Development of a hybrid kinetic-MHD equilibrium solver for runaway electron plateau modeling

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Predictive runaway electron (RE) mitigation modeling is essential to safeguard the first walls of planned high-current tokamaks such as ITER. Modeling a post-disruption RE beam requires the self-consistent coupling of a full distribution function for the kinetic-REs and a magnetohydrodynamic (MHD) cold background plasma. This work couples the Kinetic Orbit Runaway electron Code (KORC) with NIMROD's MHD equilibrium solver resulting in a hybrid kinetic-RE-MHD quasi-static state. A RE beam is initialized by drawing particles from a user-defined initial distribution utilizing a Metropolis-Hastings algorithm ported from KORC [1]. RE drift and magnetization currents are computed via a guiding center orbit-averaging method with samples taken at regular kinetic time steps. These RE currents are then expressed in terms of NIMROD's finite element (FE) basis functions by a weighted deposition scheme onto the FE mesh. The RE beam current ($\boldsymbol{J}_{RE}$) is coupled with the cold bulk plasma by a Picard iterative process in which NIMROD's Grad-Shafranov solver uses $\boldsymbol{J}_{RE}$'s parallel component as an input. The resulting framework is flexible and allows for subsequent RE plateau modeling improvements, such as the inclusion of toroidal loop voltage and collisional effects. This framework lays the foundation for the time-dependent two-way coupling of KORC and NIMROD.

[1] Beidler et al., Phys. Plasmas **27**, 112507 (2020)