Improvement of Magnetic Shielding for Transformer Tank Based on the Magnetic Flux Characteristics at Shielding Ends

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Magnetic shielding is generally laid on transformer tank and clamping frames to reduce the eddy current loss in the tank, yet the flux concentration phenomena caused by the magnetic shielding is not well paid attention by designers. According to the simulation results of the accustomed shielding structures, we noticed that the flux density near the end of shielding plates is relatively high. Thus an idea is proposed that regions with lower flux density before shielding construction may also need to be shielded, and the shielding should be made to closed path or loop, i.e., the shielding plates in different directions should be connected each other, or the end of plates should be bent to the core surface. The aim of all these measures is to avoid the flux entering the transformer tank. The improved structure of the shielding can obviously reduce the loss of the tank, which can mitigate the extent of local overheating. The effect of the magnetic shielding is calculated by the finite element analysis.

Index Terms—Finite element analysis, Magnetic flux leakage, Magnetic shielding, Power transformers.

I. INTRODUCTION

Leakage magnetic field in power transformers produces additional eddy current loss and reduces efficiency on the one hand, and the non-uniform distribution of leakage field may cause local overheating, endangering the normal operation of the transformer [1]. At present, the measures adopted to reduce the eddy current loss is laying magnetic shielding on transformer tank and clamping frames [2]-[5]. However, the shielding structure is not completely appropriate.

The problems of the accustomed shielding structure are presented in this paper. An improved shielding scheme is proposed, accounting for the regions that local overheating may occur.

II. PROBLEMS OF THE ACCUSTOMED SHIELDING

The tank of transformer is usually constructed of thick steel plates due to the mechanical structural requirements, so the eddy current loss in the structure would be large. In order to reduce the eddy current, magnetic shielding must be placed for large-capacity transformers. Magnetic shielding is generally made of materials with a large magnetic permeability and electrical resistivity (like laminated silicon steel plates), and is attached to the inner wall of the tank. It avoids leakage magnetic field entering the tank, and reduces the eddy current loss of the tank.

Due to the similar situation of the upper and lower tanks, only the upper part of tank is analyzed here in the short paper. Fig. 1 shows the upper part of the magnetic shielding structure (yellow plates) in a 334MVA single-phase transformer. The eddy current loss distribution of the upper tank calculated by ANSYS Maxwell is presented in Fig. 2(a).

It can be observed from the figure that the loss density is quite large at the corner of the tank, and it’s actually caused by the flux near the end of shielding plates in each directions.

This can also be presented by the distribution of magnetic lines near the corner of the tank, as in Fig. 2(b).

![Fig. 1. Accustomed magnetic shielding structure (upper 1/8 tank model).](image)

The left side and the upper side are the surfaces of the tank. Since the magnetic shields on both sides are not closed, there is a gap left. When the magnetic flux passes outward the shielding plates in one direction, a great amount of it enters the corner of the tank rather than the plates in another direction. That is the reason why there is a large loss density in the corner. The loss here can cause severe local overheating.

![Fig. 2. (a) Distribution of eddy current loss on the edge of tank with the accustomed shielding structure. (b) Distribution of magnetic flux lines with the accustomed structure of shielding on the top and the flank surfaces of tank.](image)

III. IMPROVEMENT OF THE SHIELDING STRUCTURE

Large local loss density is led by the leakage flux guided by the shielding plates from the transformer space to the shielding ends. The flux at the end enters the corner of the tank. So we try to connect the shielding plates in both directions and change the shape of the plates to avoid flux entering the tank.
A. Connecting the shielding on the edges

The plates in two directions are connected, and the distribution of the magnetic lines is shown in Fig. 3(b). As can be seen in the picture, due to the large magnetic permeability of the shields, the leakage flux is substantially retained inside the shielding structure. Even if there are small gaps between the plates for manufacturing reasons, most of the flux can be conducted inside the shields. The part entering the tank is negligible.

![Fig. 3. (a) Distribution of eddy current loss in the upper of tank with connected shielding structure. (b) Distribution of magnetic flux lines with connected shielding structure.](image)

Distribution of loss density under connected structure is shown in Fig. 3(a). The loss at the corner is small, indicating that the connecting can indeed improve the local loss distribution significantly. Nevertheless, the upper surface of the tank has a large loss at the end of the shielding plates. In order to reduce the loss in this region, the end structure of the shielding need further enhancement.

B. Curving the shielding at ends

After shield connecting, the loss is transferred to the other end region of shielding plates. From the previous analysis, conclusion is easily drawn that it’s because the magnetic flux flows out of the plates and enters the tank generating eddy current loss. Naturally, we try to change the shape of the shielding plates and bend the edge of the plates to the direction of the magnetic core, hoping to avoid the flux entering the tank and guide the flux back to the core. The curving structure is depicted in Fig. 4.

![Fig. 4. Structure of shielding with curved ends to guide the flux into the yoke.](image)

With curving edges, the loss density distribution has been homogenized. The total loss is almost the same, but the maximum value of loss density has been reduced to nearly half of the original flat ends.

However, it’s worth noting that the loss in the upper tank surface slightly increases. That’s because the side of the curving edges near the upper surface also attracts a part of the magnetic flux, which is more likely to enter the tank. Eddy currents are induced, so the loss increases. The process can be intuitively illustrated by the distribution of flux lines in Fig. 5.

![Fig. 5. Distribution of magnetic flux lines near the shielding ends. (a) The original straight plates. (b) The end-curved plates.](image)

C. Effect of the improved magnetic shielding

Normally, people’s understanding of magnetic shielding tends to be reducing the eddy current loss of adjacent structural members, but insufficient attention is put on the flow of magnetic flux, especially that near the end of plates. From the analysis of this paper, designers can clearly understand the cause of the high loss density and local overheating, and improve the shielding structures based on end characteristics of magnetic flux.

After the improvement of shielding structures, the eddy current loss of each surface of the tank is calculated. The total loss of tank is 68.6% of the accustomed structure. Therefore, the shield connecting can not only improve the loss distribution, but also reduce loss furtherly.

In addition, optimization are performed for the dimensions of the shielding at each positions, and the process is omitted here in the short paper.Eventually the overall eddy current loss is reduced to 34.7% of the accustomed structure after all the optimization procedures, and the problem of local overheating get solved.

IV. CONCLUSION

In the design process of magnetic shielding, just laying shielding plates at high-flux-density positions is not reasonable. The effect should be considered that the shields will guide the flux to the end, which makes the flux density and loss density at the end quite large, even causing local overheating. The shielding plates are supposed to be made to closed path or loop, avoiding the magnetic flux entering the tank at the shielding end region.

REFERENCES