Stochastic Transport of Runaway Electrons due to Low-order Perturbations in Tokamak Disruption

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During disruption events in tokamak devices, runaway electrons are often generated due to the toroidal loop voltage induced with increasing the resistivity. Experimentally, avoidance of runaway generation has been demonstrated by means of magnetic perturbations applied externally or induced spontaneously [1]. If runaways are escaped from the core region in the timescale much shorter than that of avalanche multiplication, the runaway current observed after the plasma current quench is expected to be suppressed significantly. However, necessary levels of magnetic perturbations were not yet fully understood [2], which requires detailed 3-D simulations of runaway electrons in mixed magnetic topologies including nested flux surfaces, island chains and stochastic volumes.

In this paper, 3-D relativistic drift orbits are investigated numerically, in presence of low-\(n\) magnetic perturbations, for interpreting confinement properties of runaways between present tokamaks and ITER, where \(n\) is the toroidal mode number. Topologies of confining magnetic field during disruption are described as bands of stochastic region separated by good flux surfaces and low-order magnetic islands. We discuss the onset of stochastic trajectories of runaways, concerning its energy and device-size dependence. It is shown that the resonant trajectories due to coupling between low-\(n\) modes and cross-field drift [3] affects the overlapping criterion and yields the situation such that high-energy tails of runaways are escaped in lower fluctuation level, exhibiting the tendency opposite to the runaway losses studied for short-wavelength magnetic turbulence [4].