1 WHY AND HOW POWER TRANSFORMERS PRODUCE ACOUSTICAL NOISE

Transformer noise has two sources: winding vibrations and core vibrations. The single most effective way to reduce windings noise is by having a good quality controlled winding process when assembling them. This research focusses on the cores of normally silent transformers, which make noise under adverse mains conditions. Transformer cores can become noisy as well under specific secondary load conditions which can be translated (transformed) into the adverse mains conditions at the primary as discussed in this paper.

There are three physical phenomena that produce noise in the magnetic core [1-16]:

1. The movement of the 90-degree Bloch walls inside the magnetic domains, frequently called Magnetoacoustic Emission (MAE); see Figure 1.
2. The rotation of the magnetic domains, that is responsible for the bulk magnetostriction; see Figure 2.
3. The Lorentz Force Acoustic Signal (LFAS) causing mechanical forces between laminations of the core; see Figure 3.

MAE occurs in the steep section of the hysteresis loop; see Figure 4. Not much sound is emitted and the bulk magnetostriction is small. The rotation of the magnetic domains is dominant near saturation in the hysteresis loop. The magnetostriction becomes "large" and the core laminations move considerably, thus generating acoustic noise; see Figures 4 and 5.

The rattling of laminations of the core (LFAS) depends largely on the construction of the core. The EI-type cores are more prone to make noise due to their many separated pieces of lamination which mostly are only sturdy clamped at the four corners. In toroidal cores the long role of core band is sturdy clamped everywhere due to the mechanical rolling tension and the pressure caused by the winding tension.

In general: magnetostriction, occurring near saturation of the core, is the main cause of the acoustical transformer noise, while LFAS largely depends on the construction of the core. Due to magnetostriction the core vibrates at the fundamental mains frequency and its harmonics and at core resonance frequencies. In this regard it is important to notice that a noisy transformer means that a) the transformer is badly constructed -or- b) that the transformer is forced to operate in a magnetic region close to or at core saturation.

The main reason why the transformer is noisy may be a combination of the above given causes. Anyway, the device has become noisy and the amount of acoustical noise produced should be measured to determine whether or not the produced noise level is acceptable.

2 MEASURING AND QUANTIFYING ACOUSTIC TRANSFORMER NOISE

It is not so difficult to measure the amount of noise produced by a transformer. First, we need to isolate the noisy device from the environmental noise, to be sure that we are only measuring the transformer noise and not the environment noise. This means that a "silent" room or isolating chamber should be constructed. Transformers in general are not freely floating in the air, but sturdy mounted in cases. Each of those cases is different in shape and construction and each case will contribute in a different way to the total amount of noise produced. Therefore a "standardized" case should be defined on which the transformer under test should be mounted. A calibrated microphone is needed plus some calibrated pre amps and so on. A minimal measurement time length should be defined and related to the lowest frequency to be measured. Noise level and the distance -r- to the noisy product are related and consequently the distance between microphone and transformer should be defined. The noise signal in the time domain needs to be converted (by means of FFT) into the frequency domain. For each frequency, there should be a weighting factor, coupled to the sensitivity of the ear, to determine the perceptibility of the noise. There should be a clear definition of the mains conditions: is the mains "clean" or "distorted" and in what way and how do distortions affect the noise produced and measured as indicated above.

Figure 6 and Photo 7 give an impression of a suitable sound isolation chamber. The character of this design is such that the internal reflections of the transformer noise are absorbed by the chamber. The microphone detects the acoustical transformer noise only in one direction; from the transformer directly to the microphone.