High Performance Integrated Plasma Control in DIII–D*

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The DIII-D mission to explore the advanced tokamak (AT) regime places significant demands on the DIII-D plasma control system (PCS) [1], including simultaneous and highly accurate regulation of plasma shape, stored energy, density, and divertor characteristics, as well as coordinated suppression of MHD instabilities. To satisfy the control demands of AT operation, we apply the integrated plasma control method, consisting of construction of physics-based 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 off-line and actual machine control platforms, and iteration of the design-test loop to optimize. Present work describes selected new solutions which address key control problems in DIII-D, and the approach, benefits, and progress made in integrated plasma control at DIII-D.

One element of DIII-D AT control which has been successfully addressed is the problem of high accuracy plasma boundary control. The problem is complicated in DIII-D by the need to produce good performance in a wide range of shapes and configurations, as well as by a uniquely constrained PF coil circuit and power supplies routinely operated near current limits. We describe the development and implementation of a complete predictive solution to this problem including multivariable controllers based on novel linear nonrigid, resistive plasma models, and nonlinear algorithms to avoid saturation and windup effects.

Integrated plasma control was essential in the successful development of the DIII-D NTM control system, which has achieved full and sustained suppression of 3/2 and 2/1 NTM modes (separately) using the 3 MW ECCD/ECH gyrotron system to replace missing island bootstrap current. Validated models of island response to ECCD were used to design nonlinear controllers, which vary plasma position or toroidal field to achieve alignment of island and ECCD deposition location. We report on design and experimental use of novel algorithms using direct feedback on the q-profile, reconstructed with a realtime Grad-Shafranov calculation [2] including MSE measurements.

[1] B.G. Penaflor, *et al.*, Proc. of 4th IAEA Tech. Mtg. on Control and Data Acq., San Diego, 2003.
[2] J.R. Ferron, *et al.*, Nucl. Fusion **38**, 1055 (1998).

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