MODELING OF FEEDBACK STABILIZATION OF THE RESISTIVE WALL MODE IN GENERAL GEOMETRY*

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The macroscopic stability of many magnetic fusion configurations including tokamaks and RFPs, requires the presence of a nearby perfect conducting wall. Yet even with the conducting wall present, when the resistivity of the wall is taken into account, the configuration is unstable to the resistive wall mode (RWM). It is driven unstable by the plasma but with growth rates determined by the diffusion of the perturbed magnetic flux through the resistive wall. Therefore, long term stability of the plasma requires stabilization against the RWM. The most promising method for stabilization of the RWM is feedback stabilization by using a set of external sensor loops and feedback coils. In this work, we present a general formulation for the modeling of feedback stabilization of the RWM for an ideal plasma. We show that conceptually, this issue consists of two related problems, each corresponds to a different operation of the system in the experiment; i.e. the open and closed (feedback) loop operations. When the feedback loop is open, the feedback system acts passively. With the plasma obeying ideal MHD, the dynamics of the plasma together with a thin resistive wall can be cast into a self–adjoint form. It describes the very low frequency response of the plasma with respect to an arbitrary skin current distribution pattern on the external resistive wall. The dynamics of the system can be described as a set of (both stable and unstable) spatially distributed L/R circuits with a set of associated eigenmodes. The inverse of the L/R times of these circuits are the growth (decay) rates; the amplitudes of these eigenmodes determine the amplitudes of the resistive wall mode. The magnetic fluxes induced by these eigenmodes in the sensor loops form a sensor matrix; the excitation of these open loop eigenmodes by the external coils forms an excitation matrix. By utilizing these matrices, together with the feedback logic, the closed feedback loop problem is reduced to an equivalent set of coupled lumped circuit equations. This set of equations is, in general, non-self-adjoint, yet determines the complete dynamic behavior of the system during feedback. Various quantities, such as the transfer function,[1] are then easily derived. In a special case, when the sensor loops and feedback coils are closely coupled to the wall and to each other, the closed loop problem remains self-adjoint, and can be solved with a flux conserving constraint[2] in the open loop problem. These two problems have been implemented numerically and applied to the DIII-D tokamak. We found that installing the sensor loops inside of the resistive wall is superior to installing them outside. Numerical examples showing the effectiveness of the feedback on stabilizing the RWM are also presented.

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