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平衡制御シミュレータの開発とJT-60SA運転シナリオの検討
Investigation of JT-60SA Operation Scenario through Development of Equilibrium Control Simulator

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Stable and reliable control of plasma shape, position and current are essential for not only the machine safety but also the efficient execution of physics study. That is, plasma operation scenario containing current ramp up/down as well as formation of divertor configuration must be drawn using the equilibrium controller within the limit of machine capabilities, e.g. poloidal field (PF) coil currents and voltages, avoiding the vertical instability. In order to develop and design such equilibrium controller, we are intensively developing an equilibrium control simulator for the JT-60SA tokamak as well as ITER, DEMO and future reactor. In this study, current status and future plan of the equilibrium control simulator are described and JT-60SA operation scenario is investigated using the simulator developed.

The equilibrium control simulator consists of (1) plasma simulator and (2) equilibrium controller. (1) The plasma simulator gives free-boundary Grad-Shafranov equilibrium solution coupled with closely placed conducting wall under given PF coil currents and prescribed plasma parameters (poloidal beta β_p and internal inductance l_i). Poloidal magnetic flux is consumed according to Ejima scaling during current ramp and surface loop voltage during current flattop. (2) The equilibrium controller controls PF coil currents according to the isoflux scheme, where the poloidal flux at specified multiple control points is adjusted to the poloidal flux at the plasma surface so that the plasma surface approaches to the control points. A set of PF coil currents that individually adjust the poloidal flux at each control point is identified in every control cycles.

A JT-60SA operation scenario with plasma current ramp-up and pressure increase is developed using the equilibrium control simulator; see figure. Waveforms of β_p and l_i (Fig. b) are prescribed assuming auxiliary heating application. Plasma current (Fig. a) is raised along the given waveforms of its reference value to 5.5MA through flux swing (Fig. c) by controlled change in center solenoid currents (CS2 in Fig. d). The equilibrium controller also controls plasma configuration from limiter to divertor by increasing plasma elongation, according to the given position change of the control points (up to 8). Distance between one of the control points near outboard mid-plane and plasma surface is shown in Fig. e. The distance approaches to zero by the control of coil currents (mainly EF1 located outboard side; the coil current shown in Fig. d) The outboard plasma surface is Highly elongated plasma (κ~1.8) is stably sustained without vertical instability with help of passive conducting wall and active control of PF coils including two in-vessel coils. Equilibrium control capability against change in plasma parameter (β_p, l_i) or flux consumption is also to be discussed in the presentation.

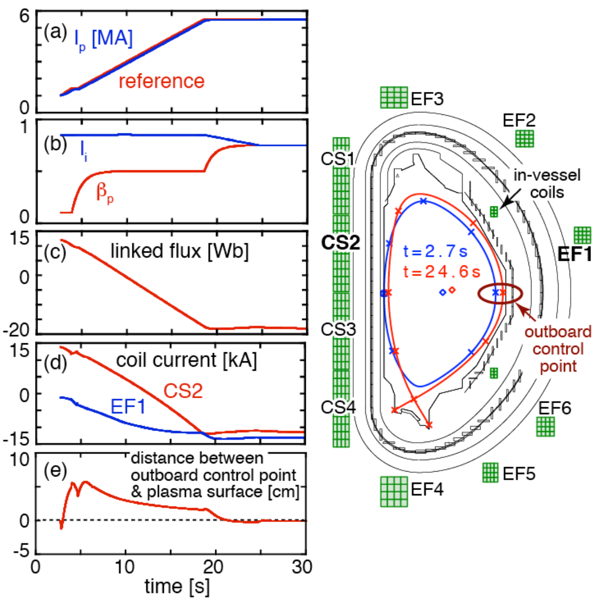

Figure: Waveforms of current ramp-up simulation (left). Poloidal cross-section of the JT-60SA device modeled in the simulator with PF coils (CS1-4, EF1-6 and two in-vessel coils; green) (right). Plasma surfaces at t=2.7s (limiter; blue) and 24.6s (divertor; red) are shown with control points (crosses).