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Design of neutral beam injection system for KSTAR tokamak

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ABSTRACT

The neutral beam injection (NBI-1) system has been designed for providing a 300 s deuterium beam of 120 kV/65 A as an auxiliary heating and current drive system of the KSTAR (Korea Superconducting Tokamak Advanced Research) tokamak. The deuterium beam is produced from a long pulse ion source composed of a bucket-type plasma generator and a multi-aperture tetrode accelerator with the help of discharge power supplies and high voltage (HV) power supplies. The beamline components (BLCs) include a neutralizer with an optical multi-channel analyzer (OMA) section, a bending magnet (BM), an ion dump assembly, a movable calorimeter, beam scrapers, and a cryo-sorption pump system in a rectangular vacuum tank. A beam duct equipped with bellows and a voltage break is placed between the NBI vacuum tank and the KSTAR vacuum vessel. All data and parameters of the NBI system are controlled by a control and data acquisition (CODAQ) system through the EPICS based Ethernet interface.

1. Introduction

The neutral beam injection (NBI) system is essential for the next-step in fusion research devices, such as the International Thermonuclear Experimental Reactor (ITER) [1], for an auxiliary heating and current drive to achieve long pulse or continuous steady-state burning experiments. Worldwide large tokamaks, such as JET (EU), TFTR (USA), DIII-D (USA), and JT-60U (Japan), have used the NBI system for the high performance operation during the last few 10 years [2–5]. And now, an NBI system for the KSTAR (Korea Superconducting Tokamak Advanced Research) tokamak [6] is being constructed and tested partially.

The first neutral beam injection (NBI-1) system has been designed to provide an auxiliary heating and current drive for the long pulse and high performance operations of the KSTAR tokamak. Basically, the KSTAR NBI system will have two beam lines, and each beam line is equipped with three ion sources of which one can deliver more than 2.5 MW of neutral beam power with a maximum 300 s deuterium ion beam of 120 kV/65 A. The final destination of the KSTAR NBI system aims at the injection of more than 14 MW of deuterium beam power through two beam lines. According to the planned role of the NBI system in KSTAR experiments, the NBI-1 system is operated for beam injection into the KSTAR tokamak plasma from the 2010 KSTAR campaign, including the system commissioning of each main components and sub-systems.

The most part of beamline components (BLCs) of KSTAR NBI-1 system is installed in a big rectangular vacuum tank. A beam duct equipped with welded bellows and a voltage break is placed between the NBI vacuum tank and the KSTAR vacuum vessel. The beamline components of NBI-1 system have been designed to accommodate full ion/neutral beams from three ion sources. However, the first NBI-1 operation starts with only one ion source. The long pulse ion source is composed of a bucket-type plasma generator and a multi-aperture tetrode accelerator. The high current power supplies applied for filaments and arc discharges and the high voltage (HV) power supplies applied for the beam extraction and acceleration have been also designed. All data and parameters of the NBI-1 system are controlled by a control and data acquisition (CODAQ) system through the EPICS (Experimental Physics and Industrial Control System) based Ethernet interface.

2. Ion source

The long pulse ion source (LPIS) has been designed to cope with a 300 s operation period and deliver more than 2.5 MW of neutral beam power with a deuterium ion beam of 120 kV/65 A at a high arc efficiency. The first LPIS (LPIS-1) is composed of a bucket-type plasma generator of large volume and a multi-aperture tetrode accelerator. The plasma generator has been developed by the JAEA (Japan Atomic Energy Agency) in Japan, and the proto-

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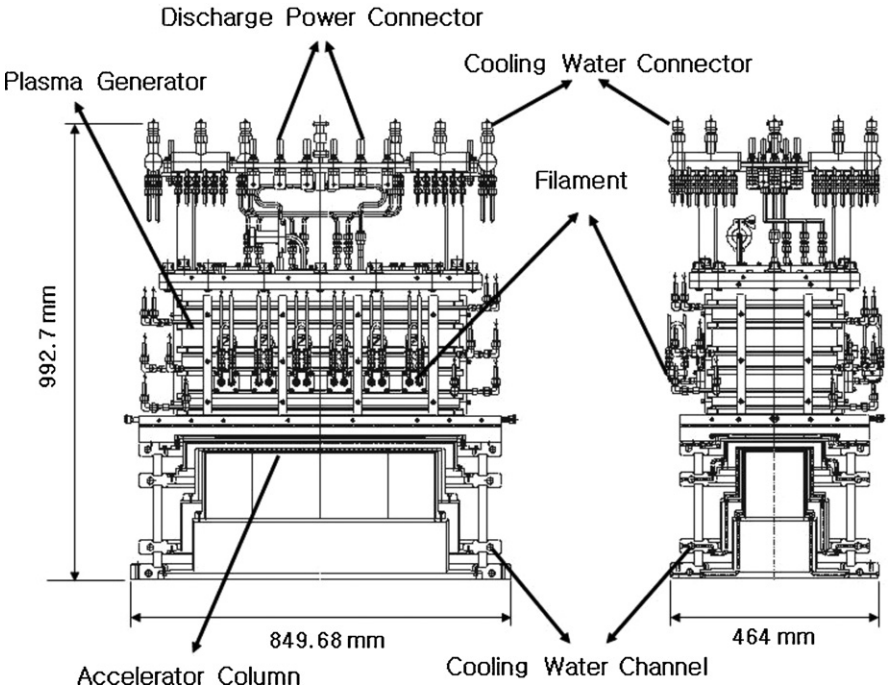

Fig. 1. A schematic of the first long pulse ion source (LPIS-1).

type accelerator has been developed by the KAERI (Korea Atomic Energy Research Institute) in Korea. The bucket has a cross section of $25 \times 59\,cm^2$ and a depth of 32 cm. The bucket wall has the potential of the anode, and the virtual area is much less than the geometrical one by using a magnetic multi-pole cusp configuration formed around the inner wall with azimuthal arrays of permanent magnets attached on the outside in a pattern of alternate polarity along the beam direction. The cooling channels are lined up. Conventional tungsten filaments, as a thermionic electron emitter, are used for a cathode. Each filament is mounted on a water-cooled feed-through, which is individually connected to each filament power supply.

The accelerator grid modules are all made of oxygen-free high conductivity (OFHC) copper. The cooling channels are mechanically prepared inside the grid plate through every row of the beam extraction holes. The accelerator is of tetrode type, whose aperture

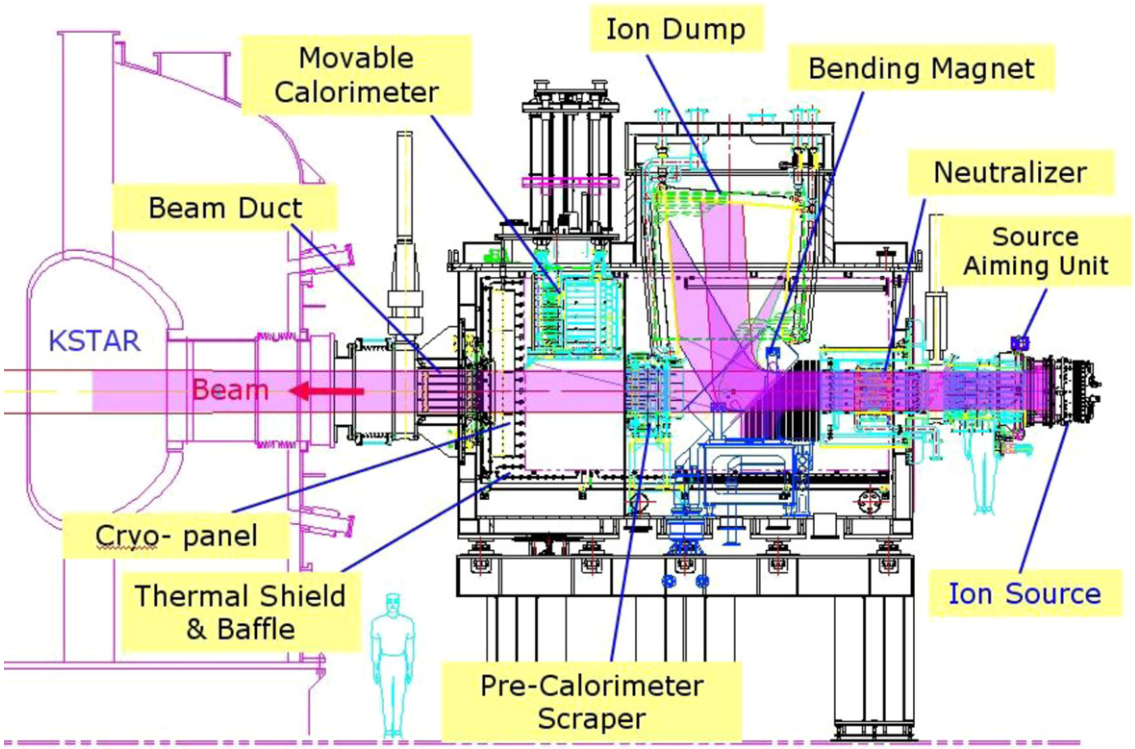

Fig. 2. A cross-sectional view of the NBI-1 system connected to the KSTAR torus.