Topic: FIP

Progress toward commissioning and plasma operation in NSTX-U *

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The National Spherical Torus Experiment - Upgrade (NSTX-U) project has entered the last phase of construction, and preparation for plasma operations is now underway. The major mission of NSTX-U is to develop the physics basis for an ST-based Fusion Nuclear Science Facility (FNSF). The ST-based FNSF has the promise of achieving the high neutron fluence needed for reactor component testing with relatively modest tritium consumption. At the same time, the unique operating regimes of NSTX-U can contribute to several important issues in the physics of burning plasmas to optimize the performance of ITER. The NSTX-U program further aims to determine the attractiveness of the compact ST for addressing key research needs on the path toward a fusion demonstration power plant (DEMO). NSTX-U will nearly double the toroidal magnetic field B_T, plasma current I_p, and NBI heating power compared to NSTX, and increase the TF flat top pulse length from 1 s to 6.5 s. The new center stack will provide B_T = 1 Tesla (T) at a major radius of R_0 = 0.93 m compared to 0.55 T at R_0 = 0.85 m in NSTX, and will enable a plasma current I_p of up to 2 mega-Amp (MA) for 5 sec compared to the 1 MA for 1 sec in NSTX. The anticipated plasma performance enhancement is a quadrupling of the plasma stored energy and at least doubling of the plasma confinement time, which would result in an order of magnitude increase in the fusion performance parameter $n\tau T$. With $\beta_T \sim 25\%$ at B_T = 1T, the absolute average plasma pressure in NSTX-U could become comparable to that of present-day tokamaks. A much more tangential 2nd NBI system, with 2-3 times higher current drive efficiency compared to the 1st NBI system, is installed. NSTX-U is designed to attain the 100% non-inductive operation needed for a compact FNSF design. With higher fields and heating powers, the NSTX-U plasma collisionality will be reduced by a factor of 3-6 to help explore the trend in transport towards the low collisionality FNSF regime. If the favorable trends observed on NSTX holds at low collisionality, high fusion neutron fluences could be achievable in very compact ST devices. Several noteworthy technological innovations were introduced for NSTX-U including design and manufacturing technology. The doubling of magnetic fields and plasma currents increases electromagnetic forces by a factor of four. Accordingly, the vacuum vessel and the support structures were enhanced. To protect NSTX-U from unintended failures due to the power supplies delivering current combinations and consequential forces or stresses beyond the design-basis, a digital coil protection system (DCPS) is being implemented. The DCPS is designed to prevent accidental (either human or equipment failure) overload beyond the design conditions of the structure which the power supply system could generate, even while each individual power supply is operating within its allowable current range. The total auxiliary heating power of 20 MW provided by the NBI and HHFW systems will allow NSTX-U to uniquely produce FNSF/DEMO-relevant high divertor heat fluxes of ~ 40 MW/m^2. Innovative divertor heat and particle solutions, such as the up-down symmetric, high flux expansion snowflake divertor configuration, will be used to control these heat fluxes. NSTX-U is also equipped with a set of six non-axisymmetric (3-D) control coils, which can be independently controlled to actively control RWMs at high beta, control error fields, and apply resonant magnetic perturbations for plasma rotation and ELM control. NSTX-U will continue to explore the use of lithium PFC coating techniques for enhanced plasma performance, and divertor power and particle handling. A lithium granular injector will be implemented for ELM pacing at high injection rate to control impurities and reduce the peak ELM heat flux. Coaxial helicity injection (CHI) will be used to create plasmas with up to ~500 kA non-inductively, and develop the solenoid-free tokamak/ST design basis needed for FNSF. NSTX-U first plasma is planned for November 2014, at which time the transition to plasma operation will occur.

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