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Physics and Engineering Assessments of the K-DEMO Magnet Configuration

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With ITER now under construction, increased attention is being paid to the roadmap from ITER to a fusion DEMO, including studies of next-step fusion facilities with nuclear missions. Among these, South Korea's K-DEMO is unique in its focus on a high toroidal magnetic field, large major radius, steady-state tokamak design for the core of a facility to test fusion nuclear components in Phase I and, after upgrades, produce 500 MW of electricity in a Phase II. Innovative features of the K-DEMO magnet set include the use of two toroidal field (TF) coil winding packs, each of a different design, to reduce the amount of costly superconducting material in the low-field regions. Also, the configuration is constrained by maintenance considerations, leading to a magnet arrangement with large TF coils and widely-spaced poloidal field (PF) coils to accommodate removal of in-vessel components as large modules. A Princeton Plasma Physics Laboratory team has supported the pre-conceptual K-DEMO study with the following physics and engineering assessments of the magnet configuration: 1) design point and operating space assessment, 2) conductor assessment, and 3) structural assessment. It is found that a reference design point at 6.8 m major radius and 7.4 T toroidal field provides sufficient operating margins for the 500 MWe Phase II mission. An analysis of the electro-mechanical behavior of candidate cable-in-conduit conductors predicts 10-30% critical current degradation in the initial load cycle, and an additional degradation in the range of 5% with cyclic loading, supporting current design assumptions. A first-pass global analysis of the magnet system found out-of-plane deformations of the TF coil to be only ~1 cm, but the inner leg of the TF coil was found to be over-stressed by about 40%. An increase of 10 cm (25%) in the wall thickness in the wedged "nose"of the case was estimated to be sufficient to resolve the issue. Although the design evolution is still at an early stage, these assessments support the design point choices to date and the expectation that a feasible solution for the high-field K-DEMO magnet system can be found.

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