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Comparisons of Linear and Nonlinear Plasma Response Models for Non-Axisymmetric Perturbations[1]

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With the installation of non-axisymmetric coil systems on major tokamaks for the purpose of studying the prospects of ELM-free operation, understanding the plasma response to these fields is a crucial issue, particularly for ITER. Application of different response models, using standard tools, to DIII-D discharges with applied non-axisymmetric fields from internal coils is shown to yield distinctly different results. To resolve the discrepancies, the problem is posed from a more general point of view intended to identify and highlight the assumptions made in each approach so that they can be fleshed out in a comparative study, with the aim of identifying the conditions under which they are valid. The plasma response to non-axisymmetric field perturbations can be treated as an initial value (or dynamic) stability problem, following the system dynamically from an initial unperturbed state, or from a nearby perturbed equilibrium approach, and using both linear and nonlinear models. The different approaches, and even the same approach in many cases, can yield different responses in principle and criteria are discussed under which each of the approaches can yield a valid response. In the DIII-D cases studied, these criteria show a breakdown in the linear theory despite the small 10^{-3} applied perturbations. For the nonlinear response, the nearby equilibrium approach bypasses the detailed evolution and search for the appropriate final state but to assure accessibility one needs to relate the two-dimensional (2-D) and nearby three-dimensional (3-D) system through some set of invariants or constraints on the global parameters and symmetries and the profiles. While a universally valid set of constraints is not presently known, some general principles for setting the right constraints that lead to the dynamically accessible solution to the plasma response are discussed.

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