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Improved Fusion Reactor Designs as per Integration of Advanced Physics and Technology Systems Code Modules

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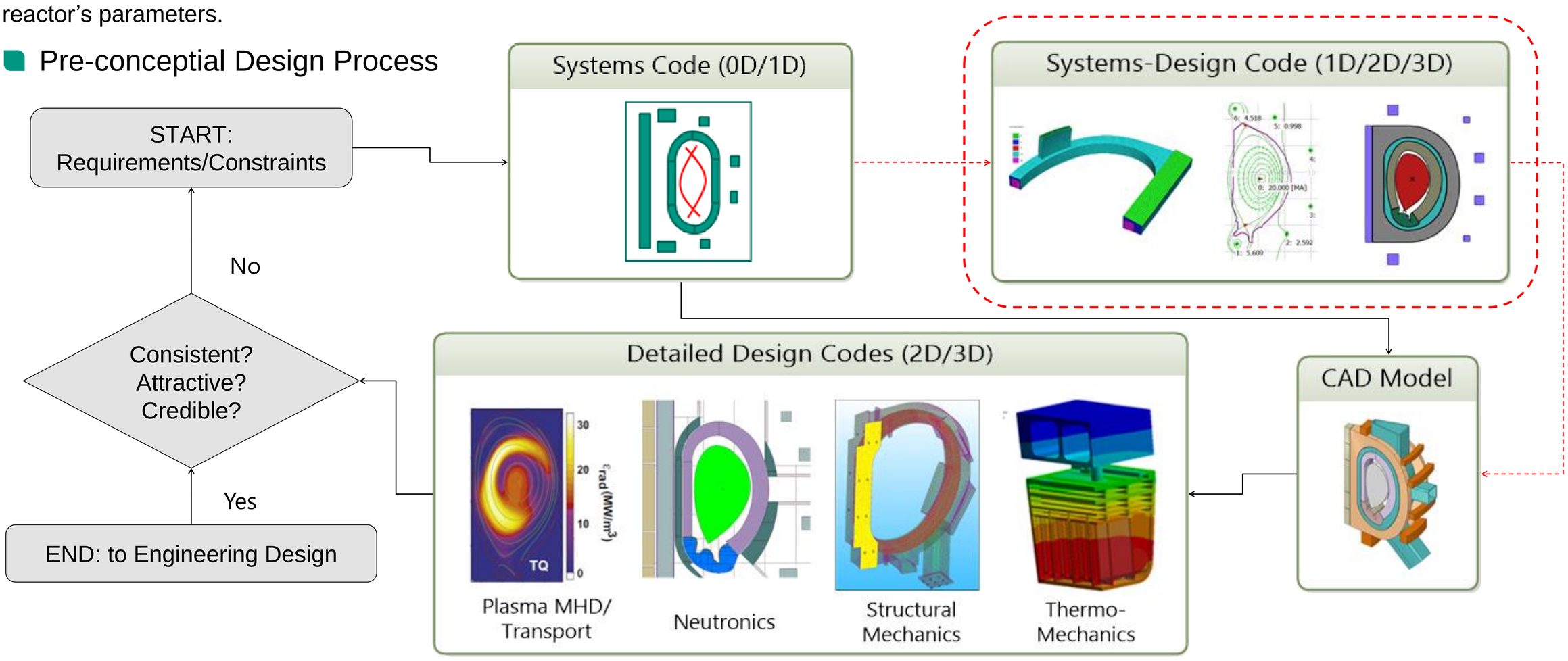
Abstract

At Karlsruhe Institute of Technology a new modelling activity has been recently launched aiming to develop advanced models for fusion reactors systems codes, focusing on the main technology areas such as neutronics, thermal-hydraulics, electromagnetics, structural mechanics, fuel cycle and vacuum systems. Moreover, in order to prove the plant design so obtained from the physics standpoint, two important physics submodules were added and adapted to the project: the TREND and the TOKES codes, developed at Max-Planck-Institute for Plasma Physics Garching and KIT respectively. In this study the applied methodology is briefly described and the numerical results related to some improved reactor designs (e.g. based on current DEMO proposal) are reported and discussed. The main goal is to show the impact of accuracy and assumptions of the implemented models on main reactor's parameters.

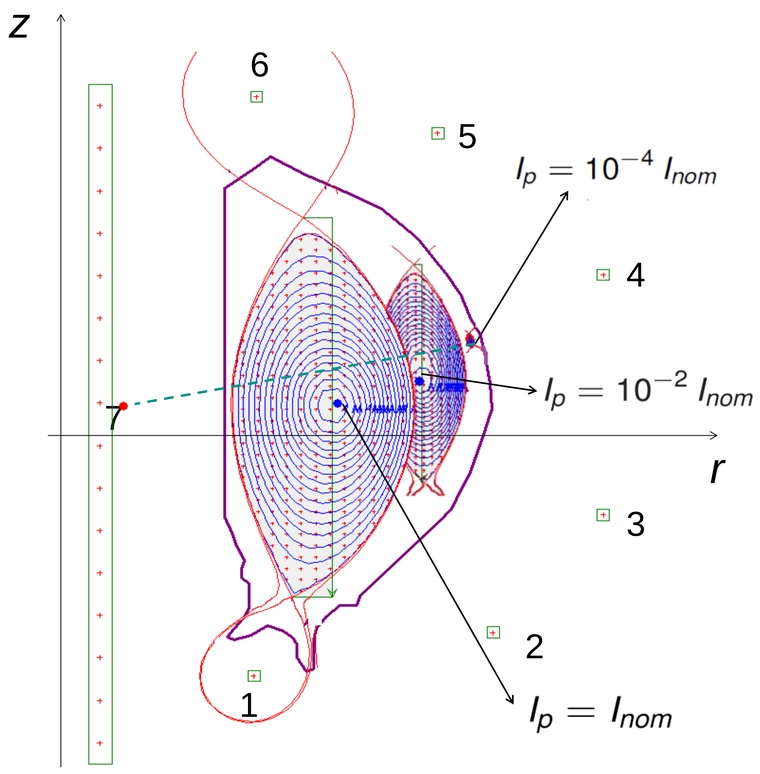
- Pre-conceptial Design Process



- Integration of TREND code (IPP)
  - Zero-dimensional plasma power balance

$$P_\alpha + P_{add} + P_{oh} = P_{rad} + P_{con} = P_{sep}$$

- Integration of TOKES code (KIT)
  - Simulation of ramp-up as per ideal plasma model ($0 \le t \le \tau_{RU}$)
  - Characterization of complete magnetic configuration
  - Use of Green function $\boldsymbol{G_{s,k}}$ for current $I^{(k)}$ and pol. field $\boldsymbol{B_s}$ *(s=r,z)*

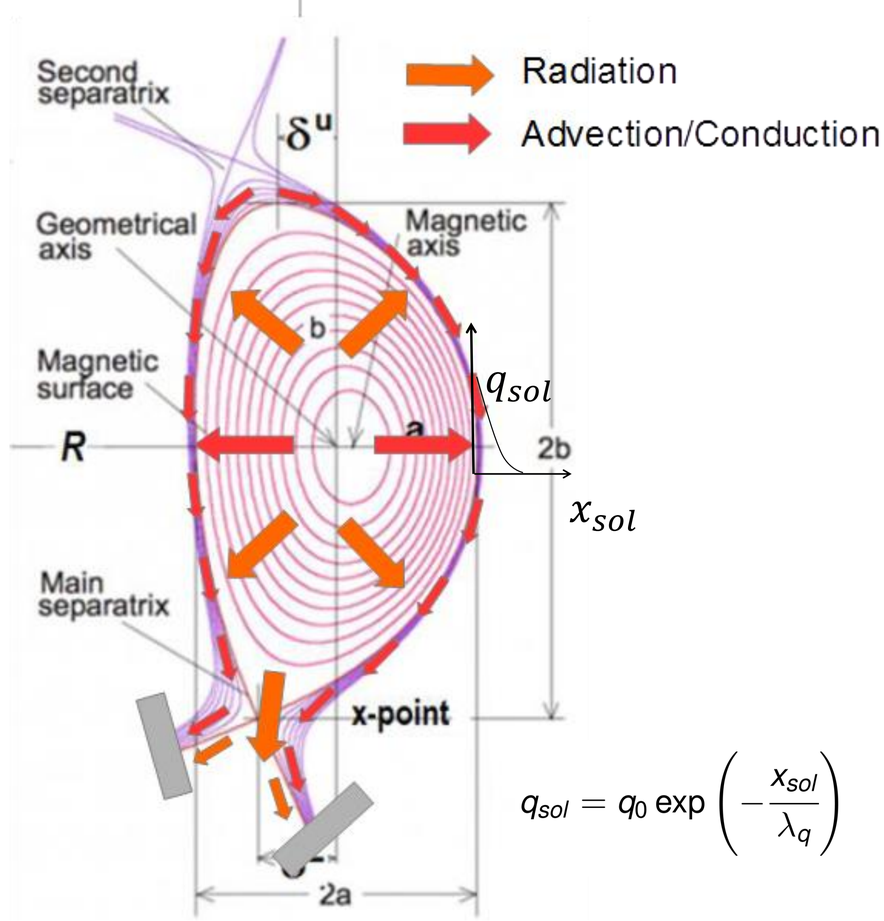


$$\begin{cases} B_s(\boldsymbol{p_x}(t_i)) = \sum_k G_{s,k}(\boldsymbol{p_x}(t_i)) I^{(k)} = 0 \\ \sum_k I^{(k)} = -I_p(t_i) \\ I_p(t_i = \tau_{RU}) = I_{nom} \end{cases}$$

Calculation of PF Coil currents

$$I^{(k)}(t_i) \qquad 0 \le t_i \le \tau_{ru}, \quad k = 1, \ldots, 7$$

- Divertor Model (IB and OB peak heat flux)



$$q_{sol} = q_0 \exp\left(-\frac{x_{sol}}{\lambda_q}\right)$$

$$q^{peak}_{con,ob} = P_{sep,ob} \cdot \left(\frac{\sin\beta_{ob} \cdot (1 - f_{rad})}{2\pi \overline{R_{w,ob}}\, \lambda_q f_{exp,ob}}\right)$$

from TREND — from TOKES