Comparisons of linear and nonlinear plasma response models for non-axisymmetric perturbations

A.D. Turnbull,[1] N.M Ferraro,[1] V.A. Izzo,[2] E.A. Lazarus,[3] J-K. Park,[4] W.A. Cooper,[5] S.P. Hirshman,[3] L.L. Lao,[1] M.J. Lanctot,[1] S. Lazerson,[5] Y.Q. Liu,[6] A. Reiman,[4] and F. Turco[7]

[1]General Atomics, P.O. Box 85608, San Diego, California 92186-5608, USA
[2]University of California-San Diego, La Jolla, California, USA
[3]Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
[4]CRPP/EPFL
[5]Princeton Plasma Physics Laboratory, Princeton, New Jersey, USA
[6]Culham UKAEA
[7]Columbia University, New York, New York, USA

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 the applied fields is a crucial issue. Application of different response models, using standard tools, to DIII-D discharges with applied non-axisymmetric fields from internal coils, is shown to yield qualitatively different results. The plasma response can be treated as an initial value (or dynamic) problem, following the system dynamically from an initial unperturbed state, or from a nearby perturbed equilibrium approach, and using both linear and nonlinear models [A.D. Turnbull, Nucl. Fusion **52**, 054016 (2012)]. 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} relative magnitude of the applied magnetic field perturbations in this case. For nonlinear dynamical evolution simulations to reach a saturated nonlinear steady state, appropriate damping mechanisms need to be provided for each normal mode comprising the response. Other, related issues arise, in the technical construction of perturbed flux surfaces from a linearized displacement and from the presence of near nullspace normal modes. For the nearby equilibrium approach, in the absence of a full 3-D equilibrium reconstruction, constraints relating the 2-D system profiles to the final profiles in the 3-D system also need to be imposed to assure accessibility. The magnetic helicity profile has been proposed as an appropriate input to a 3D equilibrium calculation and tests of this show the anticipated qualitative behavior.

PACS: 52.30Cv, 52.55Fa, 52.35Py