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Integrated Robust Control of the Global Toroidal Rotation and Total Plasma Energy in Tokamaks

Content

In a tokamak, several coupled control problems need to be solved simultaneously by means of a limited number of actuators. Moreover, the relative priority of the control objectives, as well as the availability of the actuators, may change throughout a plasma discharge depending on the plasma state and machine operating conditions. Therefore, future plasma control systems will require integrated architectures in which multivariable controllers are managed by real-time supervisory systems with actuator management capabilities. In the present work, the problem of simultaneously regulating the global toroidal rotation (Ω_ϕ) and total plasma energy (W) is tackled. These two zero-dimensional variables, Ω_ϕ and W, depend on the ion toroidal rotation and electron temperature profiles, respectively. Both Ω_ϕ and W also depend on the electron density and safety factor profiles. The actuation methods considered are co-current and counter-current neutral beam injection. A nonlinear, robust controller that makes use of Lyapunov redesign techniques is synthesized based on zero-dimensional, simplified, heuristic models of the Ω_ϕ and W dynamics. In addition, an actuator management scheme is designed to handle variations in the control priorities and availability of the neutral beam injectors. The actuator manager solves an optimization problem in real time in order to find the most appropriate course of action when unexpected changes occur. The integrated control architecture is tested for a DIII-D scenario by means of the one-dimensional code COTSIM (Control-Oriented Transport Simulator), which predicts the time evolution of the electron temperature profile, electron density profile, ion toroidal rotation profile, and safety factor profile.

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