Suppression of runaway electrons in SPARC with a passive 3D coil

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Runaway electron (RE) suppression by a passively driven 3D runaway electron mitigation coil (REMC) during a SPARC [1] current quench (CQ) has been predicted using a combination of four codes to model vacuum fields, nonlinear MHD, RE transport, and RE generation and current evolution. The REMC concept, first proposed by Boozer [2], relies on the induced loop voltage associated with the CQ to drive a much larger current in an external 3D coil than could easily be produced with actively driven coils, generating large error fields that will deconfine seed REs before they can avalanche to produce a potentially damaging RE beam. Using vacuum fields for an n=1 REMC design calculated with COMSOL, NIMROD 3D MHD simulations of the CQ are carried out to calculate of destruction of flux surfaces by the coil perturbations and the nonlinear plasma response. Based on these time-dependent 3D fields, advection and diffusion coefficients for REs are calculated using the orbit-following code ASCOT5, and these coefficients are incorporated in the DREAM code to calculate the total RE current evolution including generation, avalanching and losses. The proposed n=1 REMC design is predicted to fully suppress RE formation, while n=2 and n=3 configurations also modeled are not able to fully stochasticize the core. A set of further NIMROD simulations explore the effects of the final plasma temperature, the conducting wall location, and inclusion of both thermal quench MHD and coil-driven CQ MHD fluctuations.

[1] A. Creely, M. Greenwald, S. Ballinger, et al, Journal of Plasma Physics 86 (2020) 865860502
[2] A. Boozer, Plasma Phys. Control. Fusion 53 (2011) 084002