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Design status of the DEMO-FNS Steady State Tokamak in RF

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Development of a fusion neutron source DEMO-FNS for demonstrating energy valuable hybrid technologies based on a conventional superconducting tokamak (CT) with the power of deuterium and tritium fusion up to 50 MW has been started in Kurchatov Institute in 2013. The design is aimed at steady state operation of the device providing the DT-neutron flux (~0.2 MW/m^2) and the fluence (~2 MW-y) with the blanket area (~100 m^2) sufficient to test materials and components in fusion spectra for DEMO program support and to develop hybrid technologies for transmutations, fissile nuclides production and energy generation.

The concept of DEMO-FNS has been formulated assuming amplification factor Q ~1, duty factor ~0.3, electric power consumption < 200 MW, tritium consumption < 700 g/y, divertor loading < 10 MW/m^2, plasma current 5 MA, magnetic field 5 T, major radius 2.75 m, aspect ratio 2.75 and auxiliary heating power up to 36 MW, construction cost ~1 $B. From safety point of view the device was considered as a radiation source with opportunity to become a subcritical nuclear facility with generated heat power less than 500 MW. Commercially available materials are considered in the design owing to reduced neutron loadings and fluencies compared with DEMO.

A zero-dimensional system code and one/two-dimensional models have been developed and used in this analysis. The necessary operation limits of the plasma confinement, stability and current drive have been determined. Scenarios to achieve and maintain the steady state operation have been considered and optimized. Recent design results will be presented.

In 2014 the design was transferred to engineering stage. Design of enabling systems has been fulfilled. Prospective technical solutions for tokamak systems have been validated, and choices of enabling technologies and materials have been made. ITER like technologies using low temperature superconductors Nb_3Sn and NbTi were chosen for toroidal and poloidal field coils respectively. Radiation shield of 0.5/0.6 m thickness protects the superconducting coils and forms the external vacuum vessel. Plasma facing first wall capable to survive at heat loading up to 5 MW forms an internal vacuum volume and a domain for blanket allocation. Remote handling maintenance of in-vessel components remains a challenge for design. Several options were considered and will be discussed.

Design of a double-null divertor for the DEMO-FNS has been completed which is capable to withstand heat fluxes up to 10 MW/m^2. Lithium technology is assumed to control the border plasma radiation and plasma-surface interaction in the scrape-off layer. First mockups of a thin-wall water cooled vacuum chamber for the heat load up to 10 MW/m^2.

Integration of blanket technology subsystems in the tokamak design was evaluated. Concepts of the DEMO-FNS blankets for the pure thermal neutron production and for the development of a thorium fuel cycle for fission reactors have been considered. Molten salt technologies were chosen as the mainstream for hybrid blankets. DT- cycle for plasma fuelling was developed and will be presented. Construction of the device planned by 2023 needs an aggressive R&D program on steady state technologies and fusion nuclear science as well as materials and component tests on a smaller scale tokamak based fusion neutron source.