Addressing The Error Field Correction Challenge for ITER*

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Experiments in DIII-D have shown a greater challenge for error field correction in ITER than previously expected. This arises from two main factors. First, error correction has a more limited benefit than expected from recent applications of ideal-MHD response models [1]. Second, thresholds for error fields to trigger modes in low torque ITER H modes are projected lower than previous Ohmic studies, placing them well below the expected intrinsic error in ITER [2]. As a result ITER needs to consider a multi-harmonic error correction strategy, possibly also deploying its edge localized mode control coils.

Experiments in DIII-D explored the limits of error field correction using two coil arrays – one to make a known large amplitude pure $n = 1$ proxy error field, and the other to correct it. This addresses uncertainties in previous studies with unknown toroidal and poloidal components in the intrinsic error, and possible stability or control limits. It is found (Fig. 1) that even with optimal correction the improvement in locked mode density limit is only 50% indicating that a substantial residual field exists. This implies that multiple $n = 1$ poloidal error field harmonics must reach the plasma to brake rotation and facilitate mode formation. The interpretation is consistent with further studies where the correction field was tuned using 3 independent arrays of coils to optimize coupling to the least stable plasma mode, but still resulted in similar limits to those obtained with single array correction. Further, studies using a localized test blanket module simulator as an error field source also showed that minimization of magnetic response yields a different correction to rotation optimization, suggesting an action through non-resonant braking.

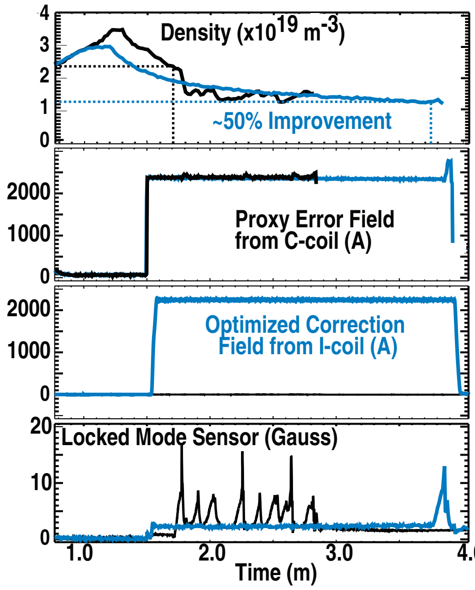

Figure 1: The locked mode density limit with a proxy C-coil $n = 1$ error field (black) improves by 50% when optimal correction fields (deduced from a phase scan measuring mode onset thresholds) are applied with the DIII-D I-coils (blue).

These results have been compared with the predicted degree of correction required for low torque H-modes [2], where a resistive response to error fields is confirmed by modeling with the MARS-F and M3D-C1 codes, leading to braking and destabilization of intrinsic tearing instabilities. New scalings have been obtained to extrapolate thresholds to ITER, while ITER's Monte Carlo simulation of expected errors has been updated for the ideal response formalism, indicating correction required. This level of correction will require a well-optimized multi-harmonic approach to error correction.

References

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