Second Technical Meeting on Plasma Disruptions and their Mitigation

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Mitigation of runaway electrons with a passive 3D coil

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A 3D coil, which would be passively driven by the current quench (CQ) loop voltage during a disruption, has been incorporated into the design of SPARC, a high-field tokamak under development by Commonwealth Fusion Systems, and a similar coil is planned for installation on DIII-D. The effects of each of these runaway electron mitigation coils (REMC) on magnetic flux surfaces and runaway electron (RE) confinement have been modeled with the 3D MHD code NIMROD. For SPARC, an n=1 coil geometry was found to be much more effective at promoting RE losses than n=2 or n=3 coil designs. Using the ASCOT5 code to calculate RE advection and diffusion coefficients and the DREAM code to calculate runaway current evolution, the n=1 coil, with a maximum current of 590kA (˜7 % of the flattop Ip), was found to fully suppress the runaway current with only the coil-induced MHD activity during the CQ accounted for. When the coil current is clamped at only 250kA, a runaway current plateau develops. Inclusion of the thermal quench (TQ) MHD was found to produce significantly faster losses of REs at early times, but also to modify the current profile such that flux surface reformation occurs earlier in time and allow avalanching to begin. The large avalanche multiplication factor in SPARC necessitates extremely good deconfinement to prevent a RE plateau. The effects of the close ideally-conducting wall were also studied in SPARC disruption simulations without the REMC and found to stabilize the MHD modes responsible for RE deconfinement. This suggests that when the REMC simulations are extended to a more realistic wall model, more optimistic results for the coil operation may be obtained.

In DIII-D CQ modeling with both inner-wall-limited (IWL) and lower-single-null (LSN) diverted initial conditions, a majority of RE test-particles were lost with maximum coil currents of 100 or 200kA (˜5-10% of the flattop Ip). The IWL case was found to be insensitive to the coil current amplitude, with the evolution of the q-profile playing a dominant role in determining the timing and extent of island overlap. While the retained fractions of test-particles in the DIII-D simulations is larger than in the SPARC modeling, a measurable effect on the final RE current is easily expected because of the much lower avalanche multiplier in DIII-D plasmas. The importance of the q-profile evolution, which determines resonance with the coil, is made clear from simulations of both devices. Predicting this more accurately will also require moving beyond the ideal-wall boundary condition. Ongoing work is focused on NIMROD simulations with a resistive wall.

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Speaker's title

Ms

Speaker's email address

val@fiatlux.energy

Speaker's Affiliation

Fiat Lux, San Diego, CA, USA

Member State or IGO

United States of America

Primary author: IZZO, Valerie (Fiat Lux)

Co-authors: PUSZTAI, Istvan (Chalmers University of Technology, Department of Physics); WEISBERG, David (General Atomics); TINGUELY, Roy (MIT PSFC); SÄRKIMÄKI, Konsta; SWEENEY, Ryan (Massachusetts Institute of Technology); PAZ-SOLDAN, Carlos (Columbia University); GRANETZ, Robert (MIT); GARNIER, Darren (MIT Plasma Science and Fusion Center); Dr SUNDSTROM, Andreas (Chalmers University)

Presenter: IZZO, Valerie (Fiat Lux)

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