ID: 499

Development of a new CODAS for the TCABR Tokamak

W.P. de Sá[1], G.P. Canal[1], J.J.F.G. Ramirez[3], J.H.F. Severo[1], I.C. Nascimento[1], R.M.O. Galvão[1,4], A.O. Santos[2], W. Komatsu[3], F. Kassab[3], J.G. Ferreira[4], M.C.R. de Andrade[4], and J.R.C. Piqueira[3]

[1]Institute of Physics of the University of São Paulo, São Paulo, Brazil

[2]Mauá Institute of Technology, São Caetano do Sul, Brazil

[3]Polytechnic School of the University of São Paulo, São Paulo, Brazil

[4]Nacional Institute for Space Research, São José dos Campos, Brazil

pires@if.usp.br

ABSTRACT

- An upgrade is being conducted on the TCABR tokamak, which is a small-size tokamak (R0 = 0.62 m and a = 0.2 m) operated at the University of São Paulo, Brazil. This upgrade consists mainly in the installation of
  i. graphite tiles to cover entirely the inner surface of the vacuum vessel wall
  ii. new poloidal field (PF) coils to allow for the generation of various divertor configurations such as single-null, double-null, snowflake and x-point target divertors,
  iii. in-vessel HFS and LFS non-axisymmetric control coils for ELM suppression studies, and
  iv. a coaxial helicity injection system to improve plasma start-up.

- The creation of the various plasma scenarios that are envisaged for TCABR will require a robust and flexible plasma control system.
- The new TCABR plasma shape and position control is being designed and will be based on a feedback PID technique. The design of the new PID controllers will be carried out using the so-called RZIp model

TCABR Upgrade – Needs and Challengers

WHY THE UPGRADE

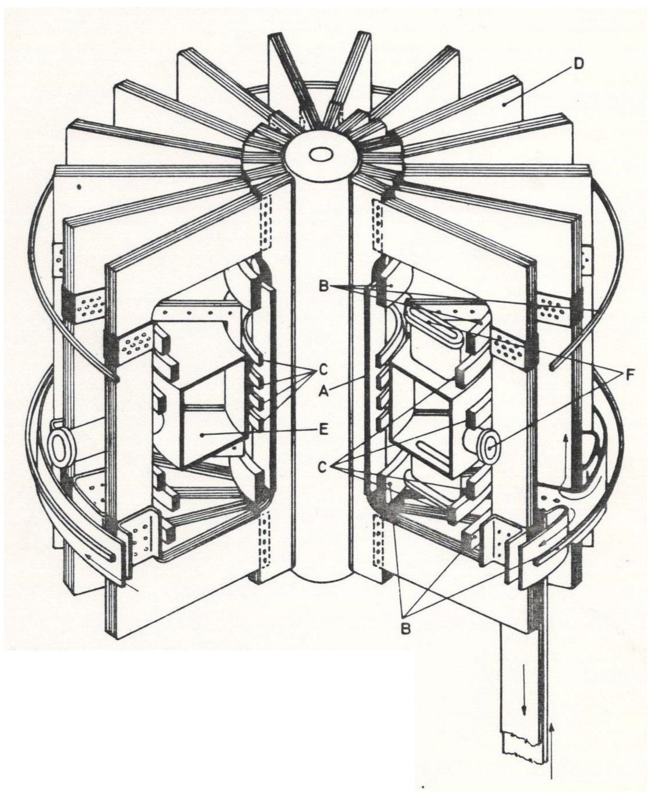
- The proposed upgrade of the TCABR tokamak provides for the study of plasmas with more varied forms that are relevant to controlled thermonuclear fusion.

CHALLENGERS

- However, plasmas with elongated configuration are vertically unstable.
  - The instability has μs time scale – too fast to control

SOLUTIONS

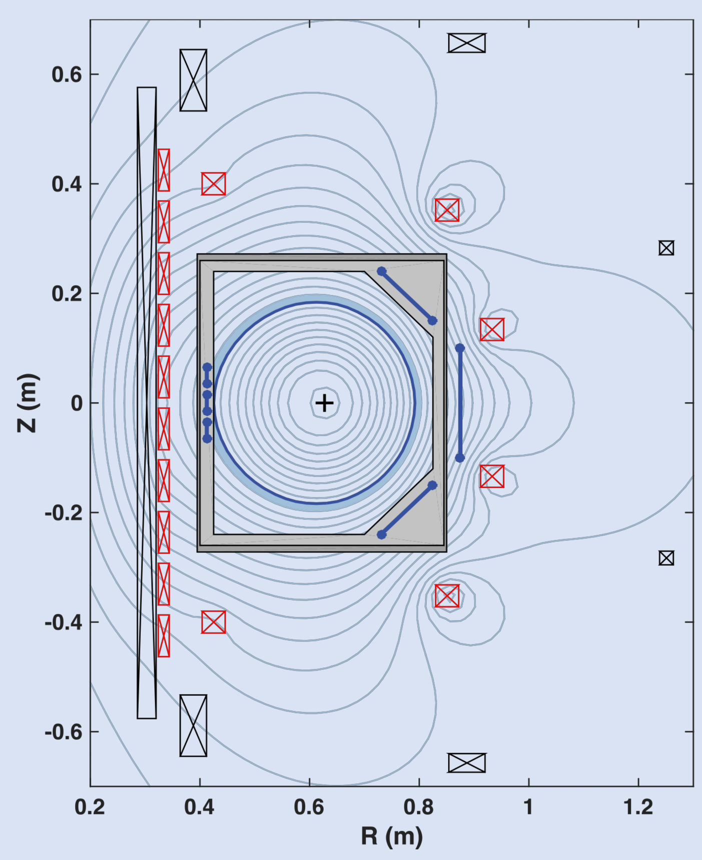
- For such plasma formats to be obtained, it will be necessary to control a set of 17 magnetic coils responsible for plasma control.
- Change vessel - continuous torus: induced vessel currents ("eddy currents") creates a counteracting radial field: up-down symmetric vessel current modes are excited.



TCABR Tokamak

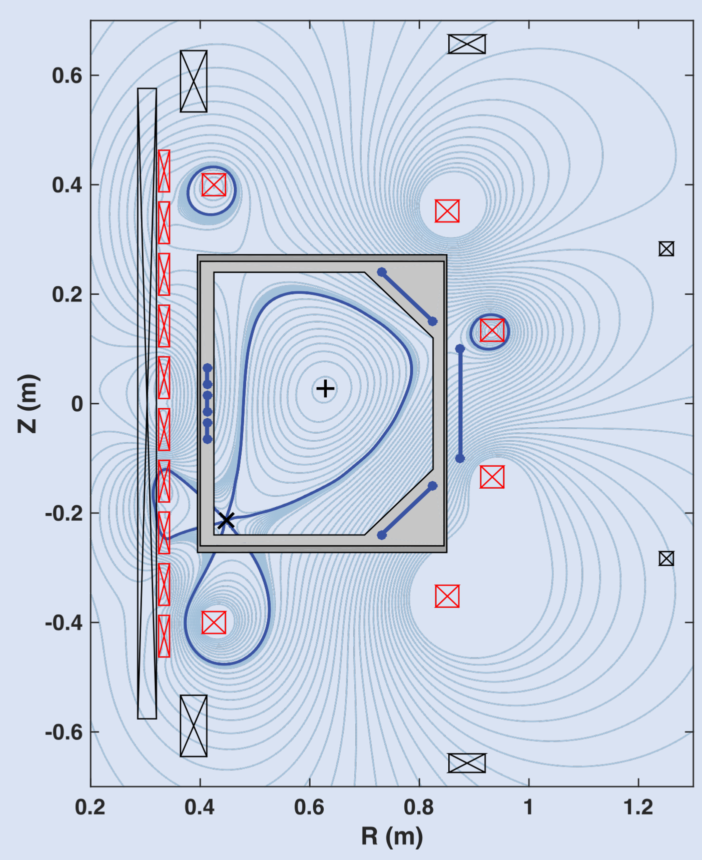
- TCABR is a small-sized tokamak (R_0 = 0.62m and a=0.2m) of maximum I_P=120kA and B_0=1.5T
- The configuration of magnetic fields allows only plasmas with circular plasma configuration.
- For position control a sophisticated control system is not required, since there is stability in vertical displacement.

Present Configurations



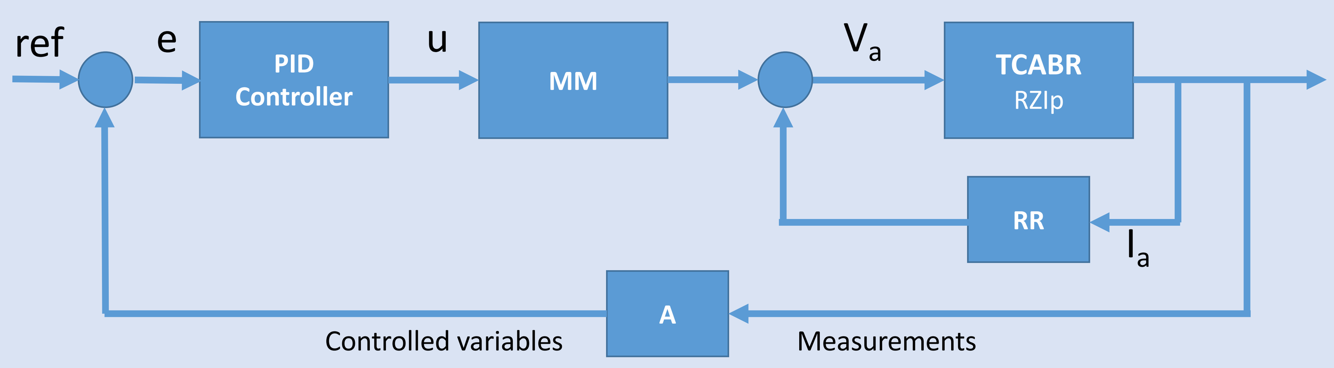
TCABR Circular Configuration

Upgrade



TCABR Snowflake Configuration

TCABR Magnetic Control Overview



TCABR RZIp model

- **RZIp**: The TCABR is going to use the conventional model
  - Circuit equations for active conductors, passive conductor, plasma
  - Force balance for plasma position
  - Linearized model

$$\begin{bmatrix} \boldsymbol{M}_{aa} & \boldsymbol{M}_{av} & \boldsymbol{M}_{ap} & \frac{\partial M_{ap}}{\partial R} & \frac{\partial M_{ap}}{\partial Z} \\ \boldsymbol{M}_{va} & \boldsymbol{M}_{vv} & \boldsymbol{M}_{vp} & \frac{\partial M_{vp}}{\partial R} & \frac{\partial M_{vp}}{\partial Z} \\ \boldsymbol{M}_{pa} & \boldsymbol{M}_{pv} & L_P & M_{pR} & 0 \\ \frac{\partial M_{pa}}{\partial R} & \frac{\partial M_{pv}}{\partial R} & M_{Rp} & M_{RR} & M_{RZ} \\ \frac{\partial M_{pa}}{\partial Z} & \frac{\partial M_{pv}}{\partial Z} & 0 & M_{ZR} & M_{ZZ} \end{bmatrix} \frac{d}{dt} \begin{bmatrix} \boldsymbol{I}_a + \delta \boldsymbol{I}_a \\ \boldsymbol{I}_v + \delta \boldsymbol{I}_v \\ I_P + \delta I_P \\ I_P + \delta R \\ I_P + \delta Z \end{bmatrix} + \begin{bmatrix} \boldsymbol{R}_a & 0 & 0 & 0 & 0 \\ 0 & \boldsymbol{R}_v & 0 & 0 & 0 \\ 0 & 0 & R_P & \frac{\partial R_p}{\partial R} & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \boldsymbol{I}_a + \delta \boldsymbol{I}_a \\ \boldsymbol{I}_v + \delta \boldsymbol{I}_v \\ I_P + \delta I_P \\ I_P + \delta R \\ I_P + \delta Z \end{bmatrix} = \begin{bmatrix} \boldsymbol{V}_0 + \delta \boldsymbol{V} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

- **The elements**: (a): $active\ coils$ (v): $vessel$ (p): $plasma$
  - **Matrix MM**: Mutual inductance matrix between the several elements
  - **Matrix RR**: Resistance
  - **Vector I**: Current at the several elements
  - **Vector V**: Voltage Induced

RESULTS

- All the matrix have been build
- The codes for the Poloidal Field coils controller have development.
- Tests using the TCABR circular plasma configurations data is going to be started

ACKNOWLEDGEMENTS

REFERENCES

- D.Muller et all, Fusion Engineering and Design, 141 (2019) 9