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A top-down modeling approach for DEMO magnetic system

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The demonstration fusion power plant DEMO by EUROfusion Consortium has now entered its conceptual design phase. DEMO is intended to demonstrate the necessary technologies for controlling a very powerful plasma, generating electricity consistently, and a reliable maintenance of the plant itself. Consequently, the plant design is a challenge not only for its physics conditions, but also for its engineering and technological requirements. Over the years, different baselines have been produced which - despite sharing a set of common characteristics - have nevertheless required revisions and updates of the studies of the magnetic system and its supporting structures. This work presents a 3-level modeling approach which is very fast and suitable to evaluate different requirements. At the macro-level, a global 3D model of the entire tokamak was developed, made of beam finite elements with an enriched formulation. This model is computationally very efficient (around 1 sec CPU time on a common laptop) allowing the development of parametric analyzes and sensitivity studies. Further, it can be used for an inverse design, i.e. to establish what are the minimum structural characteristics required to obtain the desired performances or safety margin. It is noted that, since the entire magnetic system is considered, no a priori hypothesis on the boundary conditions are needed. Going down one step, at meso-level a model of one sector of the system was developed, to analyze in detail the stress/strain fields and identify possible peaks. This model is very detailed, and the consistency is guaranteed by the imposition of the boundary conditions obtained by the global model. Finally, at the micro-level, ultra-refined local models were considered, incorporating the consistency conditions inherited from the intermediate level. All the models are developed in the thermomechanical field, considering temperature dependent material characteristics.

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