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Feedback-Assisted Extension of the Tokamak Operating Space to Low Safety Factor[1]

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Recent DIII-D experiments have demonstrated stable operation at very low edge safety factor, $q_{95} \lesssim 2$ through the use of magnetic feedback to control the $n = 1$ resistive wall mode (RWM) instability. The performance of tokamak fusion devices may benefit from increased plasma current, and thus, decreased q. However, disruptive stability limits are commonly encountered in experiments at $q_{edge} \approx 2$ (limited plasmas) and $q_{95} \approx 2$ (diverted plasmas), limiting exploration of low q regimes. In the recent DIII-D experiments, the impact and control of key disruptive instabilities was studied. Locked $n = 1$ modes with exponential growth times on the order of the wall eddy current decay timescale τ_w preceded disruptions at $q_{95} = 2$. The instabilities have a poloidal structure that is consistent with VALEN simulations of the RWM mode structure at $q_{95} = 2$. Applying proportional gain magnetic feedback control of the $n = 1$ mode resulted in stabilized operation with q_{95} reaching 1.9, and an extension of the discharge lifetime for $> 100\,\tau_w$. Loss of feedback control was accompanied by power supply saturation, followed by a rapidly growing $n = 1$ mode and disruption. Comparisons of the feedback dynamics with VALEN simulations will be presented. The DIII-D results complement and will be discussed alongside recent RFX-MOD demonstrations of RWM control using magnetic feedback in limited tokamak discharges with $q_{edge} < 2$ [1]. These results call attention to the utility of magnetic feedback in significantly extending the tokamak operational space and potentially opening a new route to economical fusion power production.

[1] P. Martin, et al., Proc. 24th IAEA Fusion Energy Conf. (San Diego, USA), paper OV/5-2Rb, 2012).

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