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Impact of toroidal and poloidal mode spectra on the control of non-axisymmetric fields in tokamaks[1]

MATTHEW J. LANCTOT, General Atomics

In several tokamaks, non-axisymmetric magnetic field studies show applied n=2 fields can lead to disruptive n=1 locked modes, suggesting nonlinear mode coupling. A multimode plasma response to n=2 fields can be observed in H-mode plasmas, in contrast to the single-mode response found in Ohmic plasmas. These effects highlight a role for n>1 error field correction in disruption avoidance, and identify additional degrees of freedom for 3D field optimization at high plasma pressure. In COMPASS, EAST, and DIII-D Ohmic plasmas, n=2 magnetic reconnection thresholds in otherwise stable discharges are readily accessed at edge safety factors q∼3 and low density. Similar to previous studies, the thresholds are correlated with the overlap field for the dominant linear ideal MHD plasma mode calculated with the IPEC code. The overlap field measures the plasma-mediated coupling of the external field to the resonant field. Remarkably, the critical overlap fields are similar for n=1 and 2 fields with m>nq fields dominating the drive for resonant fields. Complementary experiments in RFX-Mod show fields with m<nq have negligible impact. In H-mode plasmas, applied n=2 fields in DIII-D elicit transport responses with differing poloidal spectrum dependences, including a reduction in toroidal angular momentum that is not fully recoverable using fields that imperfectly match the applied field. These results have motivated an international effort to document n=2 error field thresholds in order to establish control requirements for ITER. This work highlights unique requirements for n>1 control, including the need for multiple rows of coils to control selected plasma parameters for specific functions (e.g., rotation control or ELM suppression). Optimal multi-harmonic (n=1 and n=2) error field control may be achieved using control algorithms that continuously respond to time-varying 3D field sources and plasma parameters.

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