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Normal Mode Approach to Modeling of Feedback Stabilization of the Resistive Wall Mode

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Abstract

Feedback stabilization of the resistive wall mode (RWM) of a plasma in a general feedback configuration is formulated in terms of the normal modes of the plasma-resistive wall system. The growth/damping rates and the eigenfunctions of the normal modes are determined by an extended energy principle for the plasma during its open (feedback) loop operation. A set of equations are derived for the time evolution of these normal modes with currents in the feedback coils. The dynamics of the feedback system is completed by the prescription of the feedback logic. The feasibility of the feedback is evaluated by using the Nyquist diagram method or by solving the characteristic equations. The elements of the characteristic equations are formed from the growth and damping rates of the normal modes, the sensor matrix of the perturbation fluxes detected by the sensor loops, the excitation matrix of the energy input to the normal modes by the external feedback coils, and the feedback logic. (The RWM is also predicted to be excited by an external error field to a large amplitude when it is close to marginal stability.) This formulation has been implemented numerically and applied to the DIII-D tokamak. It is found that feedback with poloidal sensors is much more effective than feedback with radial sensors. Using radial sensors, increasing the number of feedback coils from a central band on the outboard side to include an upper and a lower band can substantially increase the effectiveness of the feedback system. The strength of the RWM that can be stabilized is increased from $\gamma\tau_w = 1$ to $\gamma\tau_w = 30$. (γ is the growth rate of the RWM; in the absence of feedback and τ_w is the resistive wall time constant) Using poloidal sensors, just one central band of feedback coils is sufficient for the stabilization of the RWM with $\gamma\tau_w = 30$.

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