Electromagnetic analyses for Indian Tokamaks SST-1 and ADITYA

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Abstract

Tokamaks are the leading plasma confinement concept for future fusion power plants. As a part of Indian Fusion Programme, first Indian tokamak ADITYA and first Indian steady superconducting tokamak SST-1 are being operated at Institute for Plasma Research. These are fairly complex machines with several magnetic field coils (TF, PF & central solenoid etc.) to produce, confine and control plasma at high temperature in a toroidal vacuum vessel. In this article, finite element based electromagnetic analysis work carried out for these two Indian tokamaks SST-1 and ADITYA is summarized. Using Comsol Multiphysics AC/DC Module, a detail electromagnetic simulations have been carried out to calculate 3-D magnetic field profiles, error fields due to coil misalignments, eddy currents generated due to transient fields, transient electromagnetic forces & stresses on various coils and magnetic null correction requirements etc.

Cross section view & coil configuration in Aditya & SST-1 tokamaks:

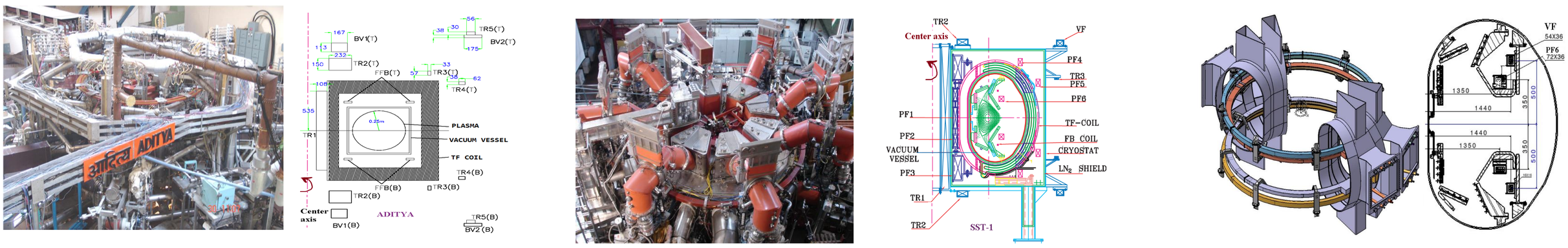

FIGURE 1. Cross section view of the machines with coil configuration in Aditya and SST-1 tokamaks

Methodology:

The complex geometry is discretized (as shown in the Finite Element Models) & AC/DC Module of Comsol Multiphysics is used to solve the governing equations.

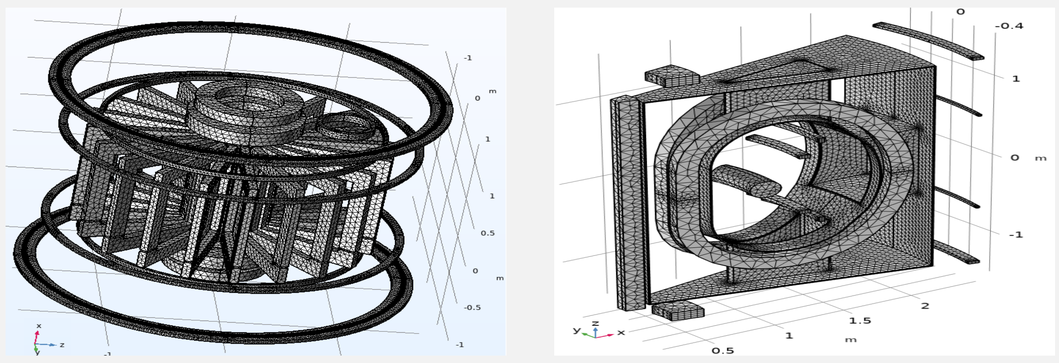

FIGURE 2. Finite Element Models of Aditya & SST-1

Governing Equations

$$\nabla \times \boldsymbol{B} = \mu \boldsymbol{J}$$

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$

$$\nabla . \boldsymbol{B} = 0$$

$$J = \sigma(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) + \boldsymbol{J_e}$$

$$\sigma \frac{\partial \boldsymbol{A}}{\partial t} + \nabla \times \left(\frac{1}{\mu_o} \nabla \times \mathbf{A}\right) = J_e$$

$$f_v = \boldsymbol{J} \times \boldsymbol{B} = \frac{1}{\mu}(\nabla \times (\nabla \times A)) \times (\nabla \times A)$$

Results:

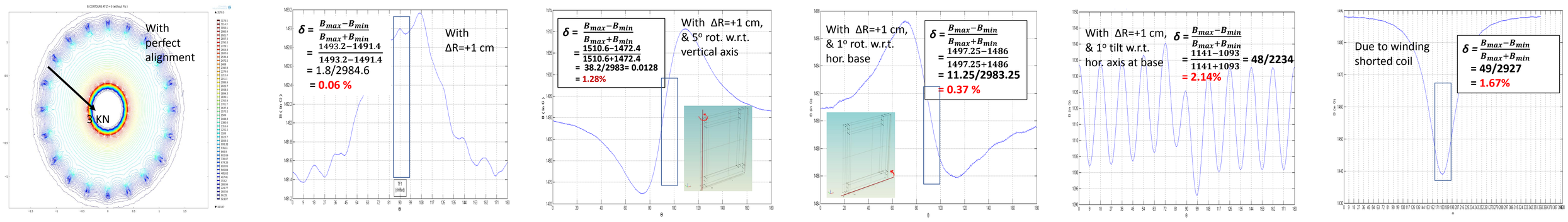

FIGURE 3: (In Aditya Tokamak) Toroidal Field with perfect alignment & radially inward force on each TF coil; Ripple with TF coil shifted outward ΔR=+1 cm; With ΔR=+1cm, 5° rot. w.r.t. vertical axis; With ΔR=+1cm, 1° rot. w.r.t. hor. base; With ΔR=+1cm, 1° tilt. w.r.t. hor. axis; Due to winding shorted

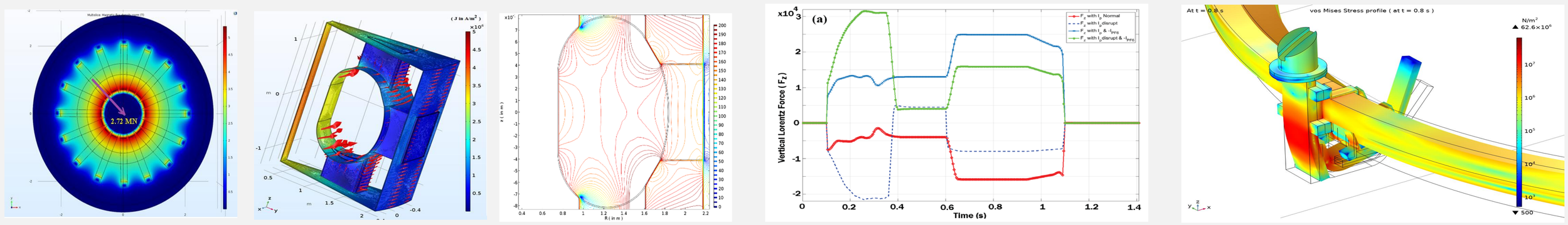

FIGURE 4: (In SST-1 Tokamak) Toroidal Field with perfect alignment & radially inward force on each TF coil; Eddy current in vessel & cryostat due to OT ramp; Distorted magnetic null due to Eddy currents; Typical transient Lorentz forces on in-vessel coil PF6; magnetic stress due to same

References:

1. Comsol Multiphysics http://www.comsol.com/
2. YC Saxena and SST-1 Team,"Present Status of the SST-1 project", Nuclear Fusion, 40, 1069 (2000)
3. Dhiraj Bora, Brazilian Journal of Physics, 32(1),193 (2002)

Excerpt from the Proceedings of the 2023 COMSOL Conference