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The Desirability of Locking for RF Stabilization of Islands in Large Tokamaks

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Although the stabilization of locked islands using RF-driven currents has been demonstrated experimentally in a pioneering series of experiments [1], experimental and theoretical research on RF island stabilization has continued to focus almost exclusively on stabilization during the rotating phase, before locking occurs. An emphasis on avoiding island locking has emerged from a concern about the damaging impact of locked islands on plasma performance, and in particular from a concern about the impact on disruptivity. However, as we discuss, there are circumstances under which it will be desirable to allow an island to lock before stabilizing it [2]. In large tokamaks such as ITER, the m=2, n=1 islands are expected to rotate slowly and to lock at relatively small width, impacting the ECCD power required to stabilize the island before it locks. Continued emphasis on stabilizing the island before it locks could have a significant negative impact on Q, the fusion gain. The impact on Q may be greatly diminished by adopting a strategy of allowing the island to lock before stabilization. The threat posed to the plasma performance by a locked island is ameliorated for sufficiently small islands. The rate of growth of the island may increase after locking, but that rate will remain on a slow resistive time scale. Experimental studies find that islands do not trigger disruptions until they become quite large [3]. Experimental results also indicate that loss of an H-mode can be avoided if the island is suppressed on a momentum confinement time scale after it locks. It will be necessary to use an externally imposed nonaxisymmetric field to control the phase of the locked island, so that the O-point will lie in front of the EC launcher. Contemporary tokamaks, in any case, have nonaxisymmetric coils for the purpose of controlling error fields. ITER will have a set of nonaxisymmetric coils for the purpose of compensating for n=1 field errors, and it is expected that the coils will be used to decrease these resonant field errors by a factor of about 4. For ECCD stabilization of the locked island it is only required that the currents in these coils be tuned such that the residual error field after imposition of the field error correction has the appropriate phase. No separate applied perturbation is required. In any case, if the phase of the error correction field is not controlled in this way then it will not be possible to employ ECCD stabilization if an off-normal event produces a locked island. These considerations suggest that it will be desirable to do locked island stabilization experiments for small islands in advance of ITER to provide validated modeling of potential stabilization scenarios.

[1] F. Volpe et al,Phys. Rev. Lett. 115, 175002 (2015).
[2] R. Nies et al, arXiv:2106.06581.
[3] P.C. de Vries et al, Nucl. Fusion 56, 026007 (2016).

Speaker's title

Mr

Speaker's email address

reiman@pppl.gov

Speaker's Affiliation

Princeton Plasma Physics Lab

Member State or IGO

United States of America

Primary authors: REIMAN, Allan (Princeton Plasma Physics Lab); FISCH, Nathaniel (Princeton University); NIES, Richard (Princeton Plasma Physics Laboratory)

Presenter: REIMAN, Allan (Princeton Plasma Physics Lab)

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