Runaway-electron model development and validation in tokamaks

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Within the next few years a new generation of large-scale tokamaks are projected to begin operation. One of the greatest challenges facing these devices is the threat posed by disruptions, in which the thermal energy is rapidly lost and the magnetic energy is converted into kinetic energy of relativistic *runaway electrons* [1]. Damage from the impact of such runaway electrons on plasma-facing components has already caused problems at several of the medium-size tokamaks around the world [2], and due to the strong avalanching of runaway electrons predicted in future high-current devices, the problem will be far greater in next-generation tokamaks.

In this contribution, we provide an overview of the models and numerical frameworks for runaway electron simulations which is the culmination of over a decade of European theoretical plasma research, and which is gathered into the DREAM [3] and SOFT [4] codes presented in the PhD thesis [9]. The work is centered around the tokamak disruption simulation framework DREAM [3] which has been widely adopted by the runaway electron and disruption community to study disruption mitigation measures, such as massive-material injection in various devices, including ITER [5, 6], SPARC [7], and STEP [8].

To validate models for runaway electrons to experiments, one common technique is to measure synchrotron radiation emitted by the runaway electrons and, and compare it against that predicted by simulations. As part of the thesis, the synthetic synchrotron diagnostic framework SOFT [4] was developed, allowing kinetic simulations of runaway electrons to be connected to experiments. SOFT has been used to explain the dynamics of runaway electrons in several tokamak experiments, including Alcator C-Mod [10], ASDEX Upgrade [11], DIII-D [12] and TCV [13, 14].

References

[1] E. M. Hollmann *et al*, PoP **22** 021802 (2015).
[2] C. Reux *et al*, IAEA FEC 2020 EX/P-1055 (2021).
[3] M. Hoppe *et al*, CPC **268**035003 (2021).
[4] M. Hoppe *et al*, NF **58** 026032 (2018).
[5] I. Svenningsson *et al*, PRL **127** 035001 (2021).
[6] O. Vallhagen *et al*, NF **62** 112004 (2022).
[7] R. A. Tinguely *et al*, PPCF **65** 034002 (2023).
[8] E. Berger *et al*, JPP **88** 905880611 (2022).
[9] M. Hoppe, PhD thesis, Chalmers University of Technology (2022).
[10] R. A. Tinguely *et al*, **59** 096029 (2019).
[11] M. Hoppe *et al*, JPP **87** 855870102 (2021).
[12] M. Hoppe *et al*, NF **58** 082001 (2018).
[13] M. Hoppe *et al*, NF **60** 094002 (2020).
[14] T. Wijkamp *et al*, NF **61** 046044 (2021).