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Prospects for runaway electron avoidance with massive material injection in tokamak disruptions

Unmitigated disruptions can cause severe damage on high-current tokamak devices such as ITER. The currently envisaged mitigation method is based on massive material injection (MMI). Recent progress in modelling the dynamics of REs during disruptions mitigated by MMI indicate a substantial increase in the avalanche multiplication gain during an ITER current quench compared to previous estimates. This is due to the increased number of target electrons available for the avalanche process in weakly ionized plasmas, which is only partially compensated by the increased friction force on REs.

We present results of simulations using a fluid model for RE dynamics in the presence of material injection, including Dreicer, tritium decay, and Compton seed runaway generation as well as avalanche multiplication with an accurate model of partial screening effects, benchmarked to kinetic simulations. Potentially important effects that are not included in the model are loss processes due to magnetic perturbations, kinetic or MHD instabilities.

Using this model we address the runaway beam formation and evolution during the current quench in ITER disruption scenarios, taking into account the temperature and electric field evolution self-consistently. Our results indicate that, if losses due to magnetic perturbations are not taken into account, impurity injection leads to high runaway currents in ITER, even if it is combined with deuterium injection. The reason is that the cooling associated with the injected material leads to higher electric fields, which, in combination with the recombination associated with the low temperatures, leads to a large avalanche generation.

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