Contribution ID: **147** Type: **Invited**

Interpretable data-driven disruption predictors to trigger avoidance and mitigation actuators on different tokamaks

Data-driven models for disruption prevention are being developed across many different experimental devices currently in operation and with the aim of designing viable solutions to prevent disruptions on next-generation devices. Many current machine learning approaches lean towards interpretable predictive algorithms to guarantee a seamless integration with the plasma control system (PCS) and the available actuators to trigger avoidance and ultimately mitigation procedures.

As an example, the Disruption Prediction via Random Forest (DPRF) algorithm is currently integrated in both DIII-D [1] and EAST PCS. DPRF provides predictions of impending disruptions in real-time, while simultaneously identifying the drivers of the disruptivity through local measures of interpretability, i.e. feature contributions. Performances on both devices show compatibility with real-time constraints as predictions and interpretations are computed in less than 200 microseconds. On DIII-D, DPRF was upgraded including real-time calculations of profile-based indicators of temperature, density and radiation. Such peaking factors prove to be relevant metrics in impurity accumulation events leading to disruptions in scenarios close to ITER baseline, providing a warning more than 1s prior to the disruption. The successful integration of DPRF in DIII-D PCS is part of a broader approach, the "Disruption Free Protocol"[2], to qualify advanced disruption prevention strategies to address ITER's critical needs. On EAST, DPRF was trained using high-density disruptive data, and during closed-loop experiments it has shown to be capable of predicting such cases, and trigger the mitigation system with relevant accuracy.

Data-driven models can potentially be an integral part of device protection system for ITER and the next generation of devices, but only if able to demonstrate optimal predictive capabilities and the possibility to reconcile the predictions with the underlying physics dynamics. This contribution will detail advancements of interpretable data-driven algorithms for disruption prevention across different tokamaks and in response to ITER needs. It is extremely important to develop tools capable of identifying and informing in real-time the PCS on the dangerous plasma parameters deviations to the disruptive space, in order to enable the proper actuators'response.

[1] C. Rea et al 2019 Nucl. Fusion 59 096016
[2] J. Barr et al IAEA-FEC 2020

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Track Classification: Prediction and Avoidance