Long Pulse High Performance Plasma Scenario Development for the National Spherical Torus Experiment

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NSTX is targeting long pulse high performance, non-inductive sustained operations at low aspect ratio. The modeling of these plasmas provides a framework for experimental planning and identifies the tools to access these regimes. Here, two scenarios are examined, the first near-term with $t_{flattop}>\tau_J$, and the second, longer term goal obtaining $\beta\approx40\%$ for $t_{flattop}>>\tau_J$. Simulations based on NBI-heated plasmas with the free-boundary Tokamak Simulation Code (TSC) and TRANSP are made to understand the impact of various modifications and identify the requirements for 1) high elongation and triangularity, 2) density control to optimize the current drive, 3) rotation/wall and/or feedback stabilization to operate above the no-wall limit, 4) Electron Bernstein Waves for off-axis heating/current drive (H/CD), and 5) High Harmonic Fast Wave for H/CD. Comparison of the profile evolution with experiment, including time-resolved kinetic and current profile measurements, provides the required benchmarking. An integrated scenario is constructed using TSC/TRANSP to provide the transport evolution and (H/CD) source modeling, supported by RF and stability analyses using CURRAY, GENRAY/CQL3D, JSOLVER/BALMSC/PEST2, DCON, and VALEN. Important factors include the energy confinement, Z_{eff}, early heating/H-mode, broadening of the NBI-driven current profile from fast ion MHD, and maintaining q(0) and $q_{min}>1.0$. Simulations show that the near-term goal can be reached at I_P=800 kA, B_T=0.5 T, $\kappa\approx2.5$, $\beta_N\leq5$, $\beta\leq15\%$, f_{NI}=92%, and q(0)>1.5 with NBI H/CD, density control, and similar global energy confinement to experiments. The non-inductive sustained high β plasmas can be reached at I_P=1.0 MA, B_T=0.35 T, $\kappa\approx2.5$, $\beta_N\leq9$, $\beta\leq43\%$, f_{NI}=100%, and q(0)>1.5 with NBI H/CD and 3.0 MW of EBW H/CD, density control, and 25% higher global energy confinement than experiments.

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