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## Development of DC Ultra-High Voltage Insulation Technology for ITER NBI & Progress in Long Pulse Production of Powerful Negative Ion Beams for JT-60SA and ITER

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A

In the ITER NBI for plasma heating and current drive, a 1 MeV, 40 A deuterium negative ion (D<sup>-</sup>) beam is designed to be accelerated for 3600 s. The beam energy and the pulse duration of the D<sup>-</sup> beam are 2-5.5 times higher and 360 times longer than those in the negative-ion-based NBIs on LHD and JT-60U, respectively. Thus, to realize higher voltage and longer pulse duration, the generation, transmission and insulation of DC ultra-high voltage are critical issues for the ITER NBI. In addition, the high-current busbar, cooling water and gas pipes at -200 kV<sup>-</sup> -1 MV potential are simultaneously transmitted through the HV bushing from the gas-insulated transmission line in the PS to the beam source (BS) to minimize the installation space. Those are significant differences from that in existing N-NB systems. Especially, a DC 1 MV insulating transformer for feeding an electric power from the ground to 1 MV potential is one of most challenging components. For stable power transmission through the HV bushing, 1 MV vacuum insulation and a stiffness to withstand the maximum pressure difference of 0.9 MPa in a limited space are required. Japan Atomic Energy Agency (JAEA) is in charge of the procurement of these high voltage parts of the 1 MV PS and the HV bushing. As for the insulating transformer, a DC long pulse insulation structure and a composite bushing for the isolation of the high-voltage to the air have been newly developed. The mockup transformer successfully demonstrated a stable insulation of DC -1.2 MV for 3600 s. The HV bushing serves as the terminal of the HV transmission line. It is made in five 200 kV stages and a two-stage mockup has been developed, and stable voltage holding at 480 kV for 3600 s was demonstrated. These R&D results fulfill the ITER requirement, which allows the realization of the PS and HV bushing for the ITER NBI.

B

The long pulse generation of the powerful negative ion beams of 500 keV, 22 A (130 A/m<sup>2</sup>) and 1MeV, 40 A (200 A/m<sup>2</sup>) is the essential challenge to realize the negative-ion-based neutral beam injectors (NBIs) for JT-60SA and ITER, where 10 MW D<sup>0</sup> beam for 100 s and a 16.5 MW for 3600 s are designed, respectively. In Japan Atomic Energy Agency (JAEA), after the achievements of the beam current density and energy required for JT-60SA and ITER with a short pulse duration, the target of R&D is focused on the extension of the pulse duration in JT-60 negative ion source and the MeV accelerator.

Significant progress in the extension of pulse duration of the powerful negative ion beams has been made to realize the neutral beams injectors for JT-60SA and ITER. The pulse duration and the current density of the JT-60 negative ion source has been successfully improved from 30 s at 80 A/m<sup>2</sup> in the previous operation to 100 s at 120-130 A/m<sup>2</sup>, which satisfy the rated values for JT-60SA. This progress has been achieved by controlling the negative ion production via the surface temperature of the plasma grid. The pulse duration of the MeV class negative ion beams for ITER has been also extended by more than an order of magnitude in the MeV accelerator. A long pulse acceleration of 8.7 s has been achieved at 880 keV, 130 A/m<sup>2</sup> by improving the cooling capability of the extraction grid where the aperture displacement for the beamlet steering is also modified, so there is no limitation to increase the power density and the pulse duration. This is the longest pulse duration of the MeV-class negative ion beams in the world.

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