SOUND IN TRANSFORMER: HOW IT HAPPEN AND HOW TO PREVENT IT

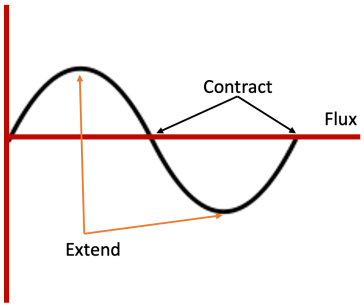
Transformers are everything when it comes to power regulation. They do their job reliably and effectively over the past century, however, transformer noise can be a significant problem. Even small amounts can prevent power transformers from working the way they're designed, thus it's important to know exactly what transformer noise is, what's causing it, and how to prevent it.

INTRODUCTION

Noise generated by transformer

Even though a transformer has no moving parts and considered as reliable and efficient electrical machine, humming and buzzing noises caused by a phenomenon called magnetostriction are a common complaint with electrical transformers. The causes and reduction of transformer noise has been a subject of interest for at least two decades. Accordingly, noise levels produced by power transformers have begun more and more important and they have established itself as one of the research field. It has also come to prominence again, mainly because transformers are placed closer to the populace—in high rise office buildings, apartments, shopping malls and residential house.

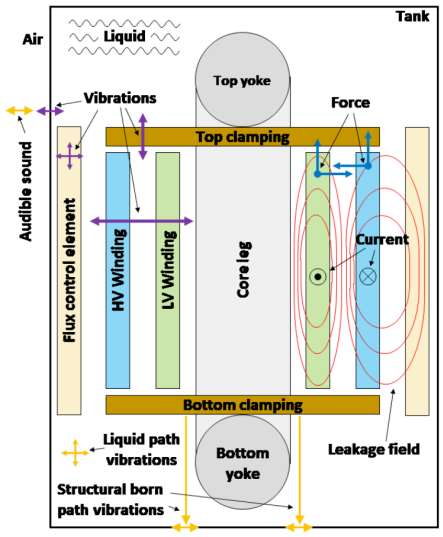
WHAT MAKES A TRANSFORMER NOISE?



Extension and contraction of silicone steel

The main cause of transformer noise is the Magnetostriction Effect. The act of magnetisation by applying a voltage to a transformer produces a flux, or magnetic lines of force in the core. In very simple terms, if a piece of magnetic sheet steel is magnetised it will extend itself. When the magnetisation is taken away, it goes back to its original condition and shape. A transformer is magnetically excited by an alternating voltage and current so that it becomes extended and contracted twice during a full cycle of magnetisation. However, this extension and contraction is not uniform and varies all over a sheet. Since these extensions are only small dimensionally, and therefore cannot usually be seen by the naked eye. They are, however, sufficient to cause a vibration, and as a result noise. Flux density, core material, core geometry and the wave form of excitation voltage are the factors that influence the magnitude and frequency components of the noise levels.

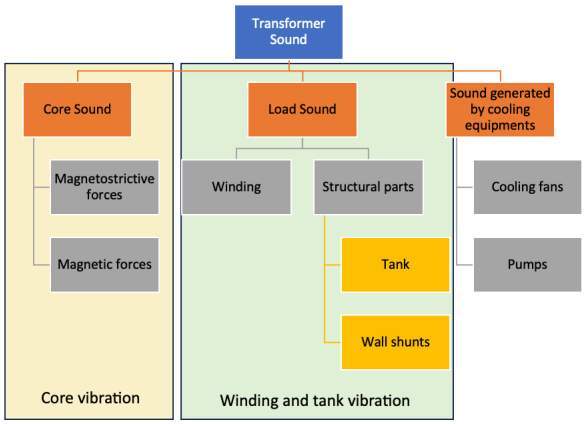
Nonetheless, noise is not only caused by magnetostriction effect. Load current flowing in transformer winding produced load sound. The contributing elements to load sound are; winding, stray flux control elements and structural parts. The vibrations emitted from the windings are usually the dominant contributor to the load sound. Since the magnetic field is proportional to the



Cross-section of a transformer illustrating the generation process of load sound

load current, the resulting force is proportional to the load current squared, at twice the excitation frequency. The magnitude of the vibrations depends also on the elastic properties of the conductor, the electrical insulation and the proximity of mechanical resonance frequencies of the complete winding assembly (e.g. windings, insulation, insulating liquid, clamping construction, clamping pressure).

The third factor which is effective on the transformer noise is fan and pump noise. As known magnetic induction that occurs between the nucleus and the transformer windings in the core, cause to rise in the heat level. Because of reaching very high level of heat value, the transformer needs to cooling system. Fan and pumps are used in power transformers in order to form the cooling apparatus. Noise produced by cooling fans usually contribute more to the total noise for transformers of smaller rating and for low-induction transformers. Factors that affect the total fan noise output of a transformer include: tip speed, blade design, number of fans and arrangement of the radiators. Cooling equipment noise typically dominates the very low and very high frequency ends of the sound spectrum, whereas the core noise dominates in the intermediate range of frequencies between 100 Hz and 600 Hz.

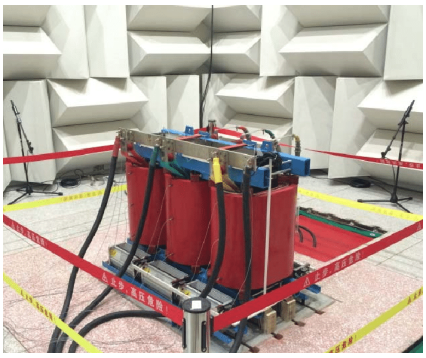


Transformer noise

HOW TRANSFORMER NOISE ARE MEASURED?

Transformer noise are measured in dB (decibel), but what do they really mean? In simple terms, we are trying to take what we hear and relate it to scientifically measurable terms. The decibel as used in acoustics is a measurement comparing the pressure generated by a noise against some standard level. The determination of sound power levels of power transformers is described in international transformer standards; IEC 60076-10 ”Power Transformers – Determination of sound levels”, published in year 2016. The noise level is measured basically by two methods, sound pressure measurement and sound intensity measurement. Sound pressure level is a scalar quantity and requires simple instrumentation. Sound intensity is a vector quantity and the method measures directional sound. It is, therefore, less affected by a background noise. Hence, the sound intensity method can give more accurate measurements in the presence of background noise. However, sound intensity measurements require higher skill and more sophisticated instrumentation.

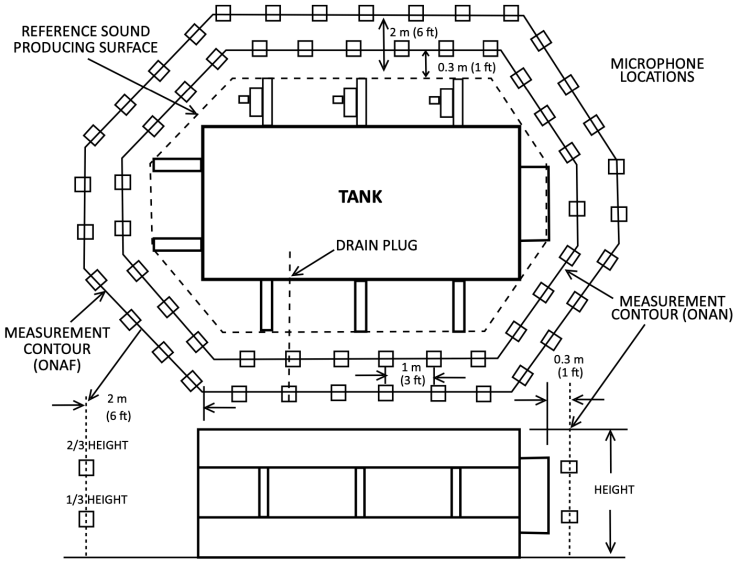
Noise Level Measurement Facility



Noise test of transformer in semi-anechoic room

The minimum level of noise which can be measured is limited by the ambient noise conditions in the test area. Special enclosures may have to be used to shield the instruments that are the test set-up and transformer from the high ambient noise. The noise level measurements can also be performed in large room or open areas where the interference of background noises are much minimal.

Test Condition



Noise measurement zone and layout measuring points

Measurements should be made in an environment having an ambient sound pressure level at least 5 decibels below the combined sound pressure level of the transformer and the ambient sound pressure level. According to IEC 70076-10, in the condition of forced cooling system is off the measurement has to be taken 0.3 meters away from the transformer surface. And the measurement has to be taken 2 meters away from the transformer if the cooling systems are on. If the tank height is less than 2.5 meters the measurement has to be taken from the half of the total tank height. If the tank height is greater than 2.5 meters, then the measurement has to be taken from total tank height's 1/3 and 2/3 heights. The microphone must be positioned at the stated height and distance. In addition, a measurement must be taken from at least six microphones. The horizontal distance between the microphones mustn't be more than 1 meter.

WHAT CAN WE DO ABOUT REDUCING TRANSFORMER NOISE?

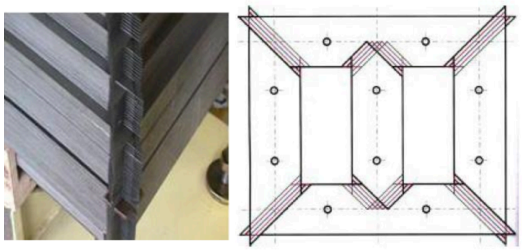
First of all, we need to accept that the operation of power transformer will produce noise and vibration. Noise is usually air borne, whereas vibration is structure borne. We have to consider how to avoid making it a nuisance to people. The most obvious strategy is to place the transformer in a field miles away from habitation. The noise level drops away as the square of the distance from the noise, but even so, it would take a very large field to hide it. However, we invariably have to place transformers near people and we must face up to that fact. As the noise has become one of the key issues, it should be addressed starting from the design stage.

Noise reduction from core

- Since the magnetostriction is related to the amount of flux, reduction in core flux density will reduce transformer noise. Reduction in flux density by 10% will give noise reduction 3 to 5 dB or approximately 2 dB per flux density reduction of 0.1 T. The flux density is inversely proportional to core weight, therefore, the method has adverse effects on the cost and size of transformers.

- In addition, the noise level can be reduced by application of suitable viscoelastic or adhesive coating to the core laminations. It should be ensured that any links or attachments to the core are flexible so that they do not transmit the vibrations.

- Improve on the design of core joints such as step-lap joint gives reduction by about 4 to 5 dB as compared to the mitred construction for the commonly used flux densities (1.6 to 1.7 T). The corner protrusions of the built core should be cut since they may contribute to noise due to vibrations.



Step-lap joints in transformer core

- Tightening the core yokes and limb structure and reducing gaps in the corners will help reduce the core noise. Core laminations are tightened with a glass tape (stage B epoxy) banding. This uniformly tightens the core when it is heated and leads to very strong and steady tightening of the core steel. The use of non-metallic bolts for tightening of the core yokes will provide additional tightening of the core lamination, which helps the core to produce less noise.

Noise reduction from winding

- Tightness of the winding during the manufacturing process, as well as pressing them axially to a certain extent during the drying stage, will reduce the noise effect during operation.

- For large power transformers, a special kind of transposed conductor is used for making the windings, in order to reduce losses in the windings and con- tribute to the winding noise reduction.

- Specific winding noise reduction is achieved by increasing the conductor’s size or increasing the transformer’s impedance. However, this will increase the amount of copper and hence the cost of transformer.

Noise reduction to tank

- Isolate the core-winding assembly from the tank base by use of oil compatible anti-vibration pads will reduce the structure borne vibrations. It should also be made between frames and tank. Such isolations can give a noise level reduction of 2 to 4 dB.

- Use wall sound barriers to reduce oil-borne noise. Oil barriers and cushion padding may also help to insulate the transformer noise and prevent it from spreading.

Noise reduction from fans

- Reduction of the fan noise can be achieved with fewer rotor revolutions of the fan per minute. However, this will reduces the cooling capacity. In order to compensate the reduced of cooling capacity, the commonly used fans should have more blades of larger diameter.

- The fan-structure-borne noise can be reduced by balancing the rotating masses, quality of bearing and a stable structure for securing the fan to the tank or the radiator for cooling.

Overall external noise reduction

- Installation of anti-vibration system under the transformer can help reducing the sound of vibration and hence it will decrease the noise appearing to the users. Anti vibration pads can absorb shocks and vibrations with an efficiency up to 70%.

- Noise is usually reduced or attenuated as it tries to pass through a massive wall. By putting a screen wall around the transformer, we can cutting air borne noise generated by the transformer.

Anti vibration pad

PERMISSIBLE TRANSFORMER NOISE LEVEL

The transformer and its corresponding sound level has been stated in National Electrical Manufacturers Association (NEMA) Standards or special requirement according to the regulations of the national electric power distribution networks. Recommended values of permitted noise of power transformer are defined depending on the power of transformer, test voltage and cooling modes. With increasing stress levels, allowed noise level of power transformer is increasing as well. For small distribution transformers up to 1000 kVA which

KVA	NEMA Standard Sound Level
0 – 9	40 dB
10 – 50	45 dB
51 – 150	50 dB
151 – 300	55 dB
301 – 500	60 dB
501 – 700	62 dB
701 – 1000	64 dB

Permissible transformer noise level by NEMA

are installed in distribution substations in urban areas, the level of allowed noise is up to 64 dB. Most national standards have stricter requirements regarding permitted noise level than international standards.

Next Issue

Transformer Explosion Prevention

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