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Exploring Macroscopic MHD Stability Trends Using Perturbed Equilibria: Successes and Limitations of Application to Toroidal Geometry[1]

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The effects of equilibrium parameters on long wavelength ideal MHD instabilities in toroidal plasmas are traditionally studied using numerical parameter scans. Previously, we introduced a new perturbative technique to explore these dependencies: changes in the potential energy δW due to small equilibrium variations are found using a perturbation of the energy principle, rather than with an eigenvalue-solver instability code.

With this perturbed equilibrium approach, stability dependencies can be quickly determined without numerically generating complete MHD stability results for every set of parameters (which can be time-intensive for accurate representations of several configurations). Compared to a routine parameter scan, this approach may also provide the researcher a more intuitive feel for the effects of various parameters.

Previous attempts to validate this approach in toroidal geometry using GATO (an ideal MHD stability code) and experimental equilibria gave correct stability trends in some cases, but not all. Analysis focused on DIII-D shot 87009, which exhibits global internal m=2 and m=3 kink modes. This technique should work well with global modes; however, changes more than only $\sim 0.1\%$ to q_o predicted δW several orders of magnitude too large.

We first briefly review the perturbed stability analysis for a cylindrical circular equilibrium, which works well with this approach, and also the previously presented results from DIII-D shot 87009, which are discouraging. Between the circular equilibrium and the shaped toroidal equilibrium of 87009 lie several other equilibria, which should produce intermediate results. We construct several of these intermediate equilibria, starting with a circular cross-section and making progressive changes to shape and profiles until ending at 87009. To gain some understanding about why q_o in 87009 is so sensitive, we perturb q_o in each of these intermediate equilibria.

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