MEANINGFUL MEASUREMENTS TO ASSESS POWER TRANSFORMER NOISE

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1 Introduction

Electric power transformers provide a link between the power transmission system and the distribution system. They transform the high voltage power (e.g. 138 kV) from the transmission system to the lower voltage (e.g. 25 kV) of the distribution system. These transformers are situated where electric power is used – frequently, close to people. Due to their hum and the noise of cooling fans they may cause intrusive noise [1] levels. The noise emitted by transformers can be characterized as continuous noise.

Utilities are frequently required to consider transformer noise when planning or expanding a substation, when residential developments are planned near existing substations. Standard CAN/CSA-C88-M90 [1] is typically used as a reference document when selecting a transformer. This standard defines the maximum acceptable average noise level in "decibels" for transformers of a given capacity and construction. Noise levels are to be determined in accordance with Standard "IEEE[2] C57.12.90-2010 [2]. That standard applies to measurements around transformers in a laboratory or factory setting or transformers installed in a substation. It produces a single number sound power level (PWL) and includes an elaborate measurement procedure in the near sound field around a transformer.

This paper aims to compare the measurement procedure and results according to IEEE standard C57.12.90-2010 to other relevant standards such as ISO 3744 [3] or measurements at some distance, assuming the transformer as a point source.

2 Sources and Frequencies of Transformer Noise

Transformer hum is mainly caused by vibrations in the core of the transformer (caused by magnetostriction) and, typically to a lesser extent by vibrations in the windings surrounding the core, caused by electromagnetic forces [4].

If the core is poorly supported, or in very silent transformers, the noise contribution from the windings may become more significant. In North America, the fundamental frequency for core noise is 120 Hz and can be recognizable for observers nearby and sometimes is tonal according to Standard ISO 1996-1 2003 [5] or ANSI S12.9-2005 part 4 [6]. Tonal noise can be perceived as more intrusive and can be penalized according to the standard. The noise from cooling fans is typically broadband and needs to be added to the core noise. The increase in the average noise level due to the cooling fans from a transformer can be approximately 3 - 5 dB.

Since the fans are located to the side of the tank, the tank may act as a noise barrier for fan noise, especially if the radiators are placed on one side of the transformer. Taking advantage of this barrier effect when positioning a transformer may reduce noise levels for nearby residents, or prevent the need to install low-noise cooling fans on the transformer.

3 Why Deviate from Standard C57.12.90-2010?

Standard C57.12.90-2010 may not be the most suitable to follow for noise measurements around installed transformers when assessing environmental noise impacts for a number of reasons:

A large number of individual measurements around and close to a transformer are prescribed. Individual readings are collected at 1 m horizontal intervals around the transformer. If the height of the tank or enclosure is 2.4 m or more, measurements are conducted at 1/3 and 2/3 of the tank or enclosure height. Otherwise, measurements are conducted at 1/2 height of tank and enclosure. See Figure 1 for an illustration of the measurement positions.

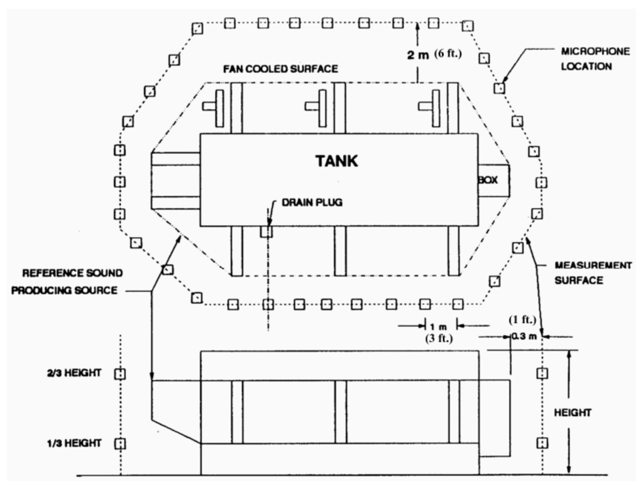

Figure 1. Measurement Positions According to IEEE C57.12.90

The prescribed procedure can easily result in hundreds of individual measurements. Assuming 30 seconds are required to collect each sample, the total uninterrupted measurement time is approximately 2 hours. It would be much quicker to allow for the microphone to be traversing over the measurement surface, resulting in an average sound pressure reading for that surface. This well-known procedure is allowed according to a more general standard

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[1] Noise is defined as unwanted sound.

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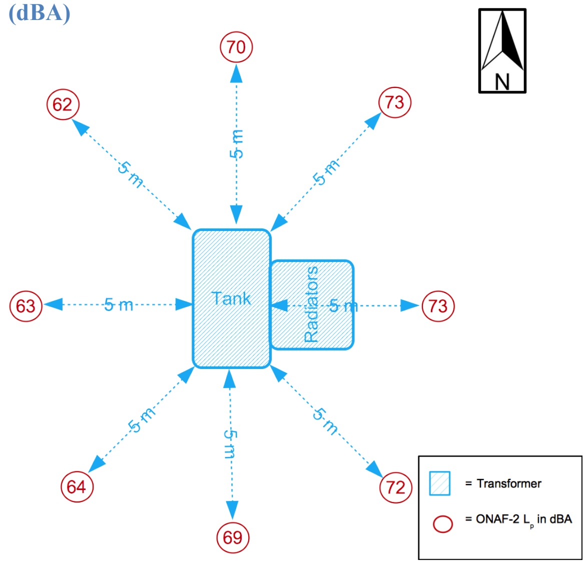
ISO 3744, frequently applied in noise measurements for all kinds of machinery.

The collected broadband or spectral data is energetically averaged to a single broadband or spectral number, representing the average sound pressure L_p around the transformer. This is the sound pressure L_p that standard CAN/CSA-C88-M90 refers to. From that average sound pressure, the average sound power is calculated without taking directivity into account. Directivity however may affect the noise impact. Standard ISO 3744 contains a procedure to assess directivity by comparing the measured sound pressure to the average sound pressure. It would also be possible to conduct measurements in the far sound field around a transformer at fixed distances (e.g. a circle at a fixed distance, with 8 equidistant measurements at a 45° spacing) to assess directivity. This is the preferred method. Practical considerations are background noise caused by other equipment in the substation and obstacles that may be challenging to overcome however. Under those circumstances, measurements according to ISO 3744 could be considered.

Measurements are conducted at a distance of 0.3 m from a reference surface around the transformer, except when cooling fans are running. If fans are running, the distance is 2 m. from any portion of radiators, fans etc. For frequencies up to approximately 500 to 1,000 Hz this is in the near sound field around the transformer. The large number of samples can be expected to compensate for potential deviations from the average sound pressure caused by local pressure variations, especially in low and mid frequency bands. However, considering transformer hum (120 Hz) and that the noise is experienced in the far sound field, it would be much simpler to conduct measurements also in the far field near the transformer. For a frequency of 120 Hz, this distance can be calculated to be up to approximately 4 m [7]. A very practical rule of thumb is that in order to characterize a noise source as a point source, the distance to the source should be at least double the maximum dimension of that source. See Figure 2 for an illustration of this approach. Measured sound pressure levels

Figure 2: Far Field Measurement Positions and Results (dBA)



in dBA are included in Figure 2 for ONAF-2[3] operating conditions. These results illustrate the directivity around a transformer as a result of the noise barrier function of the tank.

The required operating conditions according to [2] are that the transformer is energized at the rated voltage and frequency with no load and the tap changer at the principal tap. The "no-load" condition is typically not achieved when measuring operating transformers in a substation, and in such a scenario the tap changer may be at a different setting, depending on grid requirements. "No-load" indicates that the transformer windings do not produce noise. This may prevent a straight comparison between an operating transformer and factory-tested data for the same transformer. It should be noted however that winding noise is typically marginal compared to core noise.

4 Conclusion

Summarized, for operational transformers the procedure according to C57.12.90 is not preferred as it is elaborate, does not provide directional information, is measured in the near field and the load setting requirements are typically not achieved in an operational substation. Practical alternatives are equidistant and evenly spaced far field noise measurements or near-field measurements according to ISO 3744-2010.

References

[1] CAN/CSA-C88-M90 (reaffirmed 2014), Power Transformers and Reactors

[2] IEEE C57.12.90-2010 [2], Standard Test Code for Liquid-immersed Distribution, Power and Regulating Transformers

[3] ISO 3744-2010 Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane

[4] Handbook of Acoustical Measurements and Noise Control, 3rd edition, Cyril M. Harris, reprint by the Acoustical Society of America – 1998, Woodbury USA

[5]ISO 1996-1 2003, Acoustics, Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment and procedures

[6] ANSI S12.9-2005/Part 4, Quantities and Procedures for Description and Measurement of Environmental Sound – Part 4: Noise Assessment and Prediction of Long-term Community Response

[7] Handbook of Noise and Vibration Control, 2007, Malcolm J. Crocker, Published by John Wiley and Sons, Inc. Hoboken, New Jersey USA

[3] Oil Natural Air Forced. Typically, all cooling fans are running under ONAF-2 operating conditions.