Study on Magnetic-thermal Coupling of Converter Transformer Under Non-sinusoidal Current

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Abstract

This paper investigates one of the key equipment in UHVDC transmission, which is the converter transformer. The harmonic current generated by the converter can cause localized overheating in the transformer windings. Finite element models of the magnetic field and thermal field of the core winding are established based on experimental data. Finite element simulation results are provided for sine excitation, rated excitation, and variations in winding conductivity with temperature. Finally, the hot spot temperature of the winding is verified using analytical and the experimental scaling model, confirming the necessity of considering harmonic current and variations in winding conductivity with temperature.

1 Introduction

Due to the influence of the converter valve, the converter transformer in UHVDC transmission produces non-characteristic harmonics, with the number of harmonics being 6k±1. Additionally, the winding conductivity decreases with increasing temperature. These factors contribute to high harmonic losses in the iron core and winding, which can lead to local overheating and impact the normal operation of the converter transformer. Therefore, it is necessary to consider the impact of harmonic currents on the temperature of the converter transformer core and winding[1]. In [2], the effect of temperature on the magnetic properties of electrical steel in transformers was discussed, but the change in winding conductivity due to temperature was not considered.

Through finite element analysis, analytical model verification, and shrinkage model verification, this paper investigates the influence of the two-way coupling between harmonic currents and material parameters on the temperature rise of the converter transformer core and winding. Firstly, the magnetic properties of electrical steel sheets at different temperatures are obtained through experiments. Then, a magnetothermal coupling finite element model is established, and its temperature rise is calculated. Finally, the simulated hot spot temperature is verified by an analytical model.

2 Analysis and Simulation on Temperature of Converter Transformer's Core and Winding

The research flowchart and simulation results are shown in Fig. 1 and in Table 1. The magnetic characteristic curve data shown in Fig. 1 were incorporated into the finite element model of the transformer (V_N=750kV/200kV, S_N=412.3MVA) considering boundary conditions, and the results are presented in Table 1. The results indicate that the hot spot temperature of the winding increases with the increase of harmonics. When considering the full wave, the hot spot temperature of the winding can reach 85℃. Furthermore, when taking into account the variation of winding conductivity with temperature, the hot spot temperature increases sharply, reaching up to 105.3℃,

which significantly exceeds the A-level thermal resistance grade of oil-immersed transformers and poses a threat to the service life of the transformer.

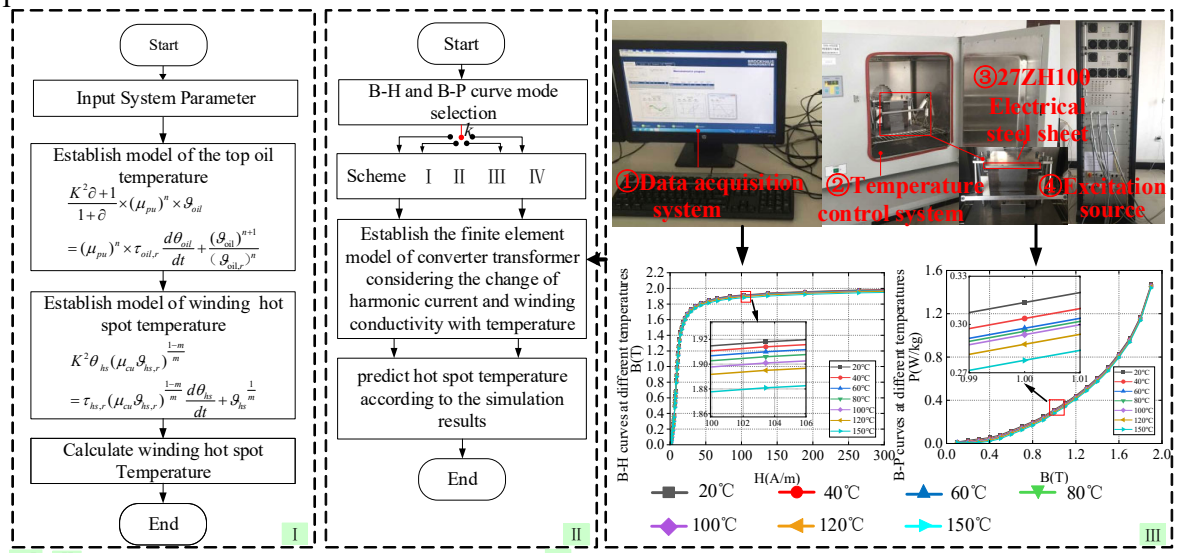
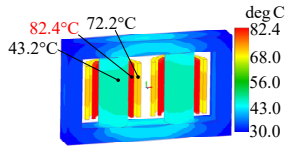
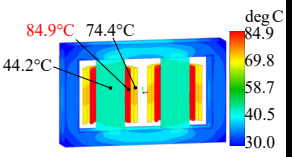
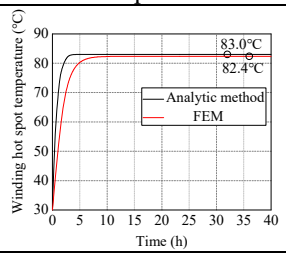
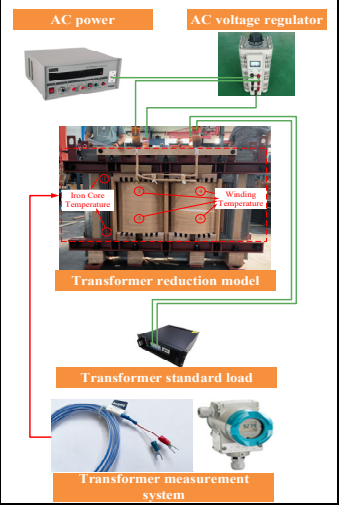
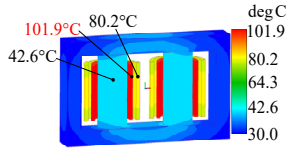
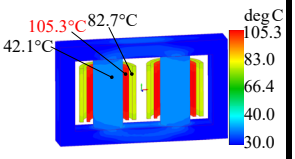
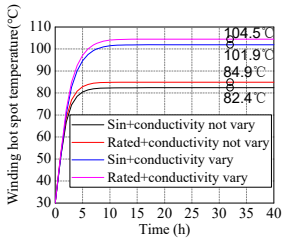


Figure 1: Research process flowchart

Table 1 Analytical method, finite element method and experimental comparison

Simulation		Comparison	Experiment
Sinusoidal excitation	Rated excitation		
			
			

3 Conclusion

Considering the magnetic characteristic curve of electrical steel, a three-dimensional finite element model of electromagnetic thermal coupling is established in this paper. The temperature field of the core winding and the hot spot temperature of the converter transformer are analyzed using four schemes, providing guidance for local overheating. The results show that harmonics and changes in conductivity have a significant influence on temperature, with an error of 0.7% between the simulation and analytical results. Detailed analysis results and comparisons are presented in this paper.

References

[1] J. Zhang and L. Cheng, Simulation Analysis of the Influence of Harmonics Current on the Winding Temperature Distribution of Converter Transformer, 2021 6th Asia Conference on Power and Electrical Engineering (ACPEE), 2021. 1566–1571.

[2] D. Chen and Y. Zhang, Study of transformer magnetic properties considering temperature influence of electrical steel sheet, *International Journal of Applied Electromagnetics and Mechanics*. **64** (2020) 761–769.