A 2D THERMAL ANALYSIS OF THE SUPERCONDUCTING PROPOSAL FOR THE TF MAGNET SYSTEM OF FAST

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FAST (Fusion Advanced Studies Torus), the Italian proposal of a Satellite Facility to ITER, is a compact tokamak (R = 1.82m, a = 0.64m, triangularity $\delta = 0.4$) able to investigate non linear dynamics effects of α-particle behavior in burning plasmas and to test technical solutions for the first wall/divertor directly relevant for ITER and DEMO (e.g.: full-tungsten wall and divertor and advanced liquid metal divertor) [1]. In the present design phase, the feasibility of a superconducting solution for the magnet system is being investigated by ENEA. It consists of 18 Toroidal Field, 6 Poloidal Field and 6 Central Solenoid module coils, all of which wound by Nb3Sn and NbTi Cable-In-Conduit Conductors (CICCs) [2]. In particular this paper focuses on the analysis of the TF magnets thermal behaviour.

One of the main critical aspects in the operation of a superconducting TF magnet is the heating of the conductor due both to a direct component of energy deposited by neutrons and by secondary gamma generated during plasma operation, as well as to heat generated by the radiation on casing and transferred to the winding pack. The operating temperature and the relevant temperature margin (*i.e*. the operating safety margin) of the magnet depend strongly on the heat loads and on the capability of the coolant to remove it. Furthermore, the heat power to the conductor depends on several aspects, namely the thickness of steel casing and isolating materials, the mass flow rate of helium flowing in the conductors and its thermodynamic properties at operating conditions, and the layout of the superconductors constituting the winding pack (WP). Moreover, a crucial aspect in the machine design is the presence and characteristics of the neutron shield.

In this paper a 2D analysis of heat transfer from casing to WP is presented along with an estimation of the heat power directly generated in the conductor itself; it is based on the reference layout of the magnet and is also aimed at defining thickness and position of the neutron shielding. The approach employed, similar to the one already applied by the authors for the analysis of the thermodynamic behaviour of the JT-60SA NbTi TF magnets [3], consists in coupling 2D thermal calculations of the coil structures with 1D analysis of the conductor constituting the most critical pancake in the WP, in order to calculate a fundamental parameter of the TF coils, namely the temperature margin ΔT.

[1] A. Cucchiaro, et al., *Fusion Engineering and Design*, vol. 85, Issue 2, 2010, Pages 174-180.
[2] A. Di Zenobio, et al, *FAST: conceptual design for a completely superconducting magnet system*, presented at the ASC 2010, Washington DC (USA), 1-6 August 2010.
[3] G. M. Polli et al., *Fusion Engineering and Design*, vol. **84**, 2009, pp. 1531-1538.