Study on Electromagnetic Loss Characteristics of Magnetically Controlled Transformer

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Abstract

The multifunctional magnetically controlled transformer (MCT) organically integrates the magnetically controlled reactor with the distribution transformer. It has the advantages of fast and smooth adjustment of reactive power, and small overall floor area. Because of the topology of MCT is complex and affected by DC current, the analysis of electromagnetic loss characteristics on MCT iron cores is rather necessary. Firstly, this paper studied the structure and operating principle of MCT through the circuit analysis; Then, established the instantaneous core loss calculation model; Finally, quantitatively calculated the electromagnetic losses of MCT via finite element analysis (FEA), providing reference for its parameter design and heating verification.

1 Introduction

To solve the problem of reactive power imbalance in distribution transformer, many studies combined transformer with power electronics technology[1-2], the voltage amplitude and phase can be controlled flexibly, but they have high cost and large loss. Besides, there is a multifunctional transformer, which can change the reactive power by adjusting the size of nano-composite magnetic material [3], but this material is still in the preliminary research stage. This paper coupled the magnetically controlled reactor and the traditional distribution transformer, further analyzed its electromagnetic loss characteristics by finite element simulation.

2 Working mechanism analysis of MCT

MCT adopts the core structure of 3D six-pillar, includes AC windings and DC windings, as show in Fig.1. By controllably increasing the size of the I_D in DC windings, the saturable degree of the iron core is increased, then the magnetic inductance L_m is reduced, in equation (1), the input voltage U_1 almost unchanged, the inductive reactive power Q_L will increase finally, to achieve the goal of balancing the excess capacitive reactive power Q_C in the distribution power system.

$$Q_L = \frac{U_1^2}{X_m} = \frac{U_1^2}{\omega L_m}, \qquad \min \Delta Q = \min\left|Q_L - Q_C\right| = 0 \tag{1}$$

3 Electromagnetic loss calculation model

The iron core will generate electromagnetic losses during operation, including hysteresis loss p_h, eddy current loss p_c, and residual loss[4], f is frequency, $\theta=2\pi ft$, as equation (2).

$$p_h(t) = \frac{k_h B_m \cos\theta}{\pi}\frac{dB}{dt}, \qquad p_c(t) = \frac{k_c}{2\pi^2}\left(\frac{dB}{dt}\right)^2 \tag{2}$$

Ignored residual losses under 50Hz sinusoidal excitation, Hysteresis loss coefficient, eddy current loss coefficient, peak magnetic flux density is k_h, k_c, B_m respectively.

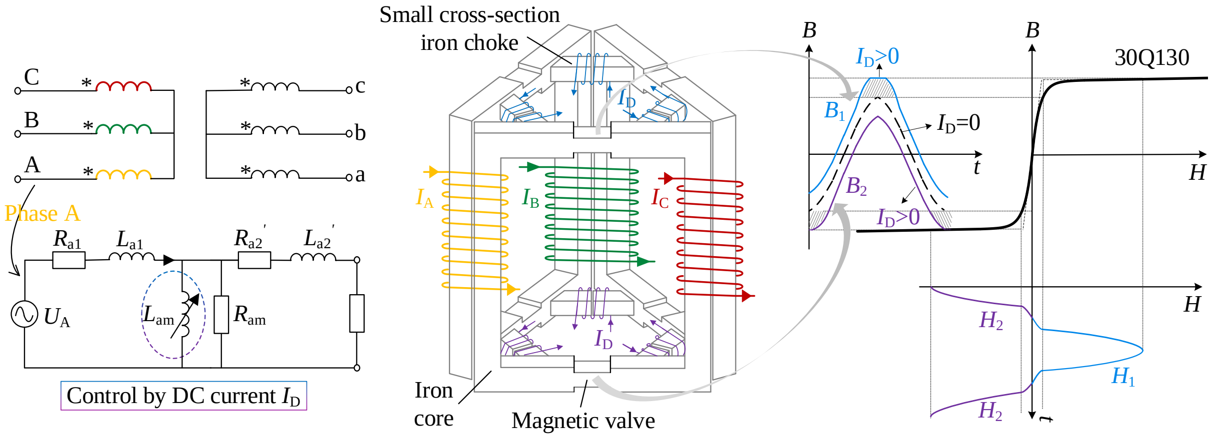

Figure 1: The equivalent circuit and topological structure of MCT

4 Finite element simulation

The iron cores of MCT are made of 30Q130 silicon steel sheet, its thickness is 0.3 mm, obtain k_h=54.038, kc=0.296 through *B*-*P* curve fitting. Setting the material and circuit parameters in finite element simulation and then conduct field-circuit coupling analysis, the results as Fig.2.

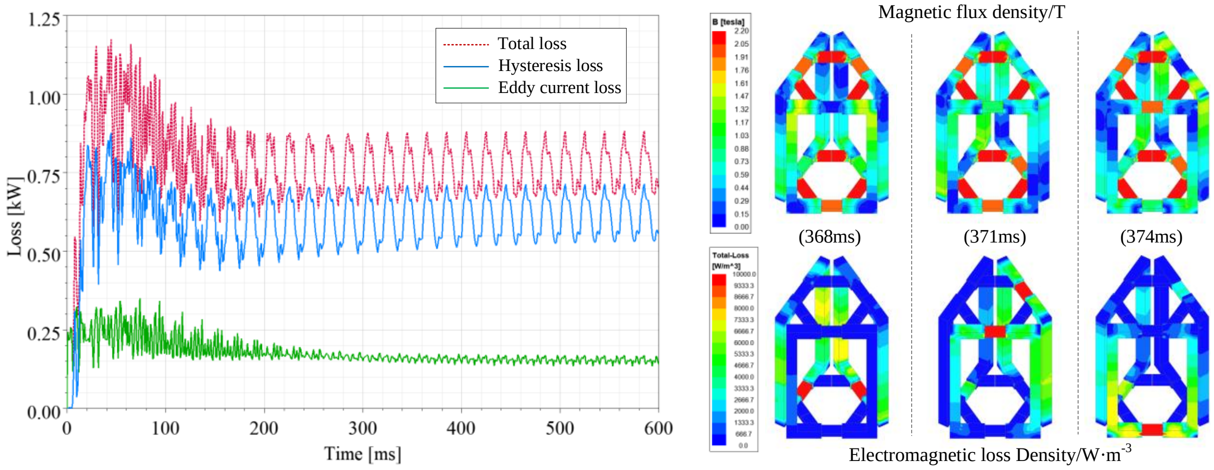

Figure 2: Finite element simulation results

5 Conclusion

This paper designed a three-phase 10kV/0.4kV MCT. In steady state, the FEA indicates that MCT can consume maximal reactive power is 93 kVar, the offset of transformer ratio is 0.45%, verified its multifunctional features. The average loss of cores is 762.5W, hysteresis loss is 605.1W, eddy current loss is only 157.4W due to the small thickness of silicon steel sheet. The loss on the magnetic valve of MCT is the largest and should be focused on in the heat dissipation design.

References

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