MODEL BASED PREDICTIVE CONTROL OF TOKAMAK PLASMA CURRENT PROFILE

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The control of the current density profile is now recognised as a key issue to improve the confinement and stability of tokamak plasma experiments. The control of one single profile shape parameter has been experimentally performed in several fusion devices but control of the entire profile is still an area of lively research that requires, due to the complex distributed nature of the problem, a model-based approach.

In this work, we use a new predictive control strategy based on a control-oriented model using a 1D magnetic flux diffusion equation ([1]). Contrary to standard approaches based on black boxes linearized plasma response model, this approach allows to keep the non linear fully distributed features of the current profile dynamics. The objective is to design a controller using both inductive means (variation of magnetic flux at the plasma edge) and non-inductive means (Lower Hybrid Current Drive and Electron Cyclotron Current Drive). Kinetic variables such as the electronic temperature, usually available in real time, are considered as inputs for the estimation, for instance, of the plasma resistivity.

The principle of the predictive control strategy is the following: at each sampling step, the request to the actuators is derived from the minimisation of a criterion based on the error between the current profile target and model prediction at steady state. The actual current profile target is also reprocessed at each sampling step in order to handle the difference between the current profile model prediction and measurements (self – compensator).

Successful closed-loop simulations have been performed using Tore Supra experimental data while taking as a target the current profile experimentally obtained at the end of flat-top. An extensive sensitivity analysis has also been made by varying several parameters of the reference model, showing the robustness of the proposed strategy. The real-time relevance of the method was also successfully checked. Test of this strategy on a more sophisticated plasma response simulator, like for instance the CRONOS suite of codes ([2]), is foreseen, before final implementation on real experiments.

[1] E. Witrant et al., « A control-oriented model of the current profile in tokamak plasmas », Plasma Physics and Controlled Fusion 49, 2007, p. 1075-1105.

[2] V. Basiuk et al., « Simulations of steady-state scenarios for Tore Supra using the CRONOS code », Nuclear Fusion 43, 2003, p 822 -830.