Control of MHD Stability in DIII-D Advanced Tokamak Discharges*

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The advanced tokamak program seeks to optimize the tokamak approach for fusion energy production. Attractive tokamak based power systems are characterized by high power density and steady-state operation with low recirculating power. Such plasmas require reliable operation at high normalized beta near the MHD stability limit, and therefore a high degree of active MHD stability control. The DIII–D advanced tokamak program has made significant progress in control of the resistive wall mode and reliable operation above the no wall stability limit, active feedback control of neoclassical tearing modes allowing a significant increase in beta, control of the temperature and current profiles to obtain stable high performance, high bootstrap fraction plasmas, and successful mitigation of disruptions.

The large bootstrap fraction needed for steady state operation leads to broad current density profiles, which require wall stabilization of the ideal kink mode at high beta. DIII-D experiments have sustained beta values well above the no-wall limit with strong plasma rotation and feedback-controlled reduction of magnetic field asymmetries. Internal control coils installed this year are predicted to allow operation up to the ideal-wall stability limit at low plasma rotation through direct feedback stabilization. Stabilization of neoclassical tearing modes has been achieved through replacement of the missing bootstrap current with electron cyclotron current drive. DIII-D experiments have demonstrated NTM suppression with precise feedback control of the current drive position by variation of the plasma position or toroidal field. Modification of the current density profile evolution with feedback control of the local electron temperature by electron cyclotron heating has recently been demonstrated, as a first step toward detailed profile control. Disruption mitigation by injection of a high-pressure gas jet leads to a radiative thermal quench and rapid current decay, reducing runaway electrons, thermal loads, and electromagnetic forces. Real-time detection of off-normal conditions has been successfully used to trigger such a controlled termination.

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