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

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Disruption prediction and avoidance is critical for ITER and reactor-scale tokamaks to maintain steady plasma operation and to avoid damage to device components. Physics-based disruption event characterization and forecasting (DECAF) research determines the relation of events leading to disruption, and forecasts event onset. The analysis has access to data from multiple tokamaks to best understand, validate, and extrapolate models. Recent code improvements allow fully automated analysis spanning an entire device run campaign or even the entire device database. Significant new hardware and software for real-time data acquisition and DECAF analysis are being installed on the KSTAR superconducting tokamak. Real-time magnetics, electron temperature, T_e, profiles from electron cyclotron emission (ECE), 2D T_e fluctuation data from ECE imaging, and velocity and T_i profiles show excellent agreement with offline data/analysis. An MHD mode locking forecaster has been developed for off-line and real-time use using a torque balance model of the rotating mode. Early warning forecasts on transport timescales potentially allow active profile control to avoid the mode lock. Mode stability alteration by ECCD is examined and recent experiments have shown the ability to avoid mode lock-induced disruption by applying rotating 3D fields. Innovative counterfactual machine learning is used to examine hypothetical RWM stabilization scenarios with rotating MHD. An ELM identification event module includes the ability to distinguish localized and global MHD events. Fully non-inductive current scenarios in KSTAR are examined by "predict-first" analysis of already highly (~75%) non-inductive plasmas. Resistive stability analysis including Δ' computed by DCON is evaluated with comparison to experiment examining sensitivity to localized variations of kinetic equilibrium reconstructions of the q profile using MSE magnetic pitch angle data.
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