An overview of the ITER EC H&CD system and functional capabilities

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Introduction

A 24MW CW Electron Cyclotron Heating and Current Drive (EC H&CD) system operating at 170GHz is to be installed for the ITER tokamak. The EC system will represent a large step forward in the use of microwave systems for plasma heating for fusion applications; present day systems are operating in relatively short pulses (≤10s) and installed power levels of ≤4.5MW. The magnitude of the ITER system necessitates a worldwide collaboration. This is also reflected in the EC system that is comprised of the power supplies, sources, transmission line and launchers. A partnership between Europe, India, Japan, Russia, United States and the ITER organization is formed to collaborate on design and R&D activities leading to the procurement, installation, commissioning and operation of this system.

The aim of this paper is to provide a brief review of the design improvements incorporated following the ITER design review of 2007 and the increased functional capabilities.

Technical Design

The ITER EC system (shown in figure 1) is comprised of four main sub-systems: 13 high voltage power supplies, 26 gyrotrons, 24 transmission lines and five launching antennas, and the additional ancillaries (control system, cooling, infrastructures, etc.). The functional requirements are to deliver ≥20MW at 170GHz for pulse lengths ≥800sec to the plasma for central heating, current drive and control some of the plasma instabilities. The whole system is installed in three buildings. The power supplies (PS), gyrotrons and part of the transmission line (TL) are located in the RF building. The TL pass through the Assembly hall building to the tokamak, which houses the tokamak and the EC antennas (or launchers).

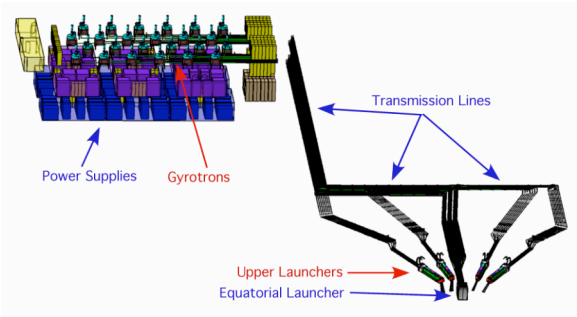

Fig. 1 The ITER EC system comprised of power supplies, gyrotrons, transmission lines and launchers.

These subsystems are integrated together to provide a maximum operating flexibility and minimum downtime due to component failure by introducing a modular structure[1]. For

example, a single power supplies is connected to two gyrotrons allowing control of the delivered power in increments of 2MW. In the event of failure a single PS, gyrotron, TL or launcher can be isolated to allow continued operation of the remaining EC plant. Pulse step modulated[2] (PSM) power supplies are to be used that enable rapid and fine control of the gyrotron output power and high frequency modulation capabilities (≤5kHz).

The gyrotrons[3-5] generate 1 to 2MW, have an electrical efficiency of >50% and a pulse length of 3,000sec. The gyrotron output power is in a TEM_{00} mode that efficiently couples to the HE_{11} corrugated waveguide (63.5mm diameter). The TL[6] guides the RF power from the gyotron over a distance of ~160m to the launchers with an estimated transmission efficiency of ~90%. In addition, the TL monitors the gyrotron output power, modifies the polarization for optimum plasma coupling and directs the power to a calorimetric load, the equatorial or upper port launchers via an in line switching system.

There are two types of launchers used to inject the EC power into the plasma: one equatorial (EL) and four upper (UL) launchers. The EL[7] has a total of 24 waveguide entries that are divided into sets of 8 beams on to three steering mirrors. The beams are steered in the toroidal (or horizontal) section, which provides access from on axis to near mid radius and maximizes the driven current. The ULs[8] have 8 entries split in two sets of 4 beams.

Functional Capabilities

The functional capabilities of the EC system strongly depend on the focusing and access range provided by the two launchers. The original baseline design (prior to 2007) partitioned the physics applications between the two launchers based on regions in the plasma. The EL accessing inside of $\rho_T \leq \sim 0.5$ for applications associated with central heating, current drive and sawtooth control. The UL accesses the region where NTMs are expected to occur between $\sim 0.55 \leq \rho_T \leq \sim 0.85$. The combination of two launchers could not achieve the desired accessibility. The design teams have modified the launcher designs increasing the access range and avoiding regions of non-accessibility as shown in figure 2. In addition the physics applications have been repartitioned between the two launchers[9], dividing the functional requirements based on the need for broad (EL) or narrow (UL) deposition profiles. The EL would still be used for central heating and current drive applications, while the UL used for the control of both the NTM and sawtooth instabilities. In addition, one third of the EL beams are to provide counter current drive to decouple the heating and current drive contributions when depositing power centrally[10].

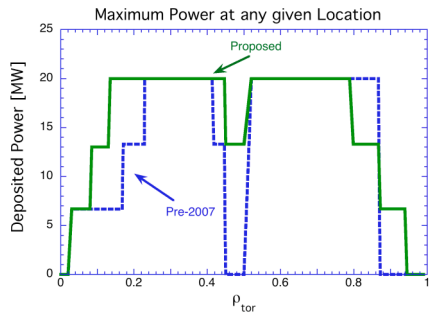

Fig. 3 The accessibility of the combined EL and UL is illustrated as the maximum power that can be deposited at any given location. The blue dashed line corresponds to the baseline configuration and the green line to the proposed re-partitioning of the physics applications between the UL and EL[9].

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