Physics-based Control-oriented Modeling of the Current Density Profile Evolution in NSTX-Upgrade

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Active control of the toroidal current density profile is among those plasma control milestones that the National Spherical Tokamak eXperiment - Upgrade (NSTX-U) program must achieve to realize its next-step operational goals characterized by the high-performance, MHD-stable plasma operation with neutral beam heating, and longer pulse durations. Motivated by the coupled, nonlinear, multivariable, distributed-parameter plasma dynamics, the first step towards feedback control design is the development of a physics-based, control-oriented model for the current profile evolution in response to non-inductive current drives and heating systems. The evolution of the toroidal current density profile is closely related to the evolution of the poloidal magnetic flux profile, whose dynamics is modeled by a nonlinear partial differential equation (PDE) referred to as the magnetic-flux diffusion equation (MDE). The proposed control-oriented model predicts the spatial-temporal evolution of the current density profile by combining the nonlinear MDE with physics-based correlations obtained at NSTX-U for the electron density, electron temperature, and non-inductive current drives (neutral beams). The resulting first-principles-driven, control-oriented model is tailored for NSTX-U based on the predictions of the time-dependent transport code TRANSP. Main objectives and possible challenges associated with the use of the developed model for the design of both feedforward and feedback controllers are also discussed.

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