Contribution ID: **518** Type: **Poster**

FTP/P1-22: Advances in Lower Hybrid Current Drive Technology on Alcator C-Mod

Tuesday, 9 October 2012 08:30 (4 hours)

Lower Hybrid Current Drive is an attractive option for non-inductive tokamak operation due to its high current drive efficiency and ability to drive current off axis. The parameters of the Alcator C-Mod LHCD system (f = 4.6 GHz, B ≈ 5.5 T, n_e ≈ 10ˆ20 mˆ-3) are similar to the proposed LHCD system on ITER. The 0.5 s pulses achieved in previous operation are sufficiently long as compared to the current relaxation timescale (tau_R ˜ 0.2 s) for quasi-steady state non-inductive operation. Longer pulses are necessary for other plasma parameters to reach equilibrium once the current profile has been modified. Modeling of LH wave propagation indicates that the loss of LHCD efficiency at high n_e can be mitigated by enhancing the single pass power absorption. This paper will describe improvements in LHCD technology on C-Mod designed to extend pulse length (to ˜ 3 s), increase power delivered to the plasma through reducing reflection coefficients (to < 10 %), and increase single-pass absorption at high n_e. Total net LH power with the additional antenna will be ˜2 MW.

An off mid-plane launcher has been designed combining the 4-way poloidal splitting concept of the current LH launcher on C-Mod with a toroidal bi-junction. The new antenna was optimized to decrease reflected power and increase directivity over a broad range of plasma conditions and launched n|| values. The four rows of the launcher are located above the mid-plane in order to exploit the poloidal upshift of n|| as rays propagate from the antenna into the plasma. The n|| upshift results in better wave penetration to the plasma core at high n_e (> 10ˆ20 mˆ-3) and stronger single-pass absorption of the LH waves.

The maximum LHCD pulse length on C-Mod is limited by heating in the collector of the klystrons. Modeling shows that the klystron can operate for 5 seconds without boiling the coolant at full RF power, but the coolant will boil after 1.2 s of beam-on time with no RF power. The maximum pulse length was restricted to 0.5 s to prevent boiling. Increasing the LH pulse length to ˜3 s will allow the LH system to remain on for ˜15 x tau_R and extend the I_p flattop. The Transmitter Protection System was redesigned to model the coolant temperature in real time. The electron beam is shut off if the TPS determines that the coolant boils. The TPS upgrade has been installed and operated on C-Mod.

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Session Classification: Poster: P1

Track Classification: FTP - Fusion Technology and Power Plant Design