The Thermo-Electric Design of the Electric Current Feeders of the HL-LHC Triplets

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Abstract

The HL-LHC Project currently undertaken by CERN that provides an upgrade to the existing LHC accelerator, is designed to increase the luminosity of the colliding particle bunches by a factor of at least five. Part of this upgrade will require the replacement of the existing groups of three superconducting LHC triplet magnets situated on each side of the ATLAS and CMS detectors with similar groups of four higher field HL-LHC triplet magnets of a new design that exploit coils manufactured with cables in Nb3Sn superconducting alloy. The HL-LHC triplet magnets require dedicated electric current feeders linking their cold masses to their cryostat vacuum vessels, thermo-electrically optimised and specifically designed to separately feed their quench protection, beam tuning and instrumentation systems with electric current. The HL-LHC instrumentation feedthrough system is similar, though containing a larger cable inventory, to that mounted on existing cryo-magnets in the LHC accelerator whereas the quench protection and beam tuning systems, both present new requirements calling for a substantially different design approach. Installed in a highly activated zone of the LHC, all three systems consequently exploit only natural heat convection to prevent the formation of condensation at their warm ends. This paper describes the functional design and thermo-electrical optimisation achieved for each of these current feeder systems.

Design parameters

The feeders’ design process respects several specified requirements which are mainly thermal and electrical, see table 1. For the CLIQ and K-mod feeders, the electrical currents that can originate through them, has also to be considered for the design, see table 2.

Design methodology

The design of feeders involves a compromise between intrinsic and external interdependent parameters, see figure 5. In practice, several iterations are needed to reach the optimum design that respect the electrical, thermal and environment requirements. Because of the nonlinearity of the material, properties as a function of temperature, an finite elements ANSYS model is used to design the feeders, see figure 6.

Results

The results obtained with the aforementioned methodology are presented here. The physical dimensions of the feeders are presented in the table 3, and the integration on figure 7 and 8.

Conclusion

The functional design and thermo-electrical optimization, together with the integration of the IFS, K-mod and CLIQ systems into their respective cryo-magnets has been completed. To benchmark the degree to which the numerical model is conservative, experimental thermal performance studies will be carried out in autumn 2019. The design of the HL-LHC triplet IFS, K-mod and CLIQ feeders is now moving from the conceptual to a detail phase. First units for assembly to HL-LHC triplets will be available in the first quarter of 2020.