Thesis Talk

Title: Biased Electrode Experiments in ADITYA tokamak

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Abstract

For achieving controlled thermonuclear fusion in tokamaks, they must be operated in higher confinement mode (H-mode), which had been discovered in ASDEX tokamak with auxiliary heating (NBI) in 1982. Although all the present day tokamaks are operated in H-modes, underlying physics of transition from low confinement mode (L – mode) to high confinement mode (H – mode) still not fully understood. Several experiments and theories established that radial electric field plays an important role in the transition. This notion has been successfully proven in an experiment in CCT tokamak where an externally biased electrode was introduced in the outer edge region of the tokamak to obtain L – H transition. Since then the electrode biasing became the most popular tool to study L – H transitions in smaller tokamaks with limiter/divertor configurations. Considerable support for the model of sheared radial electric field causing enhanced local shear flows leading to suppression of electrostatic turbulence and to attain higher confinement regimes. Several recent experiments, however, have generated renewed interest in electrode biasing experiments through observations of substantial modifications in magnetic fluctuations as well as in toroidal current density profiles.

To investigate the effect of biased electrode on ADITYA tokamak plasmas, especially on the MHD modes, a newly designed electrode biasing system (EBS) has been constructed, installed and tested on ADITYA tokamak. Especially designed double-bellow mechanical assembly is fabricated for controlling the electrode location as well as its exposed length inside the plasma. The cylindrical molybdenum electrode is powered by a capacitor-bank based pulsed power supply (PPS) using a semiconductor controlled rectifier (SCR) as a switch with forced commutation constructed in-house. Apart from the standard results of

improvement of global confinement, substantial reduction MHD fluctuations have been observed prior to the suppression of electrostatic fluctuations using biased electrode in ADITYA tokamak. This result of control of MHD modes with biasing has been used to control plasma disruptions in ADITYA tokamak and it has been shown for the first time that the electrode biasing can be used to avoid disruptions through stabilisation of magneto-hydrodynamic (MHD) modes. Disruptions, induced in ADITYA tokamak by hydrogen gas puffing, are successfully mitigated through stabilization of magneto-hydrodynamic (MHD) modes by applying a bias voltage to the electrode prior to the gas injection. Above a threshold voltage sheared $E_r \times B_\phi$ rotation of the plasma generated by the edge biasing leads to substantial reduction in the growth of MHD modes (m /n = 3/1, 2/1), which causes avoidance of disruptions through prevention of mode overlapping and subsequent ergodization of magnetic field lines. Thorough investigations revealed the causality of events in which magnetic fluctuation suppression is always found to be preceding the electrostatic fluctuation suppression.

With raising the bias voltage sharply on the electrode, the steepening of radial electric field is observed twice in a single biasing pulse. The radial electric field profile steepens almost simultaneously with the application of voltage to the electrode leading to increased shear in plasma poloidal rotation through $E_r \times B_\phi$. This sheared rotation leads to suppression of only MHD modes at this time and the radial electric field profile starts flattening after that. Slight increase in both global plasma temperature and density is observed at this time. Within 4 -8 ms into the biasing pulse a transition is observed when the electrode current falls sharply with the electrode voltage remaining constant leading to higher radial resistivity and improved confinement. At this moment the radial electric field profile steepens again and with this, suppression of the electrostatic modes are observed with the global plasma temperature and density increasing again. Hence, the observations suggest a formation of two barriers at two different times into the biasing voltage pulse with suppression of drift-Alfven waves possibly triggering the transition at the onset of bias voltage.

As different electrode dimensions have been used in different tokamaks for achieving the transition to the improved state, experiments with variable electrode dimension have been carried out using an especially designed double-bellow mechanical assembly. Most of results related to the improved confinement and disruption mitigation are obtained in case of the electrode tip being kept at ~ 3 cm inside the last closed flux surface (LCFS) with an exposed length of ~ 20 mm in typical discharges of ADITYA tokamak.