# 3-DIMENSIONAL VACUUM FIELD MODELING AND EDGE PLASMA RESPONSE TO APPLIED RADIAL MAGNETIC PERTURBATION IN ADITYA-U TOKAMAK

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Despite being small ($\delta B/B \sim 10^{-4}$) in comparison to the equilibrium field, error fields caused by unavoidable imperfections in the primary coils in tokamak can impart significant effects in tokamak plasma. The present work explores the application of a nearly steady-state radial magnetic perturbation at the plasma edge of Aditya –U tokamak and analyses the effect of the localized, non-resonant radial magnetic field on edge plasma of Aditya-U using a linear 3-dimensional MHD code, Generalized Perturbed Equilibrium Code (GPEC) [1]. Prior to simulating the edge plasma response, a three-dimensional vacuum field estimation for the Aditya-U tokamak, incorporating all existing coils and the radial field coil, was performed using COMSOL Multiphysics [2]. This study aims to examine the impact of radial magnetic perturbation on edge plasma transport, neoclassical toroidal viscosity (NTV) torque generation and its consequential effect toroidal plasma rotation in Aditya-U tokamak. The radial field coil is designed and simulated to produce ~25 G of nearly steady state radial field at edge plasma. The fabricated coil, mounted on a radial port of Aditya-U machine, is charged with the power source derived from energy storage capacitor, the time constant of the charging circuit being ~100 ms to get nearly constant radial field perturbation during Aditya-U shots. The location of the coil in the poloidal cross-section is shown in Fig 1 (i). The vacuum field for Aditya-U is estimated by incorporating OT, TR coil sets, Equilibrium coil, Correction coil and localised radial magnetic field coil [3]. The 3D model of the Aditya U coil assembly and the volumetric plot of 3D magnetic flux density are shown in Fig 1 (ii) and 1(iii) respectively.

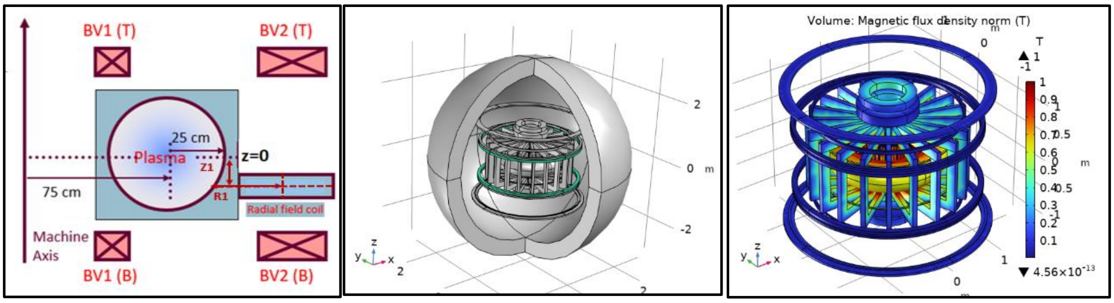


Fig 1 (i) Location of Radial Field Coil in Poloidal cross-section, (ii) 3D model of Aditya-U coil assembly, (iii) Volumetric Magnetic Flux Density plot

The Generalized Perturbed Equilibrium Code (GPEC) suite was used in the present study to evaluate the stability of tokamak plasma against non-axisymmetric perturbation and the force balance within the plasma. The equilibrium file for Aditya-U is generated through pyIPREQ code, an enhanced version of IPREQ code and is used to specify the original axisymmetric equilibrium. The toroidal current density and the poloidal flux surface of Aditya-U plasma as generated through pyIPREQ code [4] is shown in Fig 2. The three-dimensional error field data or the radial field coil geometry details are specified on the surface of the GPEC plasma boundary. Few case studies dealing with non-axisymetric perturbation in other machines like D-IIID, KSTAR are carried out using GPEC package before simulating the non-axisymmetric perturbation in Aditya-U.

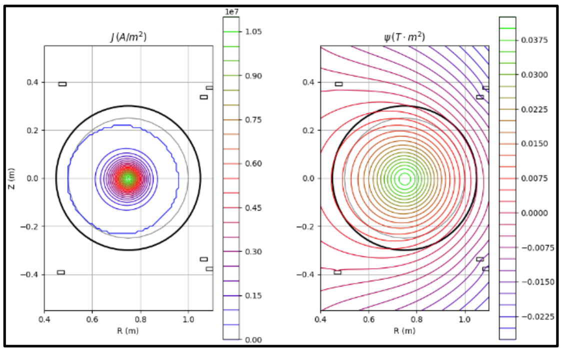


Fig 2: Toroidal Current Density and Poloidal Flux Surface Contour Plot for Aditya-U plasma

Many studies have demonstrated that non-axisymmetric magnetic perturbations can drive NTV, leading to changes in toroidal rotation profiles [5]. In Aditya-U tokamak, intrinsic toroidal plasma rotation has been experimentally measured using a multi-track visible spectrometer to detect the Doppler-shifted spectral lines of $C^{5+}$ ions at 529.05 nm [6]. The same experiment were carried out in several Aditya-U shots while applying non-axisymmetric perturbation in edge plasma. The present work will discuss about the initial signature of alternation of plasma rotation during the application of non-axisymmetric perturbation and its correlation with the simulation outcome including neoclassical toroidal viscosity (NTV) and non-resonant transport effects.

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## REFERENCES

[1] Jong-kyu Park, Allen H. Boozer, Alan H. Glasser, Computation of three-dimensional tokamak and spherical torus equilibria, Phys. Plasmas 14 (5) (2007) 052110

[2] COMSOL Multiphysics, version 6.3, License No 1070169 (FNL); www.comsol.com

[3] Tanna R. et al 2022 Overview of Recent Experimental results from the ADITYA-U Tokamak *Nucl. Fusion 62 04201*.

[4] Deepti Sharma et al, Aditya Upgradation –Equilibrium study, FUSION ENG DES 160 (2020), 111933

[5] H. Sheng, et al, Acceleration of plasma toroidal rotation driven by non-axisymmetric magnetic perturbation fields in the EAST tokamak, Phys. Plasmas 31 (3) (2024) 032507

[6] Ankit Kumar et al 2024 Nucl. Fusion 64 086019