SOME BENEFICIAL NON-AXISYMMETRIC MAGNETIC PERTURBATIONS

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1. Enhanced stability for neoclassical tearing modes (NTM's).
   a. Importance: NTM's cause disruptions; difficult to feedback stabilize.
   b. Mechanism: Lock phase of NTM so rotation can stabilize.

2. Prevention of high-energy runaways during disruptions.
   a. Importance: Runaways can destroy machine; alternate mitigation methods are undesirable.
   b. Mechanism: Disruptions can induce currents in wall that prevent magnetic surfaces from reforming.

Enhancement of NTM Stability

NTM's are destabilized kinks due to

$$(j_{||}/B)'/(mq\text{-}n)$$

being positive on both sides of a rational surface $q=m/n$.

Arises if bootstrap current near a rational surface is zeroed by the flattening of the pressure gradient due to an island of half-width δ_b.

Stationary islands that are narrower than some critical width δ_ω cannot open due to plasma rotation *(even diamagnetic rotation)*.

If $\delta_\omega > \delta_b$, an external magnetic perturbation, which without shielding would drive an island of half-width $\delta_x < \delta_\omega$, will enhance NTM stability from a critical island half-width of $\delta \sim \delta_b$ to $\delta \sim \delta_\omega$.

Without an external perturbation, the NTM island is free to rotate with the plasma, which means no rotational shielding.

Minimum Stationary Island Half-Width δ_ω

Ideal MHD gives a delta-function current on rational surfaces in response to an external magnetic perturbation.

The resonant Fourier component of $\delta\vec{B}\cdot\hat{n}/B_0\cdot\vec{\nabla}\varphi$ of the magnetic field produced by this delta-function current defines the drive field for magnetic islands δB_d.

Park's Ideal Perturbed Equilibrium Code (IPEC) can calculate δB_d.

$\delta B_d \sim 10^{-3} B_0$ in some experiments before mode locking occurs.

$$\delta_\omega = \sqrt{\frac{4R_0}{m(d\iota/dr)}\frac{(\delta B_d)_{crit}}{B_0}} \sim (5\% \text{ to } 10\%)a.$$

Note $\delta B_d \sim 10\,\delta B_x$ due to error field amplification.

Minimum Island Half-Width δ_b for NTM

Theory and experiments have many subtleties but usual estimate is $\delta_b \sim \rho_b$, the ion banana orbit width. In ITER, $\delta_b \sim 1\%\ a$.

The critical internal magnetic perturbation to launch an NTM in the presence of an external perturbations scales as $(\delta_\omega/\delta_b)^2$ times the required internal perturbation in an axisymmetric external magnetic field.

Effect is present in existing experiments.

External perturbation ties down phase of the incipient island, which makes stabilization of ECCD easier,

$$f = \frac{\delta B_{in} \delta B_{ext}}{\mu_0} \sin \phi_{phase}.$$

Prevention of High-Energy Runaways during Disruptions

Electrons can only become high-energy runaways if they can make $\sim 10^5$ circuits of the torus before they are lost.

Ensuring magnetic surfaces do not reform after a disruption should eliminate the possibility of runaway electrons.

Passive Prevention of Magnetic Surfaces after a Disruption

Plasma poloidal flux change induces a current in the wall.

If the wall has a lowered impedance strip that follows a helical path, then a helical current is passively induced. Assuming the strip encircles the torus *m* times

$$L_s I_s = m\delta\left(L_p I_p\right), \text{ where } \frac{L_s}{mL_p} \sim \frac{\ln(R/\Delta_s)}{\ln(R/a)} \sim 1.$$

Required perturbation field to destroy the magnetic surfaces is

$$\frac{\delta B}{B_\theta} \approx \frac{1}{4 s_\iota m} \quad \text{where } s_\iota \equiv \left|\frac{d\ln q}{d\ln r}\right| \sim 2.$$

The required current in the helical strip is

$$\frac{I_s}{I_p} \approx \frac{1}{4 s_\iota m^2}\left(\frac{b_{strip}}{a}\right)^m \sim 2\%.$$

SUMMARY
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