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Feasibility of different cryogenic systems for ReBCO coils based high-dynamic superconducting actuators

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We present a systematic design approach to the cryogenic system of ReBCO coated conductor based high-temperature superconducting actuators used in highly dynamic applications. While ReBCO coils operating around 20 K can in principle increase the force-density of linear actuators by nearly a decade, the thermal design of such a system poses two important challenges. First, the foreseen AC loss levels are considerable in such a high-dynamic application with an array of ReBCO racetrack stator coils typically exposed to the magnetic AC fields of copper mover coils, which can reach up to 1 T peak-to-peak and contain many higher harmonics above the main actuator frequency of 10 Hz. Second, these substantial losses created heat that needs to be drained from the moving system, since the 'stator'in many actuator applications acts as a balance mass and thus needs to be mobile, albeit typically with a lesser stroke than the mover experiences.

A range of design options is available for the various components in the cryogenic system of such a machine. In the presented initial feasibility study systematically several types of cooling schemes have been investigated including bath-, conduction- and gas-cooling. In order to assess and rank their applicability, a set of criteria is presented against which each potential cooling solution can be assessed. Following this systematic approach, the most promising cooling methods are identified and subjected to more detailed thermal modelling to assess whether or not they can maintain the intended operating temperature under the foreseen heat load. For the linear actuator under consideration, conduction cooling is the most promising candidate, since it avoids sloshing-induced vibrations associated with a bath; is relatively compact and robust; and enables a thin-walled cryostat, which reduces the air gap between the cold stator and the warm mover.

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