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Characterization and Forecasting of Unstable Resistive Wall Modes in NSTX and NSTX-U

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A comprehensive approach to the prevention of disruption of fusion plasmas in tokamaks begins with identifying disruption event chains and the specific physics elements which comprise those chains. Then, if the events in the disruption chains can be forecast, cues can be provided to an avoidance system to break the chain. Within this framework, we examine the characterization and forecasting of unstable resistive wall modes (RWMs) in the NSTX tokamak and its upgrade NSTX-U. For forecasting purposes, one can examine when the plasma toroidal rotation profile falls into a weaker RWM stability region based upon kinetic stability theory. The MISK code solves for the growth rate of the RWM through a dispersion relation dependent on the changes in potential energy, deltaW. A model for the ideal no-wall deltaW term which depends on parameters that can be measured in real-time has been recently computed. For the kinetic deltaWK term, full MISK calculations cannot be performed in real time, but a simplified model calculation based on physics insight from MISK takes a form that depends on ExB frequency, collisionality, and energetic particle fraction. The reduced model results are tested by analysis performed on a database of 44 NSTX discharges with unstable RWMs. For this analysis, we have created the Disruption Event Characterization and Forecasting (DECAF) code. For each discharge, the code finds the chain of events leading to a disruption by applying criteria that define each of the physical events. With a RWM poloidal sensor amplitude threshold of 30G the RWM warning was found in each case, typically near the disruption limit. Other events detected in all discharges were failure to meet plasma current request, loss of wall proximity control, and low edge safety factor warnings. Loss of vertical stability control was present in most discharges, as was pressure peaking, which did not cause RWMs, typically occurring with or after them. In 59% of the cases, the RWM event occurred within 20 wall times of the disruption. Additionally, the RWM warnings that occurred earlier were not false positives; they caused significant temporary decreases in betaN. The DECAF code analysis of RWM-induced disruptions is under active development, including improved approaches in determining event causality. *Supported by US DOE Contracts DE-FG02-99ER54524 and DE-AC02-09CH11466.

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