A multi-scale dynamic thermal-hydraulic modelling approach for the EU DEMO breeding blanket

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Abstract

The European Demonstration Fusion Power Reactor (EU DEMO) will be the next step, after ITER, to prove the feasibility of fusion electricity, according to the European Roadmap for Fusion Electricity. It aims to be the first power plant in the EU to yield net electrical energy from fusion and, as such, will be the first fusion plant including all the components of the power conversion chain. Although the experience of fission reactors may be partly exploited, the design of such components must nevertheless address come peculiar challenges (e.g. pulsed operation). On the other hand, the EU DEMO will also be the first reactor to include the Breeding Blanket (BB), in order to achieve tritium self-sufficiency. Since no experimental data will be available for the BB until the second operational phase of ITER, the design of such system must rely on computational tools.

A model of the thermal-hydraulic transients in the entire EU DEMO plant, from the first components heated by the plasma (e.g. BB, divertor) up to the turbine, should consider all the relevant phenomena, which take place at very different spatial scales, from the centimeters of the BB and divertor cooling channels up to the kilometers of the Primary Heat Transfer System and Power Conversion System piping. At the same time, different timescales are found in such a complex system: the coolant transit time in the in-vessel components, as well as that in the ex-vessel loop, is to be compared against the thermal characteristic timescales, which vary significantly according the different materials found in the cooled components (ceramic pebble beds, metallic pebble beds, steel structures, liquid metals, …). Considering also the much longer timescale of the plasma pulses, the numerical stiffness of such problem is evident. This effect is also amplified considering accidental scenarios, such as for instance an in-vessel Loss-Of-Coolant Accident (LOCA), where the hydraulics of the coolant discharge in the Vacuum Vessel is much faster than the heat transfer between the coolant and the vessel walls.

This work presents an analysis of all these different timescales, as well as the modelling approach and assumptions used to solve all the mentioned issue, by introducing the GEneral Tokamak THErmal-hydraulic Model (GETTHEM), a fast-running, system-level, transient thermal-hydraulic code being developed at Politecnico di Torino since 2015 with the support of the EUROfusion PMU. The assumptions used to have a fast-running tool are described, together with some results, to show examples of possible applications of this tool, which are relevant for the EU DEMO.

Keywords: **nuclear fusion, thermal-hydraulics, modelling, EU DEMO, breeding blanket**

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