The pursuit of net energy, MHD stability, and disruption resilience in the SPARC Tokamak

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SPARC [1] is a compact, high-field, burning plasma DT experiment designed to demonstrate net fusion energy and to retire risks on the path to ARC [2]. SPARC will observe thermal confinement in a burning plasma, plasma heating by alphas, energetic particle dynamics, error fields, edge localized modes (ELMs) and their suppression, and disruptions. This talk will present an overview of the SPARC project with a focus on MHD and disruptions. SPARC is designed to operate at 12.2 T and 8.7 MA in a double null, $\kappa_{sep} = 1.97$ configuration for a 10 second flat-top with up to 25 MW of 120 MHz ion cyclotron resonant heating. Empirical scalings and independent, 1.5D physics-based models predict that the baseline ELMy H-mode (H98y2=1.0) discharge with a normalized density of $f_G = 0.37$ and a normalized pressure of $\beta_N = 1.0$ will achieve $Q \approx 10$ with 100-140 MW of fusion power. A tungsten divertor is inertially cooled with active strike point sweeping. Pedestals at 0.3 MPa could result in ELMs with energies exceeding 1 MJ, so 3D field coils are designed to apply resonant magnetic perturbations. ITPA scalings suggest a modestly reduced locking threshold relative to present devices. Magnet tolerances are set using a Monte Carlo model such that the intrinsic error will be less than twice the locking threshold with 99.9% confidence, which is the assumed correction limit of the 3D coils. Given the design point, neither density limit nor high β_N disruptions are expected. While the low β_N reduces the drive for neoclassical tearing modes, the low $q_{95} = 3.4$ implies that the current profile might lack resilience to classical tearing modes and will require attention to the plasma ramp-up and early heating. In-vessel components are designed to withstand eddy current loads in the fastest current quench of 3.2 ms predicted by the ITPA scaling. The vessel is designed for halo current loads derived from the ITPA Disruption Database. Without avoidance measures, runaway electron conversions up to 70% are found using the DREAM code, motivating the design of a novel passive, non-axisymmetric Runaway Electron Mitigation Coil (REMC) that is predicted to completely avoid runaways. The REMC is complemented by an array of massive gas injectors to mitigate thermal loads and optimize the current quench duration. Funded by Commonwealth Fusion Systems.

References

[1] A.J. Creely et al., J. Plasma Phys. **86** (2020) 865860502

[2] B.N. Sorbom et al., Fus. Eng. Design **100** (2015) 378-405