Global Mode Control and Stabilization for Disruption Avoidance in High-β NSTX Plasmas*

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Abstract: Global MHD instabilities may potentially disrupt operation of ITER and other future tokamaks. The National Spherical Torus Experiment (NSTX) has previously investigated passive stabilization and demonstrated active control of resistive wall modes (RWMs), accessing high β_N = 7.2. Current research focuses on greater understanding of the stabilization physics and how it will project to future devices, quantitative comparison to experiment, and demonstration of improved active control techniques that can reduce disruptions in those devices. This work advances the understanding necessary to aid the goal of disruption avoidance in ITER. Combined radial and poloidal field sensor feedback gain and phase were used in NSTX experiments to produce a greater than three times reduction in disruption probability. Time domain analysis of active control with the VALEN code reproduces the experimental dynamics of the mode amplitude as a function of feedback phase and determines the optimal gain. Additionally, a new model-based RWM state space controller proposed for ITER, which includes a 3D model that compensates for plasma and mode-induced wall currents, was used. Open-loop comparisons between sensor measurements and the state space control model showed agreement with a sufficient number of states and improved agreement when details of the 3D wall model (including NBI ports) were added. The state space controller was demonstrated to sustain long pulse, high β_N discharges, and successfully reduced n = 1 applied fields that normally disrupt the plasma. Present calculations of kinetic stability using the MISK code show improved quantitative agreement with NSTX experimental marginal stability points at very high β_N ~ 6, and ratio of β_N/l_i exceeding 13 (where l_i is internal inductance) and emphasizes the importance of the plasma rotation profile. Collisions have competing effects: they both dissipate the mode energy and damp the stabilizing kinetic effects. The low collisionality of future machines, such as NSTX-U, can improve RWM stability, but only if the plasma rotation is in a favorable resonance. Energetic particles have been shown to be generally stabilizing, and scaling of the model to ITER high performance discharges indicates that the stabilizing effects of alpha particles will be required to maintain a stable RWM across a range of expected plasma rotation profiles. Alterations to the theory now focus on improved agreement with experiment over the entire database. One such alteration is the inclusion of anisotropic distribution functions for thermal or energetic particles from neutral beam injection.

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