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Progress on Tokamak Disruption Event Characterization and Forecasting Research and Expansion to Real-Time Application

Disruption prediction and avoidance is critical in ITER and reactor-scale tokamaks to maintain steady plasma operation and to avoid damage to device components. The present status and results from the disruption event characterization and forecasting (DECAF) research effort are shown. The DECAF paradigm is primarily physics-based and provides quantitative disruption forecasting for disruption avoidance. DECAF automatically determines the relation of events leading to disruption and quantifies their appearance to characterize the most probable and deleterious event chains, and also to forecast their onset. The code has access to data from multiple tokamaks (KSTAR, MAST, NSTX, AUG, TCV, DIII-D) to best understand and validate models and compare results between them. Present analysis of KSTAR, MAST, and NSTX databases shows low disruptivity paths to high beta operation. The disruptivity does not increase at high normalized beta, β_N, as is often mistakenly expected. Automated analysis of rotating MHD modes allows the identification of disruption event chains for several devices including coupling, bifurcation, locking, and potential triggering by other MHD activity. DECAF can now provide an early disruption forecast (on transport timescales) allowing the potential for disruption avoidance through profile control. Disruption prediction research using DECAF also allows quantifiable figures of merit (i.e. the plasma disruptivity) to provide an objective assessment of the relative performance of different models. This allows an assessment of how well the predictor performs to compare to ITER needs. The DECAF object decomposition is directly used to produce a warning level for MHD activity shown to provide an early warning forecast (~ 300 ms) for mode locking and subsequent disruption in KSTAR, potentially allowing active profile control to avoid the mode. There is an extensive physics research effort supporting DECAF model development. For example, analysis of high performance KSTAR experiments using TRANSP shows non-inductive current fraction has reached 75%. Resistive stability including Δ'calculation by the Resistive DCON code is evaluated for these plasmas. "Predict-first"TRANSP analysis was performed showing that with the newly-installed 2nd NBI system (assuming usual energy confinement quality and Greenwald density fraction), 100% non-inductive plasmas scenarios are found in the range β_N = 3.5–5.0, adding a novel regime for disruption prediction studies. Real-time DECAF analysis is now being constructed for KSTAR. The first of several real-time computers and diagnostic interfaces has been installed to detect and decompose rotating MHD activity in the device. Offline DECAF analysis of the acquired real-time signals during MHD shows that the mode decomposition and DECAF object decomposition replicates the local KSTAR spectrogram analysis.Supported by US DOE Grants DE-SC0016614 and DE-SC0018623.

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