Improvements in the fast vertical control systems in KSTAR, EAST, NSTX and NSTX-U

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The realization of a wide variety of plasma shapes with varying plasma current density profiles places challenging demands on the vertical control system. In particular the bootstrap current scales quadratically with elongation at fixed normalized $\beta_N = \beta_T a B_T/Ip$ where I_p is the plasma current, B_T is the toroidal field, and $\beta_T = P/(B_T^2/2\mu_0)$ and P is the volume averaged plasma pressure. The plasma elongation is controlled by the action of coils that generally act to produce a field shape with an index of curvature that is closer to vertical instability as the elongation is increased. In devices such as KSTAR, EAST and ITER, the superconducting coils are separated from the plasma by conducting structures that limit the plasma response time to changes in the coil currents. Fast control of the plasma vertical motion, essential for stable operation at high elongation and disruption avoidance, can be accomplished with coils internal to the vacuum vessel in these devices. Shape control systems in tokamaks are generally based upon equilibrium analysis that does not lend itself well to fast control and in particular cannot produce a reliable time derivative of the vertical position. The simple analysis of standard integrated magnetic signals to produce a vertical position (z) signal can be incapable of yielding a derivative term (dz/dt) that has sufficient signal-to-noise ratio to be adequate for control. Employing the difference of up-down symmetric un-integrated voltage loops can provide better signal to noise for dz/dt. The results of using the voltage loop-based sensors in the KSTAR and EAST fast vertical control system in their upcoming runs will be presented. In particular, the efficacy of employing these diagnostics in the fast control loop to achieve greater plasma elongation over a range of plasma internal inductance will be examined.

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