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M4Or1A-03: Electrical Performance of Cryogenic Inductors

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Inductors typically consist of copper or aluminum windings around magnetic cores. However, as magnetic cores are not suitable for cryogenic applications due to substantial eddy current loss generated by reduced core resistivity at cryogenic conditions, coreless inductor designs are preferred for cryogenic applications.

In this paper, we report the electrical performance including ampacity and energy density of inductors designed for liquid-nitrogen-cooled cryogenic power applications. The main purpose of the study is comparing the ampacity and energy density of cryogenic inductors compared to their room temperature (RT) counterparts. Although magnetic cores are absent in the cryogenic inductors, the substantially increased conductivity of the windings at cryogenic and the superb cooling capability of liquid nitrogen significantly increase the ampacity of the conductors, which enables the use of thinner conductors that provides higher inductance per volume and mass. In addition, the absence of magnetic cores substantially reduces the weight of the cryogenic inductors, which is a crucial factor for aircraft and shipboard applications.

For the experiments, coreless inductors are designed for both RT and 77 K. The RT design is built with copper conductors of 1.291 mm diameter while the 77 K design is built with that of 0.16 mm diameter. The ampacity of the two inductors is managed to be identical by controlling the number of windings for the 77 K design. We also designed an RT inductor with a magnetic core and compared its inductance to that of the same inductor without a core designed for 77 K.

The results of this study show the feasibility of utilizing inductors at cryogenic conditions. The findings contribute to the materialization of cryogenic power electronics technology.

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