PLASMA CURRENT AND POSITION CONTROL IN KTM TOKAMAK

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The KTM tokamak [1] is a relatively small machine, its primary goal is to study promising materials for the first wall of future thermonuclear reactors. The main parameters of the KTM are as follows: nominal plasma current I_{pl} = 750 kA, major radius R_0 = 0.9 m, minor radius a = 0.45 m, toroidal field at the plasma axis B_{t0} = 1 T, aspect ratio R_0/a = 2.

This work discusses the magnetic control of the plasma current, radial and vertical position in the KTM tokamak. The plasma control system was tested in several experimental campaigns on the KTM operating in ohmic heating mode without feedback plasma density control. Limiter and divertor plasma configurations with a current of I_{pl} = 500 kA and an elongation of up to k=1.7 were successfully obtained. All the designed plasma controllers operate on the same time scale.

The plasma control system in the KTM is based on the classical two-loop scheme [2], the inner closed loop uses a poloidal coils current controller, and the outer loop is responsible for plasma control. The simplified block diagram of the KTM plasma current and position control system is shown in Fig. 1. The feedforward current trajectories in the CS and PF coils are calculated using DINA code [3] and prescribed before experiment.

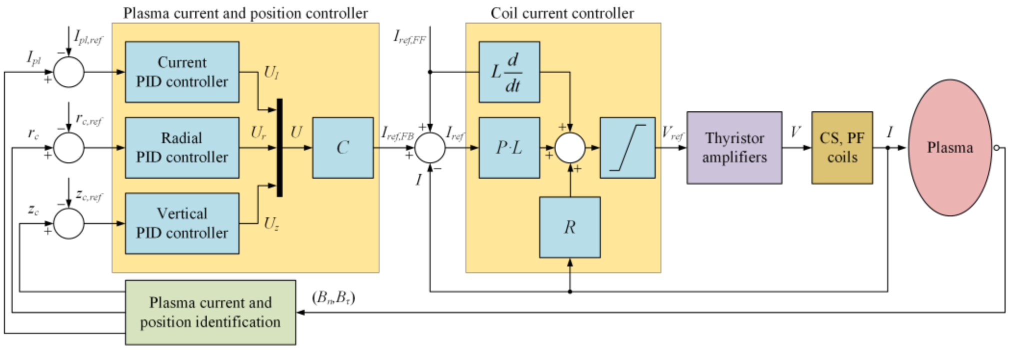

Fig. 1. Block diagram of the KTM plasma current and position control. Here, L is a CS and PF coils inductance matrix, R is a diagonal resistance matrix, P is a diagonal gain matrix for coil current controller (typical values >40 dB), C is a circuit matrix; I_{pl}, r_c *and* z_c *denote plasma current and current centroid position,* $I_{pl,ref}$, $r_{c,ref}$ *and* $z_{c,ref}$ *denote corresponding references,* (B_n,B_τ) *is a vector of measured values of normal and tangential components of the poloidal magnetic field, I and V are vectors of the currents in the coils and the voltages of the power supply,* $I_{ref,FF}$ *and* $I_{ref,FB}$ *refer to feedforward and feedback current reference*

The coil current controller is based on a well-known decoupling algorithm, first used on the JET machine [4]. The current controller ensures a steady-state error of less than 1% and provides a closed-loop bandwidth of over 20 Hz.

Both the current and plasma position are determined in terms of plasma current density moments, which can be calculated from measurements of the poloidal magnetic field (B_n, B_τ) [5]. An adapted filament method is used to extract from the magnetic field measurements the values of moments associated only with the plasma. This is especially important because, in addition to the plasma, the KTM contains a divertor facility within the measurement contour, in which toroidal eddy currents can flow, this leads to an increase in the total current inside the vacuum vessel and affects the position of the current centroid of all currents within the measurement loop.

Three independent PID controllers are used to control the current, radial, and vertical position. Circuit matrix C is used to produce feedback current reference $I_{ref,FB}$ in the coils, which allows the control action from the controllers to be distributed among the selected coils. In the simplest case, C matrix can be designed in such a way as to virtually connect the coils in series, so that the feedback currents create the necessary vertical and horizontal fields. One CS coil is used for current control, which creates an almost flat poloidal flux in the plasma region. For radial control, the equilibrium coils PF3 and PF6 are used, connected in series. The coils PF1 and PF4 are responsible for vertical position control, these coils are connected in series in such a way that the feedback currents flow in opposite directions.

The tuning of the controllers was carried out using linear plasma response models, employing the standard approach for linearizing the Grad-Shafranov equation around the base equilibrium. The DINA code simulations were used to test plasma controllers.

The results of current and plasma position control in the KTM tokamak in shot #6302 with diverted plasma are shown in Fig. 2 (a). Several plasma shapes obtained in the KTM are presented in Fig. 2 (b).

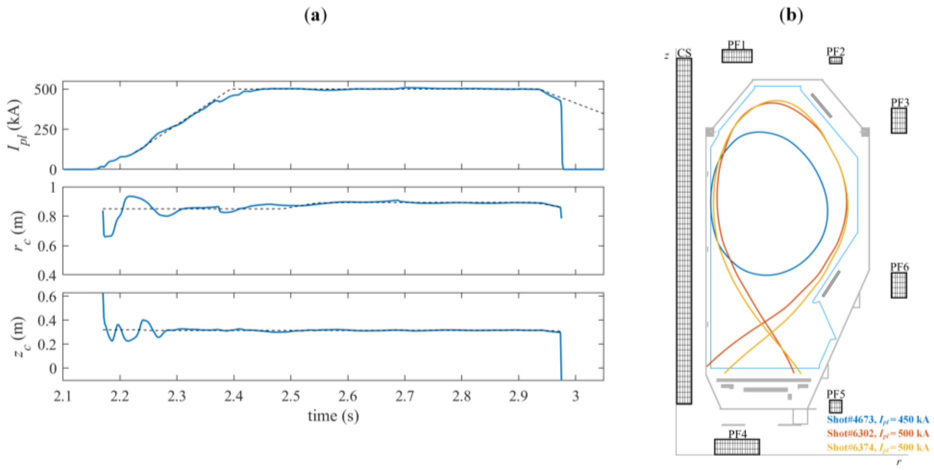

Fig. 2 Plasma current and position waveforms obtained in shot#6302 with a diverted plasma (a), solid line refers to the measured values and dashed line refers to the references. Plasma cross section for one limited and two diverted stable equilibrium configurations obtained in KTM experiments (b)

Future work will focus on optimizing the plasma control system and scenarios, as well as developing a fast vertical position and plasma shape controllers.

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