Data-driven predictive modeling of major disruptions and unstable event identification across multiple tokamaks

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In this presentation, through dedicated numerical experiments on C-Mod, DIII-D and EAST, we demonstrated our most recent progress on data-driven methods for disruption prediction and disruption precursor identification. A large family of data-driven disruption prediction algorithms are being developed, and their performance typically exceeds physics-based models.[1-3] However, most data-driven disruption prediction models lack the ability of identifying disruption precursors, and such information is extremely relevant for plasma operators in order to implement possible avoidance strategies. This contribution presents two recent results to tackle this problem. Firstly, an integrated deep-learning model combining a disruptivity warning with the prediction of several unstable precursors will be presented. Such unstable events include rotating modes, locked modes, H-to-L back transitions, and radiative collapses: their detection is based on a manually labelled unstable event database of DIII-D experimental data. Cross-machine disruption prediction numerical studies using this new integrated model demonstrate the improved cross-machine accuracy and an extended warning time. This contribution will then further focus on one of the most important disruption precursors i.e., the n=1 tearing mode (TM) onset.[4-5] An empirical boundary for the n=1 TM is developed via data-driven methods and verified on thousands of DIII-D discharges. The fitted boundary is a linear function of plasma equilibrium parameters. The boundary indicates a value related to the probability of having the TM onset within 200 ms, and it achieves ~85% of shot-by-shot accuracy in offline analysis of DIII-D data. Preliminary cross-machine analysis of TM onset prediction shows potential applicability of the empirical boundary to C-Mod and EAST data as well, but the relative importance of the individual parameters is different for different devices. This suggests the existence of different trigger mechanisms for the TMs, implying that the boundary could be generalized using data from different tokamaks representing different trigger mechanisms to improve its extrapolability. Finally, this new proximity metric to the n=1 TM onset has been incorporated into the real-time in DIII-D plasma control system and results from real-time experiments will be discussed.

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