Transformer Noise

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Introduction:

- **What is sound?**

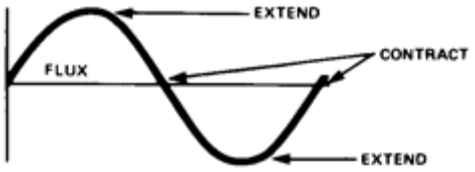
  Sound is an air pressure disturbance that human ear can 'hear'. Speech produces sound and disturbances produced by practically everything that moves. the frequency of the sound wave is perceived as pitch and amplitude is perceived as loudness.

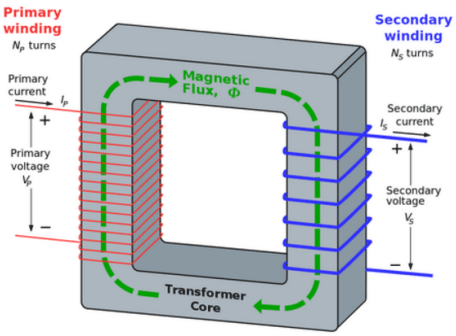
  When the sound in unwanted, it becomes "Noise". Transformers in operation emit noise, the magnitude of noise increases with its size in MVA and its voltage class.

  Sound level for transformers is specified in NEMA TR1.

- **How it is produced?**

  Transformer core noise is caused by a phenomenon called magnetostriction. In very simple terms this means that if a piece of magnetic sheet steel is magnetized it will extend itself. A transformer is magnetically excited by an alternating voltage and current so it becomes extended and contracted twice during a full cycle of magnetization. The frequency is 2X of the frequency of the voltage.





  A transformer core is made from many thin sheets of special electrical steel. It is made this way to reduce losses due to circulating eddy currents, and the consequent heating effect. If the extensions and contractions described above are taking place in various directions depend upon the clamping of the laminations, each sheet can nonuniformly behave over its length and width. This 'writhing' and twisting motion produces harmonics of the fundamental frequency up to the 16th harmonic. These extensions are a few micro inches dimensionally, however, sufficient to cause a vibration as noise. This is the core noise.

  Apart from the core noise, transformer windings contract and expand with the current. The frequency of winding noise is that of the current. The noise generated by core and winding is transmitted to the tank wall via the mechanical structure and through the oil. The magnetic shields, if used, will also vibrate with the magnetic flux and create noise.

  During operation, transformer generate heat which is dissipated by radiators, fans are used to enhance cooling. The fan motor and blades, causing additional noise. The fan noise is added to transformer noise and total noise of transformer during operation increased.

- **What is the significance of sound to the quality and reliability of transformer?**

  The transformer noise is mainly due to vibration in the core laminations due to magnetostriction. As we all know vibration is not good for any device. The effect of vibration in transformer is as bad as of any rotating equipment. More noise means more vibration and more vibration means more abrasion of transformer insulation. Vibration also cause looseness in hardware. Insulation

abrasion will lead to coil failure and lose hardware leads to increased vibration and increased insulation abrasion, and loosening of electrical connections.

How to mitigate transformer Noise?

- In order to mitigate transformer noise, it is essential to know the amount of noise generated by transformer. With wide range of transformer design and number of transformer tested designed and tested for noise level, VTC/GTC has developed an empirical formula to estimate noise level generated by transformer during operation.

  $$\text{Transformer Noise} = K_1 \lg W + K_2 B + K_3 \text{ [dB]} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

  Where, W = Core weight, B = Flux Density and K_1, K_2, K_3 = coefficients and constants
  These can be evaluated with large amount of data and then used to predict the noise from a transformer.

  Using various design considerations as explained below the overall transformer noise is reduced at design stage.

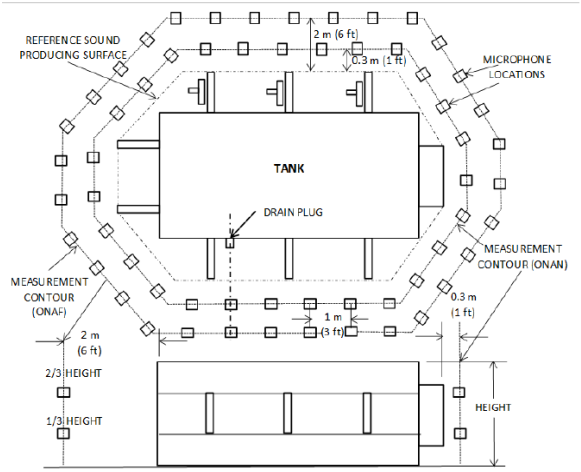
- Reduction of noise from Core:
  a. No-load sound level of core mainly depends on Magnetostriction and magnetic forces. The magnitude of Magnetostriction could be reduced by lowering flux density. The studies show that reducing induction by 0.1 Tesla flux density, noise of transformer's core reduces by 3 - 4 dB. Flux density is inversely proportional to the core weight, means the weight and cost of the transformer increases. This method, while the easiest, is the most costly method.
  b. Grade of CRGO laminations, which is used for making the core, should have properties such as low loss, high permeability and low noise generation from core. When applying high B and laser scribed laminations, it is possible to reduce transformer's noise for approximately 3 dB.
  c. Core construction is also important to reduce noise generated by core. Study shows that step-lap lap core construction reduces the noise of the magnetic core for up to 6 dB. At lower inductions with step-lap even greater noise reduction can be achieved.
  d. Well-designed clamping and tightening structure and techniques for the core yokes and legs can reduce the noise due to reduced magnetostriction and reduced interlaminar 'chatter'. Controlling the 3 dimensional 'undulation' of the core assembly will also reduce the harmonics.
  e. The vibration of transformer core sheets is the main source of noise generation in transformer. Tightening the core and reducing gaps in the corners will help to reduce core noise. Core laminations are tightened with glass tape (stage B epoxy) banding. This tightens the core uniformly when it is heated and leads to very strong and uniform tightening of core steel. Use of non metallic bolts for tightening of core yokes will provide additional tightening of the core lamination which helps core to produces less amount of noise.
  f. Bottom yoke of core and core legs after stacking, are coated with varnish or wood glue to reduce vibration of the sheet edges.
  g. The peaks in angles overhanging of laminations (horns) are cut off, since they are free and vibrate due to the magnetic flux. Alternatively, they can be covered with a putty to keep them from vibrating.

- Reduction of noise from Winding
  a. Specific winding's noise reduction is achieved by increasing the conductor's size, or increasing the transformer's impedance. This however will increase the amount of copper in the cost of the transformer.
  b. For large power transformers special kind of transposed conductors for making windings are being made in order to reduce losses in the windings and winding's noise reduction.

c. Tightness of winding during manufacturing process, and pressing these axially during drying stage, at certain pressure will reduce the 'accordion' effect during operation.
d. Moreover, on magnetic circuit assembly after drying process assure winding compression. A tightly compress winding will help to reduce winding noise.

- Reduction of Noise Transfer to the Tank
  a. Avoid mechanical connection between core and coil assembly and tank surfaces to eliminate structure borne noise transmission. No direct connection to tank base or tank wall. Use vibration damping arrangement between all connection points between core and coil assembly and tank walls bottom and top.
  b. Use of wall sound barriers to reduce oil borne noise. Oil barriers and cushion padding may also help insulate transformer noise and prevent it from spreading.
  c. The distance from the noise producing surfaces to the tank wall can be adjusted for the fundamental noise frequency to 'reflect' most of the sound pressure from the tank wall and 'dissipate' the sound energy in the oil.

- Reduction of Fan Noise
  a. Fan's noise reduction is achieved with fewer numbers of rotor's revolutions per minute of the fan, but at the same time it reduces the cooling capacity, thus the commonly used fans are with greater number or with larger diameter of blades, in order to compensate the reduced cooling capacity.
  b. Reduction of fan's noise can be achieved through balancing the rotating masses, quality of bearing and stable structure for securing the fan to the tank or the radiator for cooling.
  c. Fan structure borne noise can be reduced by providing vibration dampening material in mounting arrangement between fan to the tank wall.
  d. The location of fans on transformer also affects the overall noise of the transformer. Use multiple radiator banks and fan bank. Multiple radiator banks will help to increase overall sound producing surface and hence measurement contour for ONAN & ONAF testing. Multiple fan banks will help to reduce overall fan born noise to keep FA sound low.

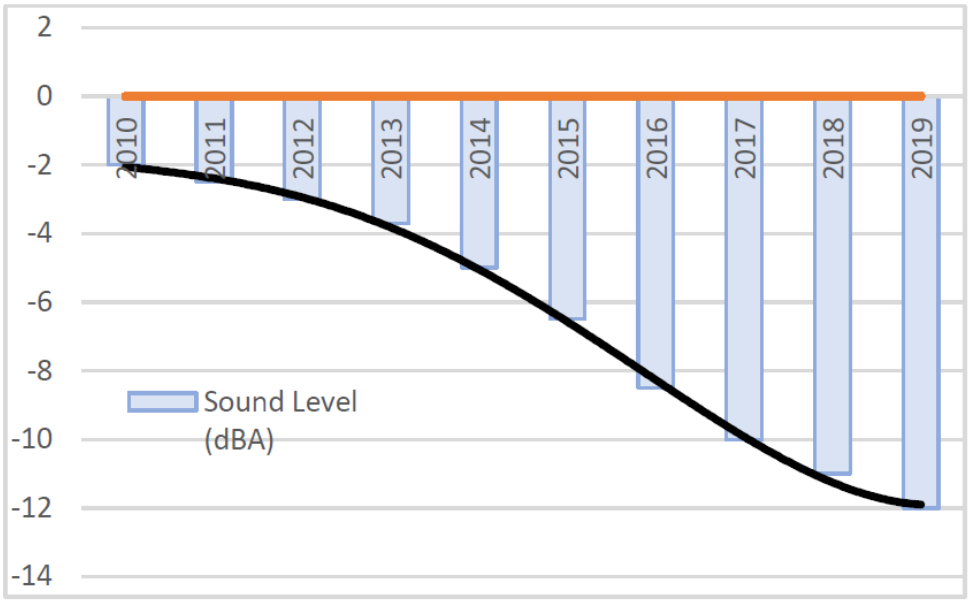


- Reduction of Overall External transformer Noise
  a. While installing transformers at customer site, use external vibration dampeners along with flexible connections and mounting methods. This prevents metal contact between the mounting surface and the unit, to reduce noise transmission.

b. Noise reduction by sound screens or sound walls would be next best option for sound attenuation. The sound barrier will help reduce the noise in surroundings and reduce sound travel.

VTC/GTC Achievement in transformer sound reduction

- VTC/GTC achieved 12dB sound reduction to NEMA TR-1 requirement by rigid mechanical design of core and coil, reduced vibration from coil by geometry and material and dampening of vibration emitted from core and coil assembly, reducing transmission of vibration and noise from transformer inside to outside. The graph below shows VTC/GTC achievement of transformer noise reduction compared to NEMA TR-1 –2013 a standard describing transformer sound level requirement. *****



Year of Mfg.	Description	Measured Sound, dBA		NEMA Rating, dBA		Difference - ONAN	Difference- ONAF
		ONAN	ONAF2	ONAN	ONAF2		
2014	22.5/30/37.5MVA, 350kV BIL, 69kV	52.7	58.11	71	74	18.3	15.89
2014	22.5/30/37.5MVA, 350kV BIL, 138kV	52.83	57.82	71	74	18.17	16.18
2014	22.5/30/37.5MVA, 350kV BIL, 69kV	53.23	59.2	71	74	17.77	14.8
2015	18/21.6/24/26.8/30/33.6MVA, 450kV BIL, 115 KV	59	63.5	73	75	14	11.5
2016	11.2/14MVA, 250 Kv BIL, 69KV	56	58	69	70	13	12

*** Disclaimer**: The transformer noise reduction depends on design, material, performance, size and cost. This paper does not confirm all transformer manufactured by VTC / GTC will have reduced sound as standard function. The noise level performance shown above are the jobs designed to achieve specific noise reduction.

References

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