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JT-60SA TF coils steady-state regime: acceptance tests modelling with CEA simulation codes and first extrapolations to tokamak operation

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The JT-60SA tokamak is a large-scale fusion installation located in Naka (Japan) to be operated as a satellite for the ITER tokamak and also to explore DEMO plasma regimes 1. JT 60SA first plasma will be run end 2020 and will represent the energization of the worldwide largest superconducting cryomagnetic system in operation for fusion. The magnet system is composed of 18 Toroidal Field (TF) coils, 6 Equilibrium Field coils and the Central Solenoid. In total 20 TF coils were procured by Alstom-GE (France) and ASG (Italy) and were extensively tested in Cold Tests Facility (CTF) in CEA Saclay (France). All TF coils were tested along a given acceptance procedure, and furthermore, among the TF coils, two of them, bound to be used as spare coils (TFC02 and TFC19) were tested within a specific test program, called Advanced Tests Activity (ATA) aiming at reinforcing the knowledge on TF coils behavior by expanding the experimental database. For these specific tests, more instrumentation (temperature sensors) was installed on TFC02 to get a better accuracy on the behavior of each hydraulic unit length of the coil windings. ATA tests were conducted with a wide range of various parameters (current, temperature rate, etc⋯) in order to quantify the influence of each of them on the coil performances, the overall aim of the ATA program being to provide experts with an extended database to allow consolidated analyses for predictions for future tokamak operation.
On the other hand, in the aim of consolidating its modelling capacities, CEA team developed several codes to address the prediction of JT-60SA magnet performances in operation. A quasi-3D simulation code was built [2], coupling THEA (thermohydraulics) and Cast3M (thermal) and besides a multiphysic platform OLYMPE [3] was also developed to allow, among other goals, parametric studies to be led in an efficient way.
In the paper we present in a first part, an extensive study, where the ATA tests carried out on the TFC02 coil are tentatively represented with the coupled tool THEA-Cast3M inserted in OLYMPE structure. In this goal, several operational parameters are varied to match the whole experimental data. For innovative purpose, we chose to consider in our studies, three parameters which are usually not explored in the modelling approaches:
- The quality of contact between the casing and the winding pack (WP). Indeed the casing is heated by external thermal loads and will transfer its heat to the conductor in the WP, this transfer being driven by the quality of contact between the two pieces. An example of a configuration is visible in Fig.1 showing the location of the contact faces considered in the study. For instance those contacts can intrinsically vary along WP perimeter and also in time between the operating phases: steady state (no WP deformation) and current loads (WP asymmetric deformation).
- The cooling channels (CC) efficiency, the CCs being located in two zones of the casing and expected to divert some of the casing heat, mitigating the heat flux to WP. They are also shown in Fig.1. The CC properties can vary along their thermal contact quality with the casing.
- The conductor winding hydraulic properties (see Fig. 1), that will drive the coolant (helium) mass flow and therefore its heat exhaust capacities. The hydraulic properties have a statistical scattering and therefore should be included in the sensitivity approach regarding impacting factors for the helium temperature.
We will show the different optimal configurations, matching with the experimental data (that can be seen with Fig. 1, with the pancakes outlet temperatures variations in TFC02).
The most appropriate model setting will be exposed and justified.

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In a second part, the simulation tools optimally set is run with the TF model in tokamak configuration in a coupled configuration with the cryoplant model represented with Simcryogenics code [4][5].
Several operation cases are analyzed and commented with the nominal operation parameters and some boundary cases. A statistical approach is also conducted using the strands performance database and results in a virtual coils performance database in operation conditions that shows a probability curve of the TF coils performances in normal operation. This database strands as a ground for a future comparison with the experimental data expected to be issued from the JT-60SA tokamak commissioning.

1 P. Barabaschi, Y. Kamada, H. Shirai and the JT-60SA Integrated Project Team, "Progress of the JT-60SA project", Nucl. Fus. Vol. 59 n°11 (2019).

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[4] S. Varin et al., “An update of dynamic thermal-hydraulic simulations of the JT-60SA cryogenic system for preparing plasma operation”, presented at CHATS conference, submitted to Cryogenic (2020).
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