Error Field Correction in Unstable Resistive Wall Mode (RWM) Regime

Y. In[1)], G.L. Jackson[2)], M. Okabayashi[3)], M.S. Chu[2)], J.M. Hanson[4)], R.J. La Haye[2)], J.S. Kim[1)], M.J. Lanctot[4)], Y.Q. Liu[5)], L. Marrelli[6)], P. Martin[6)], P. Piovesan[6)], L. Piron[6)], H. Reimerdes[4)], A. Soppelsa[6)], E.J. Strait[2)], and V. Svidzinski[1)]

[1)]FAR-TECH, Inc., San Diego, California 92121, USA
[2)]General Atomics, San Diego, California 92186-5608, USA
[3)]Princeton Plasma Physics Laboratory, Princeton, New Jersey 08543-0451, USA
[4)]Columbia University, New York, New York, 10027-6902 USA
[5)]Euratom/CCFE Fusion Association, Culham Science Centre, Abingdon, OX14 3DB, UK
[6)]Consorzio RFX, Corso Stati Uniti 4, 35127, Padova, Italy

e-mail: yongkin@far-tech.com

Abstract. The simultaneous use of feedback control for error field correction (EFC) and stabilization of an unstable resistive wall mode (RWM) has been demonstrated in DIII-D. While the conventional EFC method addresses error fields in a pre-programmed manner, it is challenged when an unstable RWM becomes dominant, because a weakly stable or feedback-stabilized RWM becomes extremely sensitive to any small, uncorrected resonant error field. Since the DIII-D tokamak is uniquely equipped with internal coils for fast time response and external feedback coils for slower time response, independent magnetic feedback control in low and high frequency ranges allows us to explore the specific roles of EFC and direct feedback (DF) in active RWM control in *stable, marginal* and *unstable* RWM regimes. For an *unstable* RWM at the edge safety factor q_{95}~3, the simultaneous operation of DF with the internal coils and dynamic (feedback-controlled) EFC with the external coils enabled us not only to stabilize the unstable RWM but also to determine the necessary EFC in the presence of a feedback-stabilized RWM. The gain dependence of the feedback-stabilized RWM differs from those of stable and marginal RWMs. Recent experiments and modeling show that the gain increase at *stable* RWMs (at q_{95}~5 or 6) leads to the coil current increase, while a *marginal* RWM (at q_{95}~4) is insensitive to the feedback gains. In contrast, according to an analytic cylindrical model, the EFC in the unstable RWM regime is predicted to require high gain to approach the desired correction current. This is also consistent with numerical RWM feedback modeling using the MARS-F code. It has been shown that a choice of an “under-relaxation” factor with high feedback gain could achieve “fast-track” EFC, requiring far fewer iterations than the conventional EFC method. Broadband magnetic feedback beyond a wall characteristic frequency τ_w^{-1} enhanced the damping rates of resonant magnetic perturbations induced by various bursty MHD events, helping to create and sustain high-performance plasmas. The established methodology to determine the optimized EFC waveform with the simultaneous use of feedback control of EFC and DF is applicable for various operational scenarios with pressure beyond the no-wall ideal stability limit. In particular, it would be highly valuable when the onset of unstable MHD is sensitive to the quality of EFC.

This work was supported in part by the US Department of Energy under DE-FG02-06ER84442, DE-FC02-04ER54698, DE-AC02-09CH11466, and DE-FG02-89ER53297. We gratefully acknowledge all the DIII-D Team members for their successful operations of the machine.