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Avoiding Disruptions by Suppressing Magnetic Islands via RF Current Condensation

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95% of the disruptions in the Joint European Torus (JET) with the ITER-like wall have been preceded by the growth of large islands.[1] The islands appear at the end of a chain of events initially triggered by a variety of different off-normal events, but investigations have suggested that the disruptions themselves are typically directly triggered by the growth of the large islands.[2,3] It would be desirable to suppress these islands before they trigger disruptions. Following the discovery of RF (radio frequency) driven currents[4,5] in the late 1970's, theoretical calculations in the early 1980's showed that such currents could be used to suppress magnetic islands.[6,7] Since that time there have been a large number of theoretical and experimental investigations of island stabilization and suppression using RF driven currents. Nevertheless, important questions remain regarding the optimal strategy for stabilizing small islands produced by neoclassical tearing modes (NTMs), and regarding the extent to which disruptions can be avoided by RF stabilization of the associated islands.

Studies intended to provide guidance on the design of the ITER upper launcher for electron cyclotron (EC) waves have largely focused on the stabilization of small islands produced by NTMs in the ITER Scenario 2 equilibrium. It has been assumed that these islands must be stabilized before they lock in order to avoid unacceptable deleterious effects. More recently, there have been new results concerning the effect of the ITER test blanket module on the locking of these islands and concerning the broadening of the EC beam by scattering off density fluctuations at the plasma edge. These results call into question the feasibility of routinely stabilizing NTM islands in ITER before they lock without significantly impacting the fusion gain, *Q*. They also call into question the necessity of doing so. It has recently been argued that, in large devices such as ITER, it may actually be advantageous to allow the islands to lock before stabilizing them.[8] It would be desirable to have additional experimental and theoretical information regarding this strategy in advance of the need to apply the strategy in ITER. The effects of small locked islands of the size expected in ITER have not been well characterized experimentally.

When large islands do appear in ITER and other large tokamaks, it will be desirable to stabilize them quickly rather than waiting for them to trigger the disruption mitigation system. Once the islands reach a size where they begin to significantly impact the performance of the device, the fusion gain will no longer be a consideration, and it will be incumbent to use the full amount of RF power available on the device, if necessary, to stabilize the island. ITER will initially have 20 MW of EC power, with an upgrade to 40MW considered likely. It has been recognized in recent years that, when such large amounts of power are used to stabilize large islands, nonlinear effects that have not been previously considered will come into play.[9-11]

The nonlinear effects arise from the sensitivity of the RF power deposition and of the local RF electron acceleration to the temperature perturbation in the island. Both lower hybrid current drive (LHCD) and electron cyclotron current drive (ECCD) are sensitive to small perturbations of the temperature. This gives rise to the RF current condensation effect. The effect can be used to concentrate the RF driven current near the center of the island, increasing the stabilization efficiency and facilitating the stabilization of large islands. Alternatively, failure to properly account for the nonlinear effects in the aiming of the ray trajectories can lead to a shadowing effect that causes the energy in the wave to be prematurely depleted, impairing stabilization.

For a tokamak where a significant fraction of the current is driven by RF, the condensation effect can automatically concentrate the current in an unstable island that grows in the plasma. This raises the prospect of designing a tokamak fusion reactor where RF driven current provides passive, automatic stabilization of islands. This requires a current drive mechanism that is particularly sensitive to temperature perturbations, which could be provided by either LHCD or top launch ECCD.

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