CLOSED LOOP CONTROL OF REVERSAL PARAMETER IN RFX-MOD

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In a fully-developed Reversed Field Pinch (RFP) plasma discharge, the toroidal flux is mainly generated by the plasma itself converting the poloidal flux through the dynamo process, a peculiar phenomenon in RFP physics [1]. The MHD equilibrium configurations lie along the so called F-Θ diagram, where the reversal parameter F=Bt(a)/<Bt> and Θ=Bp(a)/<Bt>, Bt(a) and Bp(a) being the toroidal and poloidal components of the magnetic field at the plasma edge, respectively, and <Bt> the toroidal field averaged along the minor radius. Variations in the F parameter up to one order of magnitude are possible, Bt(a) ranging between quasi-zero and a significant fraction of the total magnetic field, whereas the Θ parameter remains approximately constant. Since <Bt> is substantially governed by the plasma current, the desired equilibrium point can be achieved by controlling the toroidal field produced by the current in the toroidal winding. The actual reference of the latter control loop can be produced in different ways according to the chosen strategy: direct control of Bt(a), regulation of the toroidal flux, control of the F-parameter. The paper is focused on this last scheme.

The best performance of the RFP and the SHax (Single Helical axis) states recently found at high-current are most likely to occur at shallow F (0< F ≤ -0.05). The main drawback is that whenever F gets positive the configuration becomes a paramagnetic pinch with very poor confinement. Thus only very small deviations of Bt(a) can be tolerated and a very precise and fast control system is mandatory.

To this end, a closed-loop control system of the F parameter has been implemented as a nested two-loop system on the basis of a simple model of the toroidal field system and a detailed model of the toroidal circuit power supply, including a description of the coupling with the plasma current and the local control of the power section.

The outer control loop includes a feedback and a feed-forward part, the sum of which is fed into the inner loop as the winding current reference. First the desired F value is converted into a corresponding Bt(a) reference by real-time multiplication by <Bt>. The feedback term is simply the output of the Bt(a) controller, which processes the difference between reference and measured value of Bt(a). The feed-forward term is obtained by computing the required winding current after subtracting a real-time estimate of the vessel poloidal current contribution to the toroidal field at the plasma edge.

The required accuracy and dynamic performance of the inner loop for the current control have been achieved by taking advantage of the toroidal power supply model, which had been previously validated comparing simulations to experimental data both in vacuum and plasma shots. Results of the optimization work will be reported in the paper along with the first results of the full system obtained in dedicated experimental campaign.

[1] J. B. Taylor, Rev. Mod. Phys. **58**, 741(1986).