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Simulation of Energy-Dependent Stochastic Transport Induced by Low-Order MHD Instabilities for Runaway Electron Mitigation

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To extend the capability of RE mitigation is an urgent issue towards the safety operation of ITER. We investigate the RE losses induced by low-order MHD instabilities and clarify a dominant mechanism for determining the energy dependence of the onset of RE orbit stochasticity. This is due to that for highly relativistic REs, sideband resonance of the orbit shift with macroscopic modes is much stronger than what is expected for non-relativistic particles. We demonstrate that the sideband resonance can cause both the enhancement and the suppression of orbit stochasticity at high energy relevant to the Dreicer-generated REs, depending not only on perturbation amplitudes but also on phase differences between the modes. We also report the development of a new 3D guiding-centre code for simulating the RE generation during major disruptions. To study the RE mitigation scenarios, we have developed, for the first time, a guiding-centre Monte-Carlo code including the RE generation process, which extends an original 3D guiding-centre orbit code ETC-Rel to include the RE source model as well as collisions and radiations. It also takes into account time-evolving loop voltage in a self-consistent way with generated RE current. Different energy spectra between existing tokamaks and ITER indicate that the RE control strategies must be based on detailed understanding of energy dependence of the RE transport. While Dreicer-generated seed REs tend to accelerate towards high energy, secondary REs that develop slowly on the timescale of current quench are dominant in ITER. Consequently, the effectiveness of the RE control by inducing the prompt loss will depends on the energy dependence of the onset of RE orbit stochasticity that is explained in this paper.

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