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Predict-First Analysis and Experimental Validation of MHD Equilibrium, Stability, and Plasma Response to 3D Magnetic Perturbations

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An integrated-modeling workflow has been developed to predict equilibria and response to 3D magnetic perturbations in tokamak experiments. Starting from an equilibrium reconstruction from a past experiment, the workflow couples together the EFIT Grad-Shafranov solver, EPED model for pedestal stability, and NEO drift-kinetic-equation solver (for bootstrap current calculations) in order to generate equilibria with self-consistent pedestal structures as the plasma shape and various scalar parameters (e.g., normalized beta, pedestal density, q_{95}) are changed. These equilibria are then analyzed using automated M3D-C1 to compute the MHD plasma response to 3D magnetic perturbations. The workflow was created in conjunction with a DIII-D experiment studying the effect of triangularity on plasma response, showing excellent agreement between the analysis of the workflow's equilibria and equilibria reconstructed from the experiment. Various versions of the workflow demonstrated that the details of the edge current profile were not important for these cases, while q_{95} and the details of the global pressure profile had a significant impact on the results. A predict-first study was then carried out for a DIII-D experiment examining how plasma response varies between single- and double-null shapes. The predicted equilibria were used to guide experimental planning and the predicted response was found to agree well with the perturbed magnetic field measured on the high-field-side midplane. Applications of this workflow to KSTAR and EAST experiments will also be explored. This work forms the basis of predictive scenario development across current and future devices (e.g., ITER), allowing for higher-fidelity predictions of MHD stability and 3D plasma response.

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