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M2Or3J-03: [Invited] Tuned windings - the window of opportunity for the implementation of solid conductors in high frequency cryogenic electric machines

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Abstract
This paper presents some aspects of the implementation of superconducting coils in megawatt size electric machines designed to maximize the power density as a main optimization criterion. Such electric machines will be suitable for electric flight and alike and / or hybridization of big jet engines, albeit the technology may be applied to almost any other category of electric machines due a very cost effective fabrication technology mated with a minimal usage of materials.
Generally speaking, increasing the supply frequency of an electric machine is very helpful to decrease its weight and size, however increasing the frequency produces two parasitic effects known as the "Skin Effect" and the "Proximity Effect". The combined effect of such losses is an important fraction of the total AC losses, around 80-90% of the practical implementations considered herein. For a given magnet wire (current carrier) the intensity of these two effects is proportional to the frequency, however these effects are also dependent to the general size, the specific geometry of the current carrier and the resistivity of the material (among other specific implementation aspects). As a general rule, large conductor sizes are highly affected (negatively) by these two effects. This is the main reason why high frequency currents are used mainly for small size electric machines, while large size electric machines cannot take full advantage of a high frequency supply source. Particularly, superconductivity is highly benefic for decreasing DC losses, however the AC losses will worsen. The present work presents a specific geometry of the superconductor current carriers, herein named Tuned Winding. This geometry is able to highly decrease the skin and the proximity effects while taking full advantage of the highly increase electric conductivity. A simple computation algorithm (also presented) enables the determination of an optimum geometry for each particular application, including full practicability for Megawatt class electric machines. Basically the expression of the AC resistance is non-linear and therefore the computations are based on the Nonlinear Conjugate Gradient (NCG) method which proved to be highly adequate. The NCG method is a prominent algorithm for the numerical optimization of nonlinear problems with low memory requirements. Furthermore, certain technologic implementations for Megawatt class electric machines are also presented including the simulation of their thermal behavior operating with cryogenic coolants.

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