A 100-ppm Cryogenic DC Current Transformer for 100-kA Superconducting Cable Testing

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The design and the realization of a cryogenic superconducting DC current transformer working up to 100 kA is proposed. The typical precision of reference DC current transformers for maximum range of 100 kA is guaranteed at 4.2 K. In the sensing element, the state-of-the-art limitations of μ-metal magnetic characteristics at cryogenic conditions are overcome by using a soft Ni-Fe magnetic alloy (Ni 81- Mo 5-Fe, cryogenic permalloy). Core saturation due to mechanical constraints is avoided by an optimized geometrical design. A screening shell of pure iron is also considered to increase the overall performance. A large margin of immunity is achieved for off-centering problems.

The metrological performance is further increased by a superconducting shield. The shield consists of a hollow cylinder of MgB2 composite, manufactured by the Reactive Mg Liquid Infiltration process; its design is driven by the experimental characterization of a MgB2 sample cylinder at 4.2 K. The geometrical design is carried out both for axial and transversal field configurations by modeling the shielding currents on the cylinder inside. Well-established techniques are used to model the system. Experiments for a background field of 1 T prove a shielding efficiency of 70% in both the axial and transversal configurations.

The effectiveness of the DC current transformer design is demonstrated through electromagnetic simulations and measurement results of experimental characterization. Results of 2D electromagnetic simulations of the sensing element, at nominal working conditions are shown, which exploit the data from the experimental characterization of the cryogenic permalloy. The results show the effectiveness of the DCCT for accuracy of the order of 10 ppm.