SI-3

NBシステムの調達活動の現状
Present status of procurement activities for ITER NB system

戸張 博之、花田 磨砂也、渡邊 和弘、柏木 美恵子、大楽 正幸、山中 晴彦、前島 哲也、
梅田 尚孝、阿部 宏幸、照沼 勇斗、関 則和、椎名 大介、近藤 達夫
Hiroyuki TOBARI, Masaya HANADA, Kazuhiro WATANABE, Mieko KASHIWAGI et al.,

日本原子力研究開発機構
Japan Atomic Energy Agency

1. Introduction

Neutral beam (NB) Injector is one of key components for plasma heating and current drive in ITER. Injection power of neutral beam per one injector is designed to be 16.5 MW which is achieved via a gas neutralization of 1 MeV, 40 A deuterium negative ion (D^-) beam for 3600 s. The ion beam power and duration time required in ITER are twice higher and 36 times longer than that in JT-60 SA, respectively. To realize the ITER NB system, ITER council decided the construction of NB test facility (NBTF) in Padova, Italy, where the performance of ITER NB system is confirmed prior to the operation in ITER. The procurements of NBTF started in Japan and Europe and are well in progressed as scheduled. In this symposium, the present status of Japanese procurement activities for the ITER NB is reported.

2. Procurement sharing and schedule

The NB system in NBTF is identical to that in the ITER, and will be modified to fulfill the requirements if necessary. Japan is in charge of the procurement of the key components in NB system, which is an acceleration power supply (AGPS), HV bushing in NBTF as shown in Fig.1. The other components are procured by Europe. Since one of the accelerators for ITER will be procured by Japan, Japan is also leading the development of the 1 MeV negative ion accelerator and participating the design of the accelerator in NBTF.

The building and facilities is under construction in Padova, Italy and will be completed in 2016. Procurement arrangement (PA) of components procured by Japan was entered into in 2011 and started in 2012. The final designs of a part of the power supplies; transmission line (TL)1, TL2 and DC filter were completed in summer, 2013, and is under the preparation of the manufacturing. Those of other components will be completed in 2014. All of the power supplies will be shipped to Padova by 2016.

As for the HV bushing, the PA has signed in 2011. Half of manufacturing of large ceramic ring and brazing has been completed as scheduled and will be finished within 2014. The final design of inner conductors and other metal parts has been established in 2013, and manufacturing of those parts will start in 2014. Assembly of the HV bushing will be completed in 2016. After a delivery to Padova, the commissioning combined with power supply and the beam source for 1 MeV, 40 A D^- beam will start within 2017.

3. R&D and design

(Power supply)

Japan procures DC generators for the DC electric powers at 200 kV, 400 kV, 600 kV, 800 kV and 1 MV, DC filter for the suppression of voltage ripple and over-voltage, transmission lines of 1 to 3, High-Voltage deck 2 for feeding water and gas to the beam source at 1 MV potential. All electric parts in the power supplies are installed in high-pressure enclosures to be filled with a 0.6 MPa insulation gas in order to make the size of the power supplies compact. Each of the power supplies is designed based on the concept of the N-NBI system in JT-60. However, some of the power supplies such as the 1 MV insulating transformer requires new development to realize the ITER NB system because of a large gap from existing technologies. The voltage and pulse duration time of existing insulating transformer were a half and 1/36 of the ITER requirement, respectively. A mock up of the 1 MV insulating transformer with double layered bushing is manufactured and tested. The high-voltage test indicates a successful demonstration of high voltage sustainment of 1.2 MV during 3600 s [1]. Based on the R&D results, the 1 MV insulating transformer is designed for ITER and NBTF and are well in progress to proceed the procurements.

(HV bushing)

The HV bushing acting as a pressure boundary is mounted between the beam source and the gas-insulated transmission line of the power supply in order to feed electric power, cooling water and gas. The HV bushing consists of five-stage double-layered insulator columns (inner ring; ceramic, outer ring; fiber reinforced plastic (FRP)). Inside the ceramic ring, inner conductors at five different potentials (200 kV~1 MV) feeding electric power, cooling water and D_2/H_2 gas to the beam source must be arranged in a limited space in vacuum. The ceramic ring of which inner diameter is 1.46 m was too large to form with a conventional method, thus a new forming technique with a rubber frame modifying forming pressure on the raw material has been developed and the world largest ceramic ring successfully manufactured. In addition, the ceramic ring is brazed with 3 mm thick Kovar® (Fe-Ni-Co alloy) plates in order to form vacuum boundary. To withstand mechanical force arisen from filled gas around the ceramic ring, brazing with thicker Kovar plate than conventional one is required. By developing specific tool to equalize their thermal and a control scheme of temperature profile, the brazing technique on the large area with thick Kovar plate has been established. In parallel, the layout of the inner conductors has been analyzed to ensure 1 MV vacuum insulation, and their structural soundness has been also confirmed through mechanical analyses.

Followed by establishment of manufacturing technology on ceramic ring and brazing and detailed design work, a full-scale two-stage mockup including inner conductors having actual geometry was assembled to confirm feasibility of the HV bushing (See Fig.2). Stable voltage holding up to 480 kV (including 20 % margin for rated voltage) for 3600 s has been demonstrated to satisfy the ITER requirement. Reflecting results of those R&Ds, the final design of the HV bushing has been confirmed in 2013.

[1] Yamasaki, et al., SI-4, presented in this symposium.

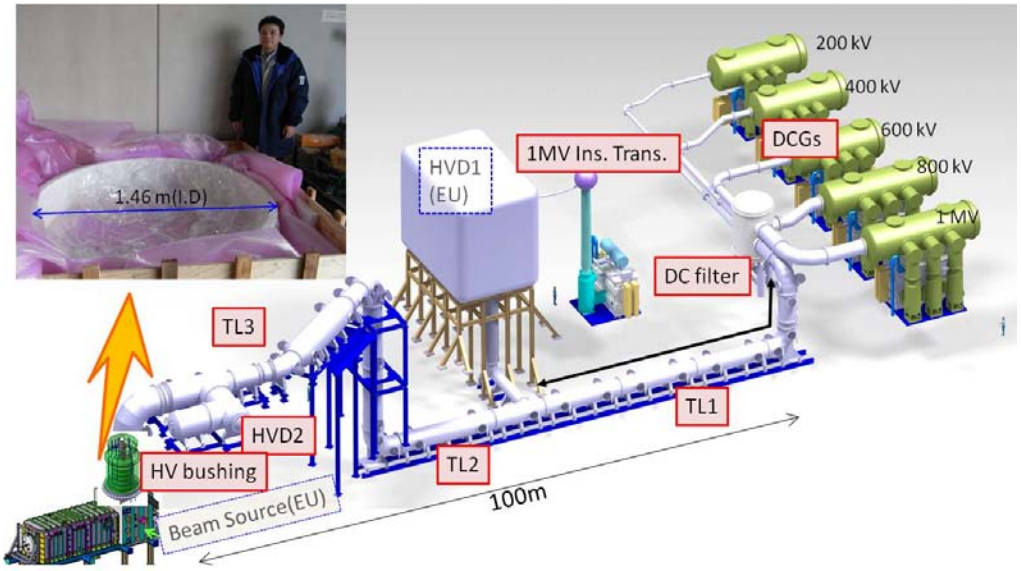

Fig.1 ITER NBTF power supply and HV bushing. Components in red rectangles are procured by JADA.

Fig.2 Full-scale two-stage mockup bushing