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A FEM-based simulation of electromagnetic forces on transformer windings under short-circuit

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As the key equipment of power plants and substations, Transformers carry heavy responsibility of power transmission, distribution and transformation of voltage levels. Recent years, with the construction of UHV projects, the highest voltage level in China has increased to more than 1000kV and has formed several UHV networks, enhancing the reliability and efficiency of power supply. However, this also put more stringent requirements on the operation and maintenance of transformers. When a short-circuit fault occurs, the current flowing through transformer windings will be bigger than before, exerting larger electromagnetic forces on transformer windings, resulting in the collapse of the transformer structure. In that case, it is of great meaning and imperative to calculate short-circuit forces precisely.

Different from traditional analytical method, the finite element method can accurately solve the magnetic field distribution in all parts of the windings, and plays an important role in the transformer design process. In order to calculate precise electromagnetic forces, this paper reviews the analytical method of electromagnetic force calculation firstly. And then, the three-dimensional and two-dimensional simulation are carried out by FEM. Because the short-circuit impedance is determined by the leakage flux in circumferential direction, the short-circuit impedance of the three-dimensional model which is more real than two-dimensional model is compared with the measured one to determine the model accuracy. The steady state analysis of the two-dimensional model are compared with the three-dimensional model to verify the accuracy of the magnetic field distribution in some specific location of the windings. Finally, the transient analysis of the two-dimensional model is carried out to find out the variation laws of short-circuit electromagnetic forces applied to the windings with time. The short-circuit electromagnetic forces obtained through the above method is accurate and quickly. And it can provide the necessary reference for the transformer design.

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