Overview of Transient CHI Plasma Start-up Research in NSTX-U

R. Raman (*University of Washington, Seattle WA USA)*

Transient Coaxial Helicity Injection (CHI) in 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. The Tokamak Simulation Code (TSC) has been used to understand the scaling of CHI generated toroidal current with variations in the external toroidal field and injector flux. These simulations show favorable scaling of the CHI start-up process with increasing machine size.

CHI is implemented on NSTX and NSTX-U by driving current from an external capacitor bank source along field lines that connect the inner and outer lower divertor plates, which are electrically separated from each other. The discharge is initiated by first energizing the toroidal field coils and the lower divertor coils to produce magnetic flux, known as the injector flux. After gas is injected into the vacuum chamber, a voltage is applied between these plates, which ionizes the gas and produces current flowing along magnetic field lines connecting the lower divertor plates. In NSTX-U, a 20-50 mF capacitor bank charged to 2 kV (with a future upgrade to 3 kV) would provide this current, called the injector current.

CHI on NSTX-U will benefit from numerous upgrades. These are: (1) Improved design of the injector coil that increases the injector flux capability, and consequently, the generated plasma current, by a factor of over 2.5, (2) improved positioning of the upper buffer field coil to minimize the generation of undesirable current paths, (3) factor of two increase in the toroidal field increases the current multiplication factor, (4) the capability for a 1 MW ECH system that is projected to increase the electron temperature of the CHI discharge, and (5) more complete lithium deposition capability that will reduce the influx of low-Z impurities.

NSTX has undergone a major upgrade (to NSTX-U) to increase the capabilities of its toroidal and poloidal field coils and to add a second neutral beam line. Analysis of the NSTX results shows that the amount of closed-flux current generated by CHI is closely related to the initially applied injector flux. On NSTX-U the available injector flux is over 240 mWb, much exceeding the 80 mWb in NSTX. The modeling projects that it should be possible to generate considerably in excess of 400 kA of closed-flux current with CHI in NSTX-U. At this current level, TSC simulations suggest that the second more tangentially injecting neutral beam system in conjunction with bootstrap current overdrive should be capable of ramping-up the plasma current to the 1 MW steady-state current sustainment levels in support of a ST FNSF.

Experimental results and the NSTX-U plans for achieving full solenoid-free plasma start-up, and full non-inductive current ramp-up to sustained operating levels will be described. This work is an important outgrowth of early CHI research conducted on Spheromaks. The differences between CHI on a Spheromak and a Spherical Tokamak, and the CHI operating modes in these two concepts will also be discussed.

This work was supported by U.S. DOE contracts DE-FG02-99ER54519 and DE-AC02-09CH11466.