Magnetostriction and its Contribution to the Noise of a One-phase Transformer

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Abstract – The deformation of magnetised ferromagnetic material, known as magnetostriction, in a transformer core produces vibrations and results in an unwanted noise. In this work, the magnetostrictive behaviour of electrical steel samples, which are often used in the transformer cores, is measured by using a heterodyne laser interferometer setup. The measurements are performed in two directions in parallel and perpendicular direction to the applied magnetic field. The measurement results are then used to calculate the vibrations of a one-phase transformer core in a finite element software. For a validation, the finite element vibration results are compared with the vibrations of a similar test transformer setup.

1 Introduction

During the last years, environmental concerns on noise reduction have gained more attention. Looking at industrial applications, transformers are widely used and thus studying their noise contribution is noteworthy. Several studies have been reported on the transformer noise and the design improvement, e.g. [1].

A great deal of the transformer noise is generated in the core of transformers, which is called the magnetic noise. Magnetostriction is one of the causes of the magnetic noise which refers to a three-dimensional deformation of the magnetic material of the transformer core when magnetised. As a result, such deformation produces vibrations and results in noise. The complex behaviour of the magnetostriction and in particular its dependence on the material structure and the applied magnetic field necessitate to properly measure it in order to calculate its contribution to the total noise.

In this work a two-dimensional magnetostrictive behaviour of electrical steel samples, in parallel and perpendicular direction to the applied magnetic field, are measured by using a heterodyne laser interferometer setup. This setup has been previously reported in [2], [3]. The measurements are performed under sinusoidal magnetic fields with 50 Hz frequency, i.e. the grid frequency. The obtained measurement results are applied to model the vibrations of a one-phase test transformer core in a Finite Element (FE) software. For the validation of this model, the results are compared with the vibrations measurement results of a similar real test transformer setup.

2 FE calculation and validation

Transformer cores are often built up of grain-oriented electrical steel due to a higher magnetic induction and lower magnetic loss than a nonoriented electrical steel for the same magnetic field. The grain-oriented materials show significantly better magnetic properties in the rolling direction compared with the other directions. Therefore, to increase the efficiency, the transformers are built so that the magnetic flux always follows the rolling direction of the material, which is made possible with different lap-

joint assemblies. However, with a lap-joint assembly, in a stack of laminations the flux going from one lamination to another lamination passes through the small air gap in between in the out-of-plane direction. As a result, there is an additional noise generated due to the clapping of the joint regions of the core.
The focus of this work is only on the magnetostriction noise and thus only this noise should be modelled. To this end, the test transformer laminations are cut in one piece to avoid any air gaps. The cutting is performed by the spark erosion technique in order to avoid any harms to the magnetic properties of the material due to cutting. Once again, since grain-oriented materials are highly oriented in one direction, the use of a nonoriented electrical steel for such a transformer with a single piece lamination is preferred. The material used for the test transformer is a nonoriented M350-50 electrical steel.
The vibration calculations are then performed by using the magnetostriction measurement results of the nonoriented electrical steel. The measurement results are first modelled with Neural Network (NN) and then the NN model is applied for the FE calculations. For the validation of the FE vibration results, a similar test transformer is built. The vibrations of the magnetised transformer core are measured by using a laser scanning vibrometer and compared with that of the FE data, as illustrated in Fig.1.

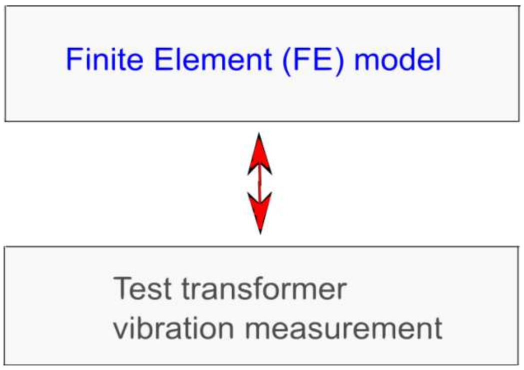

Fig.1: A validation of the FE model results by a comparison with that of the test transformer

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