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Development of quench analysis model of spiral coated conductor cables combining one-dimensional heat conduction equations and circuit equation

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Spiral coated conductor cables, in which multiple coated conductors are spirally wound around a circular cross-section metal core, such as CORC®-like cables, have advantages such as high mechanical freedom and high current capacity. Such cables are expected to be used in various applications, such as magnets for accelerators and nuclear fusion, and coils for rotating machines and generators. Additionally, even if normal transition occurs in one coated conductor, the current flowing in the coated conductor can be shared with the other coated conductors and the metal core, and thermal diffusion into the metal core is possible. Therefore, the spiral coated conductor cables are considered to have high robustness against quench. Quench analysis models for spiral coated conductor cables are needed to evaluate their quench characteristics.
As results of previous researches, we have confirmed that the temperature gradient in the thickness and width direction of a coated conductor is almost negligible, and that thermal diffusion to adjacent objects such as cores plays an important role in quench and thermal runaway processes. In addition, the purpose of this study is to know the temperature and current distribution among coated conductors and core during quench, and not to know the detailed temperature and current distribution in the coated conductors. Therefore, we propose a quench analysis model that approximates each coated conductor and core in one dimension. We combined one-dimensional heat conduction equations, each of which represents one coated conductor, and circuit equations, in which each coated conductor is represented with a series of non-linear resistance. In the heat conduction and circuit equations, the coated conductors are in partial contact with each other. If these contact points are regarded as nodes, a thermal and electrical network consisting of one-dimensional elements can be constructed. For the metal core, it is considered to be in continuous contact with coated conductors in the innermost layer and is approximated as a one-dimensional line. Then, the thermal conductivity and electrical resistivity are corrected for the length difference caused by the straight shape of the metal core and the spiral shape of the coated conductors. Although the constructed network is represented by one-dimensional heat conduction and circuit equations, it contains a three-dimensional contact structure within the spiral coated conductor cables.

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