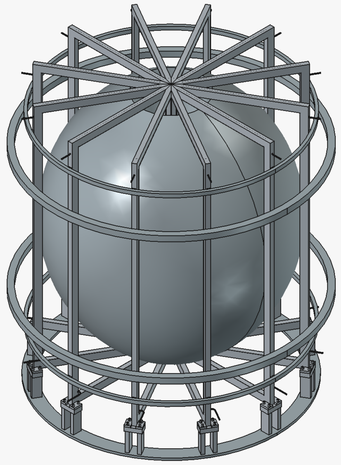
Modelling and Control of Tokamak Plasmas

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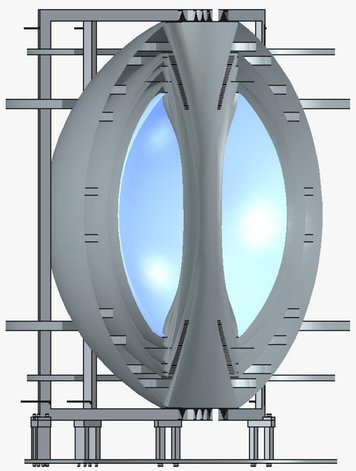
Tokamaks confine hot plasma. FORTIS helps to understand axisymmetric plasma dynamics and plan control actions.

Design 59919A

A physical reference for dynamic modelling



External reactor assembly



Cutaway and internal build

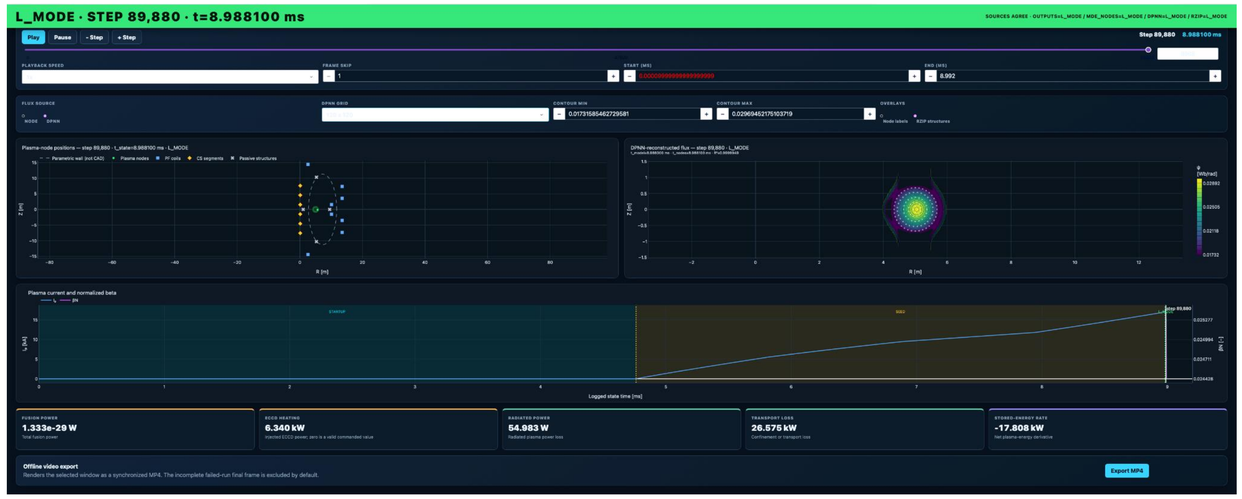
5.00 m
Major radius

26.75 MA
Design plasma current

2,200 MW
Design fusion power

FORTIS

Control-oriented multiphysics simulation



Recorded simulation: plasma geometry, magnetic flux and current history

Burn and fuel	Density, temperature, fusion power and inventories
Current and flux	Plasma current, loop voltage and magnetic evolution
Motion and rotation	Plasma boundary, node motion and toroidal rotation
Inputs and modes	Fuel, heating and current drive across discharge regimes

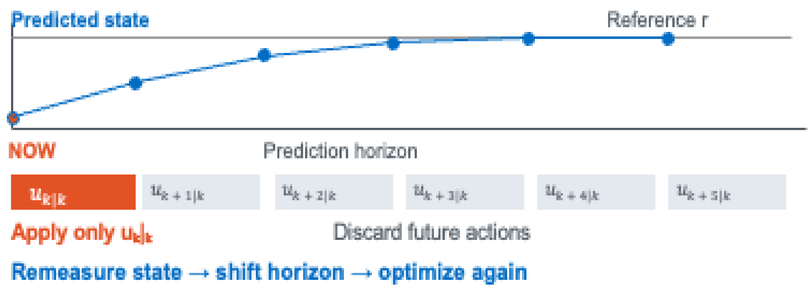
APECS (Autonomous Plasma Control and Estimation System)

Model predictive control (MPC)

$$x_{k+1} = A_d(\rho_k)x_k + B_d(\rho_k)u_k$$

$$min_U \sum_{j=0}^{N-1} \left(\|e_j\|_Q^2 + \|u_{k+j|k}\|_R^2 \right) \; Subject\ to\ LMI\ and\ state-space\ constraints$$

$$e_j = x_{k+j|k} - r$$



Controller

Objective

$$min_U \sum_{j=0}^{N-1} \left(\|e_j\|_Q^2 + \|u_j\|_R^2 \right)$$

QIS equality constraint

$$x_{j+1} = \sum_{b \in S} \tilde{w}_b(\rho_j)(A_{d,b}x_j + B_{d,b}u_j)$$

$$x_0 = \hat{x}_k, \qquad e_j = x_j - r$$

LMI inequality constraint

$$X \succ 0, \quad \begin{bmatrix} X & M_i^T \\ M_i & X \end{bmatrix} \succ 0 \qquad M_i = A_{d,i}X + B_{d,i}Y, \qquad i \in S$$

u

Plant

LPV model

$$\dot{x} = A(x)x + B(x)u$$

$$y = C(x)x + D(x)u$$

y

$\hat{x}$

Sensing, equilibrium and boundary reconstruction