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Transient CHI start-up of low inductance plasma for advanced ST scenarios

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Demonstration of fully solenoid-free start-up at the ~1 MA level and ramp-up to full current of low inductance plasma would be a major step for the ST program, as it would be a convincing enough step for the consideration of ST designs with a reduced size solenoid. In support of this objective, the TSC code, with the inclusion of plasma transport, has been used to study the Transient CHI closed flux current start-up potential in a BT =1 T NSTX-U device and at increased BT =3 T, to assess the potential capability on ST-40, as the ST-40 vessel dimensions are comparable to those of NSTX-U.

In reactors based on the ST/AT concepts, minimizing the recirculation power fraction is desired for an attractive and economical electrical power generation system. Such devices must operate at high fractions of the bootstrap current drive. The ST configuration with a low aspect ratio is particularly attractive in this regard. In addition, to sustain the high-performance regime, density and pressure profile control should be demonstrated using reactor relevant core fueling systems that during each fueling pulse does not significantly perturb the optimized profiles necessary for maintaining the bootstrap current drive.

The immediate advantage of solenoid-free start-up is that it provides more space to add structural material to the toroidal field coil to support a higher peak field and higher field on axis – which could greatly increase fusion performance and/or reduce the cost of the facility. Reducing the size of the central solenoid would allow the valuable in-board region to be used for other more critically important systems that are necessary for sustained steady-state operation. Some of these new capabilities are highspeed pellet injection from the inboard side (without the use of a guide tube with strong curvature) and high field side RF launchers for heating and current drive.

During transient CHI start-up, as well as during the merging-compression start-up pioneered on the START and MAST devices, all the start-up current is produced during the initial plasma formation pulse, and one does not continue to drive current after the plasma has formed. Consequently, the scaling of these concepts to larger devices is relatively well understood as a reliable predictive model is difficult to develop as the plasma response during the current ramp-up is not well known, especially at high current.

Transient CHI TSC simulations at 1 T show that closed flux start-up currents >500 kA should be achievable with the present divertor coil set on NSTX-U. NSTX-U is also well equipped with high power neutral beam injection capability that is optimized for sustained non-inductive current drive of the CHI target. Simulations also show that if the BT is increased to 3 T, and with increased divertor coil current rating, closed flux start-up currents more than 0.6 MA should be possible. Work is in progress to assess the requirements for 1 MA closed flux current start-up in a 3 T device. TSC simulations also show that at these high levels of magnetic flux injection the CHI plasma self-heats to 100s of eV electron temperature. Additional heating, if required, could be provided by ECH as the CHI plasma electron density is below the density limit for ECH systems considered for STs. The ST-40 device would be a particularly attractive device on which to demonstrate MA level current start-up followed by sustainment with reactor-relevant ECH.

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