AC Loss of a Quasi-isotropic Strand Stacked by 2G Wires by Numerical Simulation in Cryogenic Temperature

Changtao Kan, Yinhun Wang, Xi Yuan and Yanbing Hou, Yan Li
State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources, University of North China Electric Power, Beijing 102206, China

Background
Due to high current carrying capacity and well mechanical property at low temperatures and large background magnetic fields, quasi-isotropic strands fabricated by 2G high temperature superconducting (HTS) wires show great potential for applications such as large-scale superconducting magnets or fusion reactors at low temperatures. During the charge of superconducting magnets, quasi-isotropic strands of magnets in use will inevitably produce AC loss. The generated AC loss will results in heating of the strand and may cause the magnets quenches. In order to design and protect the magnets, it is necessary to precisely study ac loss properties of quasi-isotropic strands at low temperatures and low frequency magnetic fields.

Objectives
- Ac loss numerical study of quasi-isotropic strand fabricated by second generation (2G) wires in cryogenic temperatures of 4.2 K and 77 K.
- Field amplitude dependence and field frequency dependence of ac losses of quasi-isotropic strand
- Effects of Cu sheath and field angle with strand on ac loss characteristics of quasi-isotropic strand

Model Geometry
The model geometry is composed of the Air region, Ag layer, Cu layer, REBCO layer and Al foil.

Model Equations
The numerical study is based on the H-formulation of Maxwell’s equations solved by the finite element method (FEM).

Model Results
Field amplitude dependence of ac loss of the strand

Results
- The penetrated fields of quasi-isotropic strand at 4.2 K and 77 K are 4.5 T and 0.2 T respectively, determined by loss factor versus magnetic field amplitudes. Loss factor $\Gamma$ has a constant peak value, $\Gamma_{\text{max}} \approx 20$, at temperatures of 4.2 K and 77 K.
- As the resistivity decreases in 4.2 K, the eddy current loss and coupling loss of quasi-isotropic strand immensely increases, which is not obviously in the 77 K case.
- Hysteresis loss in the strand has a decreasing frequency dependence, when the applied magnetic fields are lower than the penetration fields at both 4.2 K and 77 K temperatures.
- At 4.2 K temperature, 0.1 T and 0.4 T magnetic fields, total ac loss and hysteresis loss along field angles are both symmetric at 45 degree field angle with a maximum value. However, when the magnetic field at 77 K increases to 0.4 T, the trends of total ac losses and hysteresis losses became the inverse with a minimum value at 45 degree field angle.
- Next, ac losses of sample strands in 4.2 K and 77 K temperatures will be tested to verify the simulated results.

Conclusions

Fig. 2. Critical current as a function of magnetic field and field angle of REBCO coated conductor at 4.2 K temperature.