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OPENSC2: the thermal-hydraulic modelling of superconducting cables moves towards Open Science

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Within the framework of Open Science, set as a priority by the European Commission in Horizon Europe, the OPENSC2 code has been developed to grant the entire research community the possibility to simulate thermal-hydraulic transients in LTS and HTS cable-in-conduit conductors (CICC) for fusion and power applications.
A Test-Driven Development (TDD) approach has been adopted for the code development. Three test cases are considered of paramount interest: 1) An ITER-like 2-region CICC, with a thousand of mm-size LTS strands, cooled by SHe; 2) A HTS twisted-slotted-core CICC for fusion application, cooled by SHe and 3) A three-phase HTS power cable, with the supply and return lines for the LN2 coolant in a counter-current concentric configuration.
The TDD allowed to build an open-source object-oriented tool (OPENSC2): exploiting the "conductor" class, each Conductor Object (CO) is the combination of different lower-level objects (both fluid and solid components) instantiated by the class. The choice of each component drives the automatic selection of the appropriate physical equation(s) in the code: 1D transient heat conduction equations for any Solid-component Object (SO), and a full set of 1D Euler-like equations in the non-conservative variables velocity, pressure and temperature for any Fluid-component Object (FO). The SOs are thermally coupled through conduction and/or radiation to other selectable SOs along their length, and to selectable FOs. The FOs are in turn hydraulically and thermally coupled to other selectable FOs. A huge variety of constitutive relations for the transport coefficient in the FO (friction factors, heat transfer correlations) are available to the user. The SE includes not only categories of strands/tapes of pure stabilizer, strands/tapes with bulk SC material, and mixed strand/tapes, but also categories of jacket materials. Thermo-physical properties of different cryogenic fluids can be attributed to the FOs. A user-friendly GUI allows monitoring the simulations while running.
In this work, the three test cases are first discussed with their peculiarities, deriving the set of characteristics that the target object-oriented tool should comply with. The OPENSC2 tool is then introduced, showing how it allows successfully the simulation of thermal-hydraulic transients in any of the three test-cases. Benchmarks with the 4C code in the first two cases are performed to support the V&V of OPENSC2. The public repository where the tool is made available to the community is also presented, together with a proposal of a public benchmark challenge.

Keywords

HTS cables, LTS cables, Object Oriented Modeling, Theaml-hydraulics, open-source

Category

Tools to support commissioning and operation phases of superconducting magnet systems

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