Topic: FTP

Progress on developing the spherical tokamak for fusion applications

J. Menard[1], T. Brown[1], J. Canik[2], J. Chrzanowski[1], L. Dudek[1], L. El Guebaly[3], S. Gerhardt[1], S. Kaye[1], C. Kessel[1], E. Kolemen[1], M. Kotschenreuther[4], R. Maingi[2], C. Neumeyer[1], M. Ono[1], R. Raman[5], S. Sabbagh[6], V. Soukhanovskii[7], T. Stevenson[1], R. Strykowsky[1], P. Titus[1], P. Valanju[4], G. Voss[8], A. Zolfaghari[1], the NSTX Upgrade Team.
email: jmenard@pppl.gov

[1]*Princeton Plasma Physics Laboratory, Princeton, NJ 08543*
[2]*Oak Ridge National Laboratory, Oak Ridge, TN, USA*
[3]*University of Wisconsin, Madison, WI, USA*
[4]*University of Texas, Austin, TX, USA*
[5]*University of Washington, Seattle, WA, USA*
[6]*Columbia University, New York, NY, USA*
[7]*Lawrence Livermore National Laboratory, Livermore, CA, USA*
[8]*Culham Centre for Fusion Energy, Abingdon, Oxfordshire, UK*

A Fusion Nuclear Science Facility (FNSF) could play an important role in the development of fusion energy by providing the high neutron flux and fluence environment needed to develop fusion materials and components. The spherical tokamak (ST) is a leading candidate for an FNSF due to its compact size and modular configuration. Two activities preparing the ST for possible FNSF applications have been advanced in the U.S. during the past two years. First, a major upgrade of the National Spherical Torus eXperiment (NSTX) has been designed, approved, and initiated. Second, previous "pilot plant" studies identified key research needs and design issues for ST-based FNSF devices and motivate studies of the impact of device size on neutron wall loading, tritium breeding, and electricity production. Progress in both research activities will be described. A key research goal of NSTX Upgrade (NSTX-U) is to access 3-5 times lower collisionality to more fully understand transport, stability, and non-inductive start-up and sustainment in the ST. Such considerations motivate the upgrade of NSTX to double the toroidal field, plasma current, and NBI heating power, and quintuple the pulse duration. Higher toroidal field and pulse length will be achieved by fabricating and installing a new center stack (CS) in NSTX-U, and a second more tangential neutral beam injection (NBI) will be installed to increase NBI current drive efficiency by up to a factor of two, support fully non-inductive operation at 1MA plasma current, enable control of the core q profile, and ramp-up the plasma current from intermediate current to ~1MA levels. Understanding the impact of varied device size is another important ongoing ST research activity. For example, for an ST-FNSF with average neutron wall loading of $1MW/m^2$, the impact of increased major radius is stabilizing, but the overall fusion power and tritium consumption increases. For higher performance operation targeting net electricity production, the smallest possible ST device that can achieve electricity break-even has R=1.6m assuming very high blanket thermal conversion efficiency η_{th} = 0.59 as was utilized in ARIES-AT design studies. A near-term issue that will be addressed is the impact of device size on tritium breeding ratio (TBR) where smaller devices will likely have more difficulty achieving TBR > 1 since a higher fraction of in-vessel surface area must be dedicated to auxiliary heating ports and blanket test modules.

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