SIMSERVER SIMULATION OF MODEL-BASED CURRENT PROFILE CONTROLLERS IN THE DIII-D PLASMA CONTROL SYSTEM

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Setting up a suitable current profile, characterized by a weakly reversed magnetic shear, has been demonstrated to be a key condition for one possible advanced scenario with improved confinement and possible steady-state operation. Active feedback control of the evolution of $q(0)$ and q_{min} during the initial phase of the discharge has been already demonstrated at DIII-D changing the plasma conductivity through electron heating, and therefore modifying the rate of relaxation of the current profile [1]. The q profile is obtained in real time from a complete equilibrium reconstruction using data from the motional Stark effect (MSE) diagnostic. The controller requests a power level to the actuator (electron cyclotron heating (ECH) or neutral beam injection (NBI)), which is equal to preprogrammed feed-forward value plus the error in q times a proportional gain (non-model-based P controller). Present limitations of this controller (oscillations and instability) motivate the design of a model-based controller that takes into account the dynamics of the q profile response to the different actuators. Experiments at DIII-D focus on creating the desired current profile during the plasma current ramp-up and early flattop phases with the aim of maintaining this target profile during the subsequent phases of the discharge. Since the actuators that are used to achieve the desired current profile are constrained by physical limitations, experiments have shown that some of the desirable target profiles may not be achieved for all arbitrary initial condition. Therefore, a perfect matching of the desirable target profile may not be physically possible. In practice, the objective is to achieve the best possible approximate matching in a short time window during the early flattop phase of the total plasma current pulse. Thus, such a matching problem can be treated as a finite-time optimal control problem for a nonlinear partial differential equation (PDE) system (the evolution in time of the current profile, or alternatively q, is related to the evolution of the poloidal flux, which is modeled in normalized cylindrical coordinates using a PDE usually referred to as the magnetic flux diffusion equation). A control-oriented model of the current profile evolution in DIII-D was recently developed for the plasma current ramp-up and early-flattop phases [2], and used to synthesize both open-loop [3] and closed-loop [4] control schemes. In this work, we report on the implementation of these advanced model-based current profile controllers in the DIII-D PCS (Plasma Control System) and on the assessment of these controllers in Simserver simulations. The magnetic diffusion equation is implemented in Simserver with the ultimate goal of simulating the time evolution of the plasma current profile in response to the active controllers running in the DIII-D PCS.

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