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Solenoid-free Plasma Start-up in NSTX using Transient Coaxial Helicity Injection (CHI)

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Transient Coaxial Helicity Injection (CHI) in the National Spherical Torus Experiment (NSTX) has generated toroidal current on closed flux surfaces without the use of the central solenoid. When induction from the solenoid was added, CHI initiated discharges in NSTX achieved 1 MA of plasma current using 65% of the solenoid flux of standard induction-only discharges. In addition, the CHI-initiated discharges have lower density and a low normalized internal plasma inductance of 0.35, as desired for achieving advanced scenarios. These results from NSTX imply a current generation potential in excess of 500 kA in the NSTX-U currently nearing completion of a major upgrade to increase its device capability.

Both conventional aspect ratio tokamaks and spherical tokamaks (STs) have generally relied on a central solenoid to generate the initial plasma current and then to sustain that current against resistive dissipation. However, in a steady-state reactor, induction alone cannot be used for plasma current sustainment. The inclusion of a central solenoid in a tokamak to provide plasma startup limits the minimum aspect ratio and increases the device complexity. For reactors based on the ST concept, elimination of the central solenoid is essential, making alternate methods for plasma start-up necessary for such a reactor.

CHI [R. Raman, et al., PRL 104, 095003 (2010)] is implemented in NSTX by driving current from an external source along field lines that connect the inner and outer lower divertor plates. NSTX CHI simulations with the Tokamak Simulation Code (TSC) show that CHI start-up current scaling with toroidal field is consistent with present understanding of CHI theory, and this suggests that potential use of CHI on larger machines is quite attractive. These exciting new results from NSTX demonstrate that CHI is a viable solenoid-free plasma startup method for future STs and Tokamaks.

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