APP4-5

Electromagnetic and Thermal Coupled Analysis of an SFCL REBCO Coil Immersed in Liquid Nitrogen Considering Boiling Phenomenon

*Kezhen Qian[1], Yutaka Terao[2], Hiroyuki Ohsaki[2]

Graduate School of Engineering, The University of Tokyo, Japan[1]
Graduate School of Frontier Sciences, The University of Tokyo, Japan[2]

A resistive type SFCL using REBCO tapes has shown high potential in limiting fault currents rapidly and improving the power system reliability. Temperature during and after the limiting operation is a key parameter when designing a SFCL, because the superconductor is sensitive to high temperature [1]. A detailed thermal analysis is helpful to study the transient distribution of the temperature. However, it is still a subject to precisely simulate the transient characteristics of coolant, which cannot be neglected and plays an important role in recovering from normal state to superconducting state [2].
In this paper, we have developed a 3D electromagnetic and thermal coupled FEM analysis model to study the transient characteristics of an SFCL REBCO coil immersed in liquid nitrogen. A thin-plate approximation and coordinate transformation (from cylindrical coordinate system to orthogonal coordinate system) is utilized to conduct the electromagnetic analysis of REBCO coils in 2D calculation space which have 3D structures. The governing electromagnetic equation is given by $\nabla\times(\rho\nabla\times\boldsymbol{T})=-\partial\boldsymbol{B}/\mathrm{dt}$ ($\boldsymbol{T}$: current vector potential; ρ: electric resistivity; $\boldsymbol{B}$: magnetic flux density), where $\boldsymbol{T}$ is defined by $\boldsymbol{J}=\nabla\times\boldsymbol{T}$ ($\boldsymbol{J}$: current density). In thermal analysis, the 3D structure of REBCO coil is modeled and the temperature rise is calculated under the condition of Joule heating, heat conduction, heat transfer, and cooling characteristics of liquid nitrogen. Moreover, the boiling phenomenon of nitrogen and hysteresis in the heat transfer coefficient are approximately modeled in this work. With this analysis model, we studied the transient temperature distribution and recovery of REBCO coils with the cooling of liquid nitrogen that considers the influence of boiling hysteresis phenomenon.

References

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