Robust plasma position, current, and shape control system simulated on plasma evolution code for the spherical tokamak Globus-M

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To simulate plasma shape and position during tokamak discharges a new plasma evolution code was developed in MATLAB. To obtain plasma position and coil currents the plasma motion equation, Faraday's law equations for PF coils, vacuum vessel and plasma circuits are numerically solved with input voltages. Forces acting on plasma and inductance matrices are obtained from a plasma current density distribution, which is calculated to satisfy Grad-Shafranov equation. To design feedback controllers, linear plasma models were obtained on the Globus-M (Ioffe Inst.) experimental data. Then these controllers were applied on the developed plasma evolution code. The hierarchical multi-loop control system includes cascades for controlling the plasma position and current with robust SISO PID controllers tuned by QFT [1]. The outer cascade of plasma shape control incorporates a plasma reconstruction code, which is created on moving filaments and has sufficient accuracy and speed of response [2]. A plasma shape MIMO controller was designed by the H_∞ robust loop-shaping approach [3] for magnetic field at X-point B_r, B_z and poloidal fluxes on the plasma separatrix Ψ_1, Ψ_2. Full thyristor current inverter models operating in self-oscillation mode up to 3 kHz were used as original fast actuators for plasma position control [4]. The plasma shape controller is turned on at 0.18 s of the discharge and transfers the plasma boundary to the desired position in less than 5 ms during the divertor phase (Fig. 1). That is critically important due to comparatively short plasma discharges on the Globus-M tokamak of about 200-250 ms.

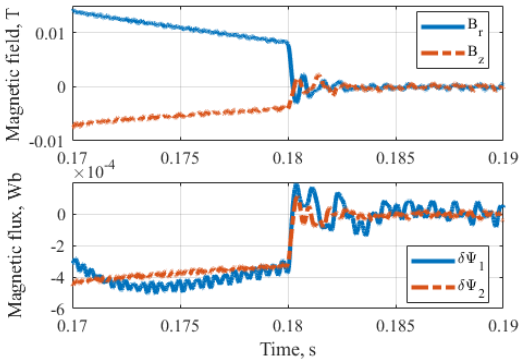

Fig. 1. Control process of the plasma shape: B_r, B_z in X-point, $\delta\Psi_1 = \Psi_X - \Psi_1$, $\delta\Psi_2 = \Psi_X - \Psi_2$, Ψ_X is the flux at X-point, Ψ_1, Ψ_2 are fluxes at the separatrix.

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