ADVANCED TOKAMAK OPERATION USING THE DIII–D PLASMA CONTROL SYSTEM*

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The principal focus of experimental operations in the DIII-D tokamak is the advanced tokamak [1] regime, which will require highly integrated and flexible plasma control to achieve. In a high performance steady-state advanced tokamak, accurate regulation of the plasma boundary, internal profiles, pumping, fueling, and heating will need to be well coordinated with MHD control action to stabilize such instabilities as tearing modes and resistive wall modes. Sophisticated monitors of the operational regime must provide detection of off-normal conditions and trigger appropriate safety responses with acceptable levels of reliability. Many of these capabilities are presently implemented in the DIII–D plasma control system (PCS), and are now in frequent or routine operational use. The present work describes recent development, implementation, and operational experience with AT regime control elements for equilibrium control, MHD suppression, and off-normal event detection and response. The highly flexible DIII–D PCS allows rapid development and testing of such subsystems, and is also in use at both NSTX and MAST.

A central characteristic of AT plasma regimes is the strongly shaped plasmas which must be accessed and the high degree of accuracy with which they must be regulated. The DIII–D isoflux shape control system [2] has demonstrated that it can produce a wide range of shapes including AT-relevant high triangularity, high elongation, double- and single-null diverted configurations. Density has been controlled by regulation of pumping via strikepoint placement relative to pumping plenums. Beam power regulation has allowed fine control of stored energy, and impurity gas puffing has been regulated to control radiated power.

Another key characteristic of the AT regime is active suppression of MHD instabilities. The DIII–D PCS has stabilized the neoclassical tearing mode (NTM) by controlling the relative location of gyrotron ECCD deposition and the mode islands. This suppresses the modes by replacing the "missing" bootstrap current that characterizes the instability. PCS algorithms for feedback control of nonaxisymmetric radial field coil currents based on measurements of n=1 magnetic signals have stabilized the resistive wall mode (RWM) beyond the no-wall β-limit.

Because AT plasmas operate close to stability limits in order to yield high efficiencies, off-normal events can conceivably produce large excursions from the operating point and result in uncontrollable instability. Monitors have been developed to detect the impending onset of such instabilities and take corrective or mitigating action. The use of such monitors has allowed recognition and early termination of discharges with performance-limiting instabilities, as well as triggering of high-pressure gas injection to almost completely mitigate disruption effects.

[1] D.A. Humphreys, 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.
[2] J.R. Ferron, et al., Nucl. Fusion **38** (1998) 1055.

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