Exploration of mitigation systems for disruption generated Runaway Electrons in a STEP concept

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STEP, the Spherical Tokamak for Energy Production, is a project currently under development by UKAEA. During operation, plasma disruption events can lead to a significant generation of Runaway Electrons (RE) which have the potential to critically damage PFCs and the reactor. STEP planned operating plasma current of > 20MA increases the potential danger posed by a high Mega-Ampere Runaway beam and yields a necessity for an extensive and reliable Disruption Mitigation System (DMS). This has been corroborated using the advanced DREAM code [1], which model RE generation and evolution in addition to several other key plasma parameters, and where STEP unmitigated disruptions produce a Runaway Beam of current greater than 10MA which far exceeds acceptable limits [2]. For mitigated disruptions, idealized impurity injections have been extensively scanned over varying densities of Argon and D_2 & Neon and D_2. No scenario has been found where a RE beam of current less than 8MA can be created, while also satisfying other DMS targets such as keeping the radiation fraction above 90%, current quench times greater than 20 ms but less than 120 ms, and a Heat Impact Factor lower than 60 $MJ.m^{-2}.s^{-0.5}$ to avoid W melting during the radiation flash. It was also found that Neon provided a marginally lower RE formation and a wider operational window compared to Argon. Subsequently, additional systems must be investigated, in particular higher-fidelity modelling of pure D_2 RE mitigation Shattered Pellet Injection (SPI) [3] which is currently the primary RE mitigation strategy for both ITER and STEP. Another alternative is the use of a passive Runaway Electron Mitigation Coil (REMC) which is planned for DIII-D and is the primary RE DMS in the under construction SPARC tokamak [4]. Initial simulations with simplified magnetic stochasticity assumptions have seen outstanding success in reducing the runaway generation, however, a more detailed study is needed to assess the viability of a REMC in STEP.

References

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