MULTIVARIABLE MODEL-BASED SHAPE CONTROL FOR THE NATIONAL SPHERICAL TORUS EXPERIMENT (NSTX)

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Magnetic control in tokamaks refers to controlling the magnetic fields, which maintain or change the plasma position, shape and current. This task is performed by a set of poloidal field coils distributed around the vessel that contains the plasma. Highly shaped plasmas are required to operate at high plasma pressure and fusion efficiency. In addition, the achievement of certain types of plasma shapes can reduce the virulence of instabilities induced by the high plasma pressure. Therefore, the plasma shape requirements in a practical, highly-efficient tokamak are very stringent. The extreme shapes that must be achieved, intrinsic instability in the plasma vertical position (the more shaped the plasma, the more unstable its vertical position is), large number of control inputs (coil voltages) and control outputs (position and shape geometrical parameters, total plasma current), and demanding regulation requirements make this problem very challenging. Recently, the demanding plasma shape control requirements for ITER have motivated researchers to improve the modeling of plasma response as well as the design of feedback controllers (see [1] and references therein). The strong coupling between the different geometrical parameters describing the shape of the plasma calls for a model-based, multivariable approach to obtain improvements in closed-loop performance. The recent implementation of the real-time equilibrium reconstruction code rtEFIT [2] on NSTX allows plasma shaping by controlling the magnetic flux at the plasma boundary. A non-model-based, empirically-tuned, single-input-single-output (SISO), PID-based shape controller that exploits this capability has been recently proposed [3]. Alternatively, we present a robust model-based multi-input-multi-output (MIMO) controller to provide real-time shaping and position control in the presence of disturbances and uncertainties in the plasma parameters. The control design is based on linear plasma response models derived from fundamental physics assumptions. The system composed of plasma, shaping coils, and passive structure can be described using circuit equations derived from Faraday's Law, and radial and vertical force balance relations for a particular plasma magnetohydrodynamic (MHD) equilibrium. In addition, rigid radial and vertical displacement of the equilibrium current distribution can be assumed, and a resistive plasma circuit equation can be specified. The result is a circuit equation describing the linearized response, around a particular plasma equilibrium, of the conductor-plasma system to voltages applied to active conductors [4]. Computer simulation results illustrate the performance of the proposed robust model-based shape controller in comparison with the present non-model-based controller.

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