REAL TIME EQUILIBRIUM RECONSTRUCTION FOR CONTROL OF THE DISCHARGE IN THE DIII–D TOKAMAK*

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To obtain optimum performance in a tokamak discharge, accurate control of the discharge parameters is required. The most complete determination of the discharge shape and profiles is obtained through off-line analysis with a computation-intensive equilibrium reconstruction code such as EFIT [1]. To compute discharge parameters rapidly enough for use in tokamak feedback control, simpler algorithms implemented at most tokamak facilities attempt to approximate the results of the full equilibrium reconstruction, but accuracy is limited when a wide range of discharge parameters must be handled. An improved technique has been implemented for the DIII–D tokamak that produces an equilibrium reconstruction in real time for arbitrary, time-varying, discharge shapes and current profiles. As in the EFIT reconstruction code, the solution to the Grad-Shafranov equilibrium relation is found which best fits the diagnostic measurements. The distributions of plasma current and poloidal flux are thus available in real time for accurate evaluation and control of the discharge parameters. The results agree well with the best off-line calculations because the same algorithm is used. Shape identification with this reconstruction technique is robust to changes in the shape, β_p, ℓ_i, and edge current density. Shape control is implemented with the "isoflux" technique in which the poloidal flux at several locations defining the desired plasma boundary is calculated from the reconstructed equilibrium and coil currents are adjusted to keep the flux equal at all of these locations and at the desired X-point locations. The divertor X-points are located by calculating where $|B_p| = 0$. The strong effect of the current density near the discharge edge on the calculated X-point location can be accounted for by including Motional Stark Effect diagnostic data in the reconstruction to obtain accurate current profiles. This also allows determination of the safety factor profile in real time as is required for control of the current profile in advanced tokamak scenarios. Multiple-input, multiple-output controller design techniques are being employed to calculate optimum feedback gains for determination of the required poloidal field coil voltages. Production of new discharge shapes is relatively easy with this technique as demonstrated, for instance, by the "bean" shaped discharges created recently with indentation up to 0.15. Also, control of the divertor strike point location was implemented simply by requiring that the flux at the desired strike point location equal the flux at the X-point.

[1] L.L. Lao, et al., Nucl. Fusion **25**, 1611 (1985).

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