Magnetic Control of Magnetohydrodynamic Instabilities in Tokamaks

E.J. Strait

General Atomics, PO Box 85608, San Diego, California 92186-5608

Abstract. Externally applied, non-axisymmetric magnetic fields form the basis of several relatively simple and direct methods to control magnetohydrodynamic (MHD) instabilities in a tokamak, and most present and planned tokamaks now include a set of non-axisymmetric control coils for application of fields with low toroidal mode numbers. Non-axisymmetric applied fields are routinely used to compensate small asymmetries ($\delta B/B \sim 10^{-3}$ to 10^{-4}) of the nominally axisymmetric field, which otherwise can lead to instabilities through braking of plasma rotation and through direct stimulus of tearing modes or kink modes. This compensation may be feedback-controlled, based on the magnetic response of the plasma to the external fields. Non-axisymmetric fields are used for direct magnetic stabilization of the resistive wall mode — a kink instability with a growth rate slow enough that feedback control is practical. Saturated magnetic islands are also manipulated directly with non-axisymmetric fields, in order to unlock them from the wall and spin them to aid stabilization, or position them for suppression by localized current drive. Several recent scientific advances form the foundation of these developments in the control of instabilities. Most fundamental is the understanding that stable kink modes play a crucial role in the coupling of non-axisymmetric fields to the plasma, determining which field configurations couple most strongly, how the coupling depends on plasma conditions, and whether external asymmetries are amplified by the plasma. A major advance for the physics of high-beta plasmas (β = plasma pressure/magnetic field pressure) has been the understanding that drift-kinetic resonances can stabilize the resistive wall mode at pressures well above the ideal-MHD stability limit, but also that such discharges can be very sensitive to external asymmetries. The common physics of stable kink modes has brought significant unification to the topics of static error fields at low beta and resistive wall modes at high beta. These and other scientific advances, and their application to control of MHD instabilities, will be reviewed with emphasis on the most recent results and their applicability to ITER.