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Resistive Wall Mode Stability Forecasting in NSTX and NSTX-U[1]

JACK BERKERY, Columbia University

Disruption prevention in tokamak fusion plasmas requires accurate identification and prediction of global MHD instabilities. We examine, in the NSTX device and its upgrade NSTX-U, characterization and forecasting of resistive wall modes (RWMs), which are crucial components of disruption event chains. The kinetic RWM growth rate is solved by the MISK code through a dispersion relation combining ideal and kinetic mode energy functionals, δW and δW_K. A model for the ideal $n = 1$ no-wall δW term, depending on parameters measurable in real-time, has been recently developed by using the DCON code on more than 5,000 NSTX equilibria. When applied to NSTX-U discharges at higher aspect ratio, the model accurately predicts the $n = 1$ no-wall limit calculated by DCON through the aspect ratio dependence of the model. Full MISK calculations of δW_K cannot be performed in real time, but a simplified model based on physics insight from MISK takes a form that depends on ExB frequency, collisionality, and energetic particle fraction. The model will examine when the plasma toroidal rotation profile falls into weaker RWM stability regions based upon this kinetic modification to ideal theory, which contains broad stabilizing resonances via mode-particle interaction. This approach enables, for the first time, the ability to anticipate a growing RWM rather than reacting to one. The reduced model results are tested on a database of NSTX discharges with unstable RWMs. For each discharge, a newly-written disruption event characterization code (DECAF) finds the chain of events leading to a disruption by applying criteria that define each of the physical events. With a simple threshold test of mode amplitude an RWM event was found in each case, and 59% were within 20 wall times of the disruption. The earlier RWM warnings are not false positives; they caused significant, transient decreases in β_N.

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