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Control of Nonlinear Resistive Wall Modes

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Abstract

We have studied feedback control of resistive wall instabilities in linear and nonlinear theory. The control is idealized in two ways. 1) the normal component of the magnetic field is measured at the resistive wall, and it is assumed that the relevant single Fourier harmonic is measured; 2) the control is applied as a single harmonic at a larger radius. With these idealizations, we have shown that real gain (zero phase shift) is equivalent to having a perfectly conducting wall between the actual resistive wall and the radius where the control is applied. We have also shown that imaginary gain ($\pi/2$ phase shift) is equivalent to rotating the resistive wall, which is in turn equivalent to plasma rotation, and that complex gain is equivalent to both effects together. These equivalences are exact in 2D linear theory, and serve as useful guidance in 3D linear theory and in nonlinear theory. Further, we have shown that "mode control", a type of feedback used in DIII-D, is equivalent to higher real gain. We have performed 2D nonlinear simulations of control of resistive wall modes driven by current and pressure. The results indicate that the amount of gain, either real or imaginary, required to give a benign saturation of the nonlinear resistive wall MHD modes is of order half the gain required for linear stabilization. We will also discuss integral and derivative gain (and the usual combination PID, proportional-integral-derivative, gain) and the possible application of the Kalman filter to such problems.