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TH/P3-07: Nonlinear Error-Field Penetration in Low Density Ohmically Heated Tokamak Plasmas

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A theory is developed in order to predict the error-field penetration threshold in low density, ohmically heated, tokamak plasmas. The novel feature of the theory is that the response of the plasma in the vicinity of the resonant surface to the applied error-field is calculated from nonlinear drift-MHD magnetic island theory, rather than linear layer theory. Error-field penetration, and subsequent locked mode formation, is triggered when the destabilizing effect of the resonant harmonic of the error-field overcomes the stabilizing effect of the ion polarization current (caused by the rotation of the error-field-induced island chain in the local ion fluid frame). The predicted scaling of the error-field penetration threshold with engineering parameters is $(b_r/B_T)_{crit} = n_e B_T^{-1.8} R_0^{-0.25}$, where b_r is the resonant harmonic of the vacuum radial error-field at the resonant surface, B_T the toroidal magnetic field-strength, n_e the electron number density at the resonant surface, and R_0 the major radius of the plasma. This scaling—in particular, the linear dependence of the threshold with density—is consistent with experimental observations. When the scaling is used to extrapolate from JET to ITER, the predicted ITER error-field penetration threshold is $(b_r/B_T)_{crit} = 5\times10^{-5}$, which just lies within the expected capabilities of the ITER error-field correction system.

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