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Sat-Af-Or5-03: AC loss characteristics of SCSC cables under various practical operating conditions

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The Spiral Copper-plated Striated Coated-conductor cable (SCSC cable) is our novel concept of high current cable with low ac loss, in which copper-plated multifilament (striated) coated conductors are wound spirally on a metal core in multiple layers. Whereas copper-plating allows current sharing among filaments against local defects in a filament, filaments are decoupled electromagnetically against transverse ac magnetic field thanks to its spiral geometry. Note that ac loss cannot be reduced effectively in a flat copper-plated multifilament coated conductor because of electromagnetic coupling among filaments. The structure of an SCSC cable, in which copper-plated filaments are spiraled, is like the structure of a conventional LTS wire, in which filaments embedded in copper matrix are twisted.

In their practical applications, SCSC cables will be subjected to magnetic fields with various amplitudes and various frequencies and will be used at various temperatures. In the stator windings of rotating machines such as propulsion motors of aircrafts, the cables will be used in magnetic fields with moderate amplitudes (from one to a couple of Tesla) and high frequencies (50 –200 Hz). In the CS coils of tokamaks and the beam bending magnets of accelerators, they will be used in magnetic fields with high amplitudes (10 –20 T) and relatively low ramp-up rate. Therefore, the quantitative evaluation of ac losses under such various operating conditions is very important.

We propose a method of quantitative evaluation of ac losses in SCSC cables under various conditions based on experimental results: we evaluate hysteresis losses and coupling losses separately. We measured the magnetization losses of SCSC cables with various configurations at various frequencies in liquid nitrogen and extracted hysteresis-loss components. Even though we could apply magnetic field up to 100 mT, this field amplitude was higher than the penetration fields of sample cables, considering small critical currents at 77 K. The plots of normalized hysteresis loss vs. normalized field amplitude of various sample cables showed us that hysteresis losses above the penetration field reasonably agree with Brandt and Indenbom's analytical values for each filament with a correction factor for field orientation. Therefore, by using the critical current at an arbitrary operating temperature measured elsewhere, we can calculate hysteresis loss above the penetration field at this temperature using the Brandt and Indenbom's formula. Meanwhile, we measured the coupling losses of SCSC cables with various configurations in a wide range of frequency up to 20 kHz at various temperatures. Using a plot of measured coupling loss vs. frequency of a sample cable at a temperature, we can determine the coupling time constant and geometry factor of coupling loss of the cable at this temperature. Note that the temperature dependence of a copper plating of multifilament coated conductor, which influences its transverse resistance, causes the temperature dependence of the coupling time constant of the SCSC cable consisting of the multifilament coated conductor. Using the determined coupling time constants and geometry factors of coupling losses, we can calculate the coupling losses of various SCSC cables at arbitrary frequency and arbitrary temperature.

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