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Advanced electrical quality assurance methods for the series production of the superconducting coils of the HL-LHC high order corrector magnets

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The INFN-LASA laboratory (Milano, Italy) is involved in the High-Luminosity LHC program for the design, construction, and test of 54 superconducting high-order corrector magnets. One of the challenging project stages was the transition from the construction of prototype magnets to the series production, awarded to industries with the demanding requirement of maintaining high-quality production standards during the production of a relatively high number of components, e.g. almost 500 superconducting coils.

This paper reports on the advanced quality assurance methods implemented at the manufacturer premises for the test of the coils electrical characteristics: the electrical insulation towards ground (measured through standards methods), the number of turns, and the internal turn-to-turn insulation.

The consistency of the number of turns during production is verified by a dedicated electromagnetic setup designed and built at LASA. It consists of a ferromagnetic yoke coupling two superconducting coils fed by alternating currents with opposite signs. A pickup coil is mounted on the yoke to measure the magnetic flux that for a perfectly balanced system is equal to zero. The design of the setup is optimized through finite element models to improve the signal-to-noise ratio, i.e. the measurement of the flux due to an unbalanced number of turns with respect to the flux due to geometrical imperfections, and make it high enough for its application in an industrial environment.

The quality of the coils internal insulation is assessed through a surge test with a capacitor bank generating an AC voltage. The data shows that the conventional numerical method used for the analysis leads to several false positives and, therefore, a dedicated numerical method with higher specificity is implemented.

The data collected on about 80% of the total coil production shows the effectiveness of the adopted methods, which in some cases allowed for early defect detection.

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