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Error Field Impact on Mode Locking and Divertor Heat Flux in NSTX-U

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Results from the 2016 NSTX-U campaign and the subsequent recovery effort have led to significant new insights regarding error fields in the NSTX-U experiment in particular, and in spherical tokamak configurations in general. During the experimental campaign, many L-mode discharges were found to be locked from the q=2 surface outward, indicating the presence of error fields. At the conclusion of the run campaign, extensive metrology was conducted on the primary vertical field ("PF5") coils, and the center stack assembly, which includes the central solenoid and the center rod of the toroidal field ("TF") coils. Error field models based on these measurements indicate that misalignment of the TF rod, while small, produces the largest error field among the sources considered. Plasma response modeling with IPEC and M3D-C1 finds that the TF error field remains the dominant source of resonant braking, despite the fact that the TF error field spectrum couples relatively weakly to the plasma, due to the large current in the TF rod and the proximity of the rod to the plasma. The plasma response to the TF error field is expected to depend significantly on the presence of a q=1 surface, since the TF error field is dominantly m/n=1/1. This is qualitatively consistent with results of several "compass"scans performed during the NSTX-U run campaign, which found that the optimal error field correction before and after the formation of the q=1 surface differed significantly. Interestingly, these discharges typically disrupted via locking of the 1/1 surface, since the 2/1 surface was often locked ab initio. It is found that certain characteristics of the TF error field present new challenges for error field correction. Specifically, the error field spectrum differs significantly from that of coils on the low-field side (such as the NSTX-U RMP coils), and does not resonate strongly with the dominant kink mode, thus potentially requiring a multi-mode correction. Finally, to mitigate heat fluxes using poloidal flux expansion, the pitch angle at the divertor plates must be small (~1 degree). It is shown that large error fields may result in unacceptable local perturbation to the pitch angle. Tolerances for coil alignments in the NSTX-U restart are derived based on both heat flux considerations and core resonant fields independently.

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Author: FERRARO, Nathaniel (Princeton Plasma Physics Laboratory)

Co-authors: BROOKS, Arthur (Princeton Plasma Physics Laboratory); Dr MYERS, Clayton (Sandia National Laboratory); Dr MENARD, Jonathan (Princeton Plasma Physics Laboratory); Dr PARK, Jong-Kyu (Princeton Plasma Physics Laboratory); Dr REINKE, Matthew (ORNL); Dr GERHARDT, Stefan (Princeton Plasma Physics Laboratory)

Presenter: FERRARO, Nathaniel (Princeton Plasma Physics Laboratory)

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