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Simulation study of interaction between runaway electron generation and resistive MHD modes over avalanche timescale

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Runaway electron (RE) generation after major disruptions is simulated over a full current quench (CQ) timescale, which covers both fast MHD events and slow RE avalanche amplification. A novel 3D RE analysis code EXTREM allows us to study (1) fast, global transport of REs with macroscopic MHD modes and (2) the RE generation triggered by electric fields induced owing to fast MHD dynamics (i.e., 'mode-induced REs'). In the EXTREM code, slow CQ process ($n = 0$; n : the toroidal mode number) is described using the current diffusion model with a time varying resistivity, whereas RE transport and fast MHD dynamics ($n > 0$) are treated on the basis of reduced MHD models. The long-timescale simulations with the EXTREM code demonstrate their advantage for the analysis of net RE generation in a self-consistent manner with the anomalous transport and generation mechanisms due to resistive MHD modes. Effects of the resistive mode on the spatial profiles of generated REs can also be compared with a 1D diffusion model. These extensions of the model is a valuable step towards self-consistent treatments of the RE generation with thermal collapse, which is a highly complex task but is an important challenge for predictive simulations of the RE generation during mitigated disruptions in ITER. In this paper, a particular attention has been paid to $m = 1$ resistive modes triggered with the current peaking resulting from massive RE generation (m : the poloidal mode number). It is shown that sawtooth-like events are triggered when the central safety factor $q(0)$ drops below unity, and the burst of Dreicer electrons is induced as a return current that compensates the expelled poloidal magnetic flux. In view of the global energy balance, the return current plays a role in converting the potential energy of the MHD instability to RE kinetic energies. It is still a small perturbation on a fast MHD timescale but can be amplified over the avalanche timescale. The scope of the paper will also be extended to the impact of tearing modes.

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