Contribution ID: **106** Type: **Oral**

Completion of 1st ITER gyrotron manufacturing and 1 MW test result & Outcome of R&D program for ITER ICRF Power Source System & Recent progress in the development of the European 1 MW, 170 GHz CW gyrotron for ITER

Monday, October 22, 2018 5:00 PM (10 minutes)

A. This paper presents a summary of recent progress pertaining to the manufacturing and inspection of ITER gyrotrons and their operation system in QST. Major achievements are as follows: (i) The final design of ITER gyrotron was accomplished and manufacturing of 2 ITER gyrotrons was finished. Then their factory acceptance test (FAT) in QST has started with ITER relevant high voltage power supply configuration. The 1st ITER gyrotron has achieved 1 MW output power for 10 s pulse and 200 kW operation for 300 s which suggests thermally stable condition and sufficient cooling performance for 1 MW long pulse operation; (ii) The coupling function of gyrotron power into the transmission line (TL) waveguide was improved and calculation result of coupling efficiency was increased as high as 96.9% for the fundamental mode purity in waveguide inlet which could produce the sufficient LP01 mode purity in whole EC H&CD system. These results lead to success of ITER EC H&CD system construction toward first plasma.

B. As a part of in-kind contribution, India is responsible to deliver nine numbers (1 Prototype + 8 series production) of RF Sources to ITER system, each having power handling capability of 2.5 MW/CW at VSWR 2:1 in the frequency range 35 –65 MHz or 3.0 MW/CW at VSWR 1.5:1 in the frequency range 40 –55 MHz, along with other stringent requirements. As there is no such amplifier chain able to meet the output power specifications as per ITER need, the RF source consists of two parallel three-stage amplifier chains, with a combiner circuit on the output side. This kind of RF source is unique in terms of its stringent specifications. A voluntary R&D program by India has been initiated for establishing the high power technology prior to Prototype and series production, using Diacrode and Tetrode tubes. In this program, single chain experimentation at 1.5MW for 2000s is conducted for the frequency range 35-65 MHz up to VSWR 2:1, with any phase of reflection coefficient. The main objective for the R&D test is to confirm the system performance for the power, duration and frequency range as per ITER need and to check the reliability of both the tube and the amplifier with matched as well as with mismatched load (up to VSWR 2:1), which essentially simulates the plasma load condition. To support the R&D program, a dedicated high power test facility has been developed at ITER-India to test RF amplifiers based on both the technologies. For Diacrode based system, high power ITER relevant tests completed in 2016 and reported elsewhere [1]. Over the past two years, assembly and integration of R&D RF source using Tetrode technology at Indian test facility is completed with validation of all the relevant sub-systems/systems as standalone mode. The high power RF test using Tetrode based RF amplifier achieved 1.7MW of power for 3600s duration at 36 MHz. For other ITER operating frequencies, the system was operated at 1.5MW/2000s successfully.
This paper reports commissioning of RF amplifier using Tetrode technology with various operating scenarios, dissipation limit, safety system and challenges faced during high power operation at Indian test facility and describes the final outcome of R&D activity.

C. The European 1 MW, 170 GHz industrial prototype CW gyrotron for ECRH&CD on ITER is a conventional (hollow-cavity) gyrotron, which is being developed by the European GYrotron Consortium (EGYC) in cooperation with the industrial partner Thales Electron Devices (TED), under the coordination of the European Joint Undertaking for ITER and the Development of Fusion Energy (F4E). The CW industrial prototype was extensively tested in the short-pulse regime (with pulse length up to 10 ms) and operated under long-pulse conditions with pulse lengths of up to 180 s, which is the limit at the High-Voltage (HV) power supply currently available at KIT. In this contribution we report on the performance of the tube during the long-pulse operation at the KIT test facility, details regarding the operating points are presented and the long-pulse phase of the experiments with pulses up to 180 s is analyzed.

Country or International Organization

Japan

Paper Number

FIP/1-2Ra

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Session Classification: FIP/1 ITER Technology

Track Classification: FIP - Fusion Engineering, Integration and Power Plant Design