Modeling of Stochastic Magnetic Flux Losses from the Boundary of Poloidally Diverted Tokamaks Due to Known Perturbation Sources*

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Attaining and maintaining high performance advanced confinement regimes in poloidally diverted tokamaks requires systems that are explicitly dedicated to the active suppression of locked modes at low densities and resistive wall modes at high beta. These systems are typically comprised of coils which are external to the plasmas and are often run in a feedback mode. While these coil systems provide excellent control over unstable modes in the core of the plasma they also perturb the edge magnetic topology causing some degree of stochastic flux loss across the unperturbed magnetic separatrix. We have calculated the scaling of this stochastic flux loss in the DIII–D tokamak as a function of divertor configuration (double, upper or lower single-null), the edge magnetic shear, and the amplitude of the current in the external control coils using the TRIP3D field line integration code. The code uses realistic, high resolution, double precision, EFIT equilibria reconstructed from experimental DIII–D magnetic data for the axisymmetric background field and then superimposes non-axisymmetric perturbation fields from a discrete line filament model of the control coils using a Biot-Savart law calculation. We find that the flux loss has a complex dependence on the divertor configuration and the control coil current. At the highest coil currents, in double-null diverted plasmas, more than 25% of the edge magnetic flux from inside the unperturbed separatrix can be connected to plasma facing surfaces primarily in the upper and lower divertors. While the flux loss qualitatively scales with the square root of the magnetic shear, taken at the center of the stochastic flux loss region, there are significant deviations from this scaling for some divertor configurations and coil currents. In some cases, the existence of a stochastic layer just inside the unperturbed separatrix is consistent with experimental observations of T_e profile flattening and bifurcation of the divertor heat flux profiles. However, these effects are not always seen for cases that are predicted to have a stochastic edge, leaving the self-consistent plasma response to such stochastic layers as an open question. We present simulation results for the control coils and several other known perturbation sources in DIII–D and highlight some of the implications these results are expected to have for similar coils and sources on other existing and future tokamaks. We will also discuss some of the more significant physics implications of edge stochastic boundary layers in diverted tokamaks and suggest some potential benefits that could arise with dedicated well controlled edge stochastic layers.

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