal magnetic field around 2 T \cite{1, 2}. The origin of this threshold is uncertain, but it has been linked to decreased levels of spontaneous magnetic fluctuations, which appear concurrently with the loss of REs. The presence of these fluctuations thus appears to be instrumental in limiting the RE beam formation in these cases, with the magnetic perturbations scattering the runaway electrons and providing a passive mitigation of the RE beam.

Interestingly, toroidal Alfvén eigenmodes (TAEs) can have frequencies and mode numbers in the same range as the experimental observations \cite{1}. TAE modes, and Alfvénic instabilities in general, can be driven unstable via resonance with a wide variety of energetic ion populations. The electric field which generates REs can also produce a runaway ion population \cite{3}, when the frictional drag due to the drifting electrons does not cancel the electric force. This is the case in the presence of magnetic trapping or impurities with a different charge to that of the ions, the latter being particularly relevant for post-disruption plasmas.

Therefore we describe here general forms for the distributions of both runaway ions and electrons \cite{4}, which have the potential to excite low frequency Alfvénic instabilities in cold, impure plasmas. We consider specifically the conditions under which the species can produce TAE growth and discuss the connection with the experimental observations. Aside from the potential consequences for mitigation, the observation and identification of such instabilities offers a non-intrusive diagnostic for both bulk plasma and fast particle properties in the post-disruption scenario.

This work was part-funded by the RCUK Energy Programme and the European Union’s Horizon 2020 Programme

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