A generalized plasma shape and position controller for the TCV tokamak

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Improved performance of a tokamak plasma for controlled thermonuclear fusion is obtained via shaping the plasma to achieve an elongated cross section. The challenge of this approach lies in the fact that elongated plasmas are vertically unstable, and need to be feedback controlled. In the TCV tokamak, an advanced shape control algorithm was recently implemented, integrated within the digital control system, and tested for accessing advanced configurations, in particular negative triangularity and snowflake plasmas. In the present architecture, shape control and position stabilization are coupled problems as they share the same set of actuators, the poloidal field coils, and rely on the same information coming from a real time equilibrium reconstruction code, introducing a computational delay in the feedback loop. This feature limits the routine use of the advanced shape controller since the delay reduces the operational window for vertical stabilization and requires fine online tuning of the controller over many shots. A new proposed approach [1] is able to tackle this issue by a frequency separation of the shape and position control problems. Fast estimations of the plasma position obtained directly from magnetic measurements are used to stabilize the vertical dynamics at high frequency, while the shape and position control act on slower time scales on a stable system. This decoupling controller is designed using loop shaping techniques from control theory on TCV plasma models with progressively increasing levels of complexity. This scheme, similar to what will be used on the ITER tokamak, is being implemented in TCV and is expected to provide reliable access to advanced configurations avoiding undesired vertical displacement events. It will be in fact possible to leverage on former operational experience on plasma stabilization with the analog control system for a large variety of plasma shapes. Experimental tests of the generalized shape and position controller in TCV plasma discharges will be presented. Improved performance will be quantified through a comparison of dedicated figures of merit for identical shots, which will be performed featuring respectively the new digital and the former analog architecture. The final goal is to commission a unified control system for TCV magnetic control to be used in routine operation.

[1] De Tommasi et al. “On plasma vertical stabilization at EAST tokamak". In: 2017 IEEE Conference on Control Technology