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Empowering the 4C code for the thermal-hydraulic analysis of coils for the design of future SC tokamaks: a novel, fully-3D model of the TF coil structures

The numerical simulation tools are of paramount importance in the ongoing design process of future fusion reactors like, e.g., the Divertor Tokamak Test (DTT) facility or the European demonstrator (EU DEMO). The application of such tools in predictive mode allows to assess the performance of the different sub-systems, giving important feedbacks to the designers.
Concerning the superconducting (SC) magnet system of future tokamaks, i.e. one of the most expensive sub-systems, the 4C code [L. Savoldi, et al., Cryogenics, 2010] for the analysis thermal-hydraulic of transients has recently demonstrated his predictive capabilities [R. Zanino, et al., Supercond. Sci. Technol., 2018] and is being widely applied in the design process of both DTT and EU DEMO.
In order to reduce the cost of the magnets, and thanks to the experience gained in several experiments and to the know-how developed for the massive production of the ITER magnets, the design margins of future tokamaks will be reduced [N. Taylor, et al., Fus. Eng. Des., 2014], demanding for more detailed and reliable simulations.
To tackle this new challenge, a new, fully-3D model of the casing has been developed for the 4C code, to be coupled to the winding pack module. The improved level of detail that is achieved will be demonstrated comparing the results from the new model with those obtained approximating the 3D casing with a set of several 2D cross sections, as done in the current version of the 4C code.
The empowering of the 4C code will open up the perspective opportunity to introduce in the tool new, fully-3D pieces of physics, such as the electro-magnetics and mechanics, to compute the eddy current losses in the steel casing during current ramps or the thermo-mechanic stress during the coil cool-down.

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