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C1Or3D-01: [Invited] Cryogenic aspects of a 20 MW class superconducting generator for the Renewables industry

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In this paper we give a progress update on the cryogenic design for cooling a 20 MW class, partially superconducting generator with stationary field coils for offshore wind renewables industry. This is a continuation of an earlier program on a 10 MW system dating back ten years. Whereas this new power rating increase leads to a radial diameter expansion of the superconducting field coils from 4 to > 8.5 m, it maintains the axial length.
We show the design based on this scaled up with enlarged diameter. The field coil size increase asks for higher cooling power that leads to a bigger cold box size to accommodate the cryocoolers. In the design, as many as 8 cryocoolers can be accessed and serviced from the nacelle that houses the main cryogenic components. A typical thermal load balance sheet with all components is given and compared against the available cryocooler cooling power at different operating conditions.
Due to the cryocoolers'local point of contact cooling within the nacelle, the temperature gradient of the thermal shield that fully encloses the cold mass with its embedded field coils needs to be balanced out to minimize the heat burden on the field coils. This requires additional analytical efforts and implementation of further design features.
The extended nacelle houses the cold box with its cryogenic infrastructure. The interface for the envisaged cryogenic pushbutton closed-loop circulating system remains invisible, requires no handling of cryogenic liquids and is hermetically closed.
The field coil diameter increase also leads to a greater initial helium gas storage volume. In addition, it requires higher initial room temperature fill pressure within the toroidal helium vapor storage tanks and in cooling tubes connecting to the cryocoolers. The toroidal helium gas tanks are thermally coupled with the thermal shield so that helium convection inside the storage tank can improve heat transfer and reduce the temperature gradient of the thermal shield.
Besides those heat transfer challenges, additional mechanical strain within this large structure is exerted on the torque tubes during initial cooldown and when energizing field coils.
Some of those design challenges are quite unexpected, leading to novel workarounds in order to maintain the chosen cooling strategy. Finally, we assess those design limitations in view of further cryogenic scalability with emphasis on manufacturability and assembly.

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