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EX/1-5: Fully Noninductive Scenario Development in DIII-D Using New Off-Axis Neutral Beam Injection

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New off-axis neutral beam injection (NBI) capability on DIII-D has expanded the range of achievable and sustainable current and pressure profiles of interest for developing the physics basis of steady-state scenarios in future tokamaks. Fully noninductive (NI) scenarios are envisioned to have broad current and pressure profiles with elevated minimum safety factors (q_{\min}), high normalized beta (β_N), and a large fraction of the plasma current I_P sustained by the bootstrap current. Using off-axis NBI, plasmas have been produced with q_{\min} between ~ 1.3 and ~ 2.5 to evaluate the suitability for steady-state operation ($f_{\text{NI}}=I_{\text{NI}}/I_P=1$). Nearly stationary plasmas were sustained for two current profile relaxation timescales (3 s), with $q_{\min}=1.5$, $\beta_N=3.5$, $f_{\text{NI}}=70\%$, and performance that projects to $Q=5$ in an ITER-size machine. The duration of the high β_N phase is limited only by the available NBI energy. Low-order tearing modes are absent and the predicted ideal-wall $n=1$ kink β_N limit is >4 . To achieve higher f_{NI} , higher β_N is needed to increase the bootstrap current, and higher q_{\min} will decrease the required external current drive near the axis. Experiments to produce plasmas with $q_{\min}>2$ showed that the use of off-axis NBI results in higher sustained q_{\min} , with q_{\min} at a larger radius (i.e. a broader current profile), and a broader pressure profile. These changes increased the predicted ideal-wall $n=1$ kink mode β_N limit from below to above $\beta_N=4$. These plasmas achieved a maximum $\beta_N=3.2$ limited by the available NBI power and reduced confinement ($H_{98\sim 1}$) relative to similar plasmas with lower q_{\min} . $\beta_N=4$ with $q_{\min}>1.5$ was transiently obtained albeit with only 2 out of 5 MW of off-axis NBI available. Off-axis fishbones and low-order tearing modes were observed in the course of the q -profile scan. These studies indicate that obtaining a sustained, high performance, $f_{\text{NI}}=1$ scenario involves a number of trade-offs related to the choice of q -profile.

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