Multiparametric Analyses of a Model Transformer Core Under Two Basic Types of DC Bias

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Abstract – DC-bias of transformers may yield very different effects, ranging from increased noise to destruction. This paper reports simulations of two basic types of bias, analyzed in multi-paramagnetic ways. Type 1 yielded strong increases of losses and magnetostriction, type 2 intensively enhanced stray fluxes in interaction with also simulated tank material. Both types enhance noise through different mechanisms.

1. Introduction

DC-bias arises in modern grid systems of complex interconnection with steadily increased intensity. However, intensive bias tends to be restricted to cases of geo-magnetically induced currents, so called GICS. The latter may even cause destruction of transformers as e.g. reported in [1].

From theoretical considerations, we can distinguish two basic types of DC-bias:

Type 1 (T1) - It enhances *interior* flux within the core (Fig.1a) as being typical for 1-phase cores, 5-limb cores and 3-phase cores under unbalanced DC.

Type 2 (T2) - It enhances *exterior* stray flux (Fig.1b) as being typical for 3-phase cores.

Earlier studies of a 3-phase core showed that the consequences of bias depend on many parameters in complex ways (e.g. [2]). The present study was performed at a 1-phase model core, type 2 being simulated through two anti-components of bias. The variety of consequences of bias was investigated by multi-parametric analyses.

2. Methodologies

Measurements were made on a model core of 400 mm height and 320 mm width, assembled from 70 layers of highly grain oriented material 23ZH90. In practice, AC current tends to be super-imposed by DC current within the same windings. Here we used separate windings (with identical turn number) which allowed for simple and well defined combinations of AC and DC. The AC magnetization was performed for a flux density of 1.7 T (50 Hz). The bias intensity was defined as the DC/AC ratio r_{DC} as the DC excitation over the peak value of AC excitation as arising without bias.

Multiparametric analyses included measurements of the following: (i) Excitation current. (ii) Local building factors (local loss / nominal loss) detected by a pair of thermistor sensors. (iii) Local in-plane induction by surface dummy sensors [3]. (iv) Local off-plane induction by surface frame-coil sensors. (iv) Local magnetostriction by surface strain gauges. For tank simulations, a cup-like cover of steel St 52 was arranged with a mean distance of 20 mm from the core. Stray-flux-induced magnetization was detected by surface dummy sensors.

3. Results and Discussion

As a very pronounced tendency, bias of Type 1 (T1) yielded strong increases of AC excitation (order of 300% for r_{DC} up to 3), in contrast to very weak ones (restricted to

30%) for T2. This corresponds with a distinct shift of induction working point for T1, while the effect of T2 is blocked by the minute susceptibility of the surrounding air, even in the case of tank simulation (Fig.1b). A corresponding tendency resulted for local losses where consequences of T2 proved to be insignificant. On the other hand, T1 with r_{DC} = 1 yielded distinct increases of regional building factors by more than 10% in limbs, and about 6% in corners and yokes. Finally, also effects on magnetostriction were much more pronounced for T1, obviously due to a strong enhancement of lancet slope domains, as confirmed by Kerr effect studies.

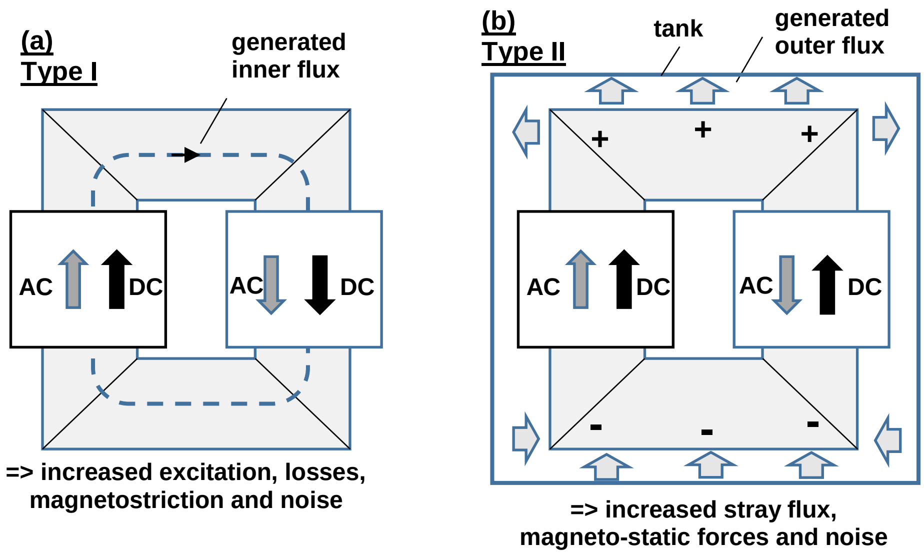

Fig.1: Two fundamental types of DC bias, illustrated for the simple case of a 2-limb 1-phase transformer core. The observed main consequences are summarized below. (a) Type 1 as causing interior flux. (b) Type 2 as causing exterior stray flux, also through the magnetic surrounding.

Increased magnetostriction was linked with rising noise. However, the latter increased also for bias of Type 2. An explanation results from strongly increased stray flux, causing magnetostatically induced vibrations especially of peripheral laminations. This effect proved to be most pronounced in cases of simulated tank, the latter revealing distinct regional magnetization.

As a main conclusion, multi-parametric analyses confirm theoretical expectations for two basically different types of DC-bias on transformer cores. Losses are mainly affected by Type 1, while increases of noise have to be expected for both types.

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References

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