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Disruption Event Characterization and Forecasting in Tokamaks

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Disruption prediction and avoidance is a critical need for next-step tokamaks such as ITER, as disruptions can place significant thermal heat loads and electromagnetic forces on the device and can potentially lead to damage from runaway electrons. Meeting these challenging goals with the high reliability required for ITER and future tokamaks requires multiple approaches, including an understanding of the connection between events leading to disruptions, and the ability to forecast such events. The Disruption Event Characterization and Forecasting Code (DECAF) is used to fully automate analysis of tokamak data to determine chains of events that lead to disruptions and to forecast their evolution. Disruption event chains related to global MHD instabilities, tearing modes, and many other off-normal events are identified. In an NSTX database exhibiting global MHD modes, resistive wall mode (RWM) and loss of boundary control events are found in all cases and vertical displacement events are found in over 90% of cases. Analysis shows 61% of RWM events occur within 20 conducting wall current diffusion times of the disruption. The remainders occurring earlier in time indicate minor disruptions. Insights are gained on the connection of mode activity to other events, including high Greenwald density fraction. Maximum amplitude of toroidal mode number n = 1 magnetic perturbations reached during disruptions and scaling with key parameters, important for ITER, are evaluated. Automated analysis of rotating tearing modes produce physical event chains leading to disruptions through mode slowing and subsequent locking. Analysis of NSTX and NSTX-U plasmas shows that the duration between mode bifurcation and locking varies with plasma conditions and can be shorter than the duration between mode locking and disruption onset. Global MHD instabilities such as external kink/ballooning modes or RWMs give the least amount of warning time before disruption. Kinetic RWM theory has shown high success in determining experimental mode marginal stability. A time-dependent reduced physics model of kinetic stabilization was created to forecast instability-induced disruptions. The initial model predicts instability 84% of the time for experimentally unstable cases with a relatively low false positive rate. *Supported by U.S. DOE grants DE-FG02-99ER54524, DE-SC0016614, and DE-AC02-09CH11466

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