NONLINEAR SLIDING MODE CONTROL OF THE CURRENT DENSITY PROFILE IN TOKAMAKS

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Research on fusion plasmas in tokamaks has led to the insight that the poloidal magnetic-flux distribution within the plasma has a crucial impact on its performance. Achieving certain types of poloidal magnetic-flux profiles, or alternatively certain types of q profiles, leads to resilience against undesirable instabilities and to higher bootstrap-current fractions, which in turns favor steady-state operation. To reliably and repeatedly achieve a desired q profile, feedback control is needed. Extensive work has been recently going on towards the development of q-profile feedback controllers. The nonlinearity of the plasma and the coupling between magnetic and kinetic variables demand a model-based control approach based on the magnetic-flux diffusion equation (MDE). The MDE is a nonlinear partial differential equation (PDE) modeling the time evolution of the poloidal magnetic-flux profile, and therefore of the q profile. Due to the complexity of the MDE, much of the previous work in this area used a linearized version of it for control design. While linear control approaches proved themselves effective in experiments, there is potential for improved performance by avoiding linearization and using the knowledge embedded in the nonlinear model to its fullest extent. One of the challenges associated with the design of model-based nonlinear q-profile feedback controllers arises from the fact that the model is non-affine in control, i.e. the q-profile dynamics depend nonlinearly on the control inputs (e.g., total plasma current and H&CD powers). In this work, we develop and test in simulations a nonlinear sliding mode controller for q-profile regulation that takes into account all the nonlinearities of the model. Assessment of the robustness of the proposed controller against unmodeled dynamics and perturbations, which is in general an advantageous characteristic of sliding mode controllers, is also part of this work.

This work has been supported by the US Department of Energy under DE-SC0010661.