INTEGRATED PLASMA CONTROL FOR ADVANCED TOKAMAKS*

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Advanced tokamaks[1] are distinguished from conventional tokamaks by their high degree of shaping, achievement of profiles optimized for high confinement and stability characteristics, and active stabilization of MHD instabilities to attain high values of normalized beta and confinement. These high performance fusion devices thus require accurate regulation of the plasma boundary, internal profiles, pumping, fueling, and heating, as well as simultaneous and well-coordinated MHD control action to stabilize such instabilities as tearing modes and resistive wall modes. Satisfying the simultaneous demands on control accuracy, reliability, and performance for all of these subsystems requires a high degree of integration in both design and operation of the plasma control system in an advanced tokamak. These requirements become even more critical in an advanced tokamak operating in a burning plasma regime. The present work describes the approach, benefits, and progress made in integrated plasma control with application examples drawn from the DIII-D tokamak and the ITER design. The approach includes construction of plasma and system response models, validation of models against operating experiments, design of integrated controllers which operate in concert with one-another as well as with supervisory modules, simulation of control action against offline and actual machine control platforms, and iteration of the design-test loop to optimize. Final implementation and machine operation can thus be done with a high degree of confidence in performance and reliability even before full experimental testing. Required levels of robustness to model uncertainties and off-normal events can be quantified and incorporated in the design process.

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[1] Humphreys, D.A., *et al.*, “Design of a Plasma Shape and Stability Control System for Advanced Tokamaks,” Proc. 18th Symp. on Fus. Technol., Karlsruhe, Germany, August 1994, **1** (Elsevier Science Publishers B.V., Amsterdam, 1995) 731.