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"Building Better Transformers"

TRANSFORMER NOISE EXPLAINED

TRANSFORMER NOISE

Noise is defined as unwanted sound. But, what is unwanted sound? A mellow sound to some can be completely unacceptable to others. Attending rock concerts with noise levels at eardrum rattling levels is totally stimulating to many people. Put those same people in a different environment, possibly next to a transformer, and there will be wild protestations. The difference then between noise and sound is in the "ear of the hearer." Since it is necessary to place electrical apparatus alongside a wide spectrum of people we have to accept the inevitable, that even under normal conditions, somebody will always complain.

Transformer "humming" has been known to soothe people (which make a sound) but generally it is reckoned to be a nuisance (which makes it a noise).

The causes and reduction of transformer noise has been the subject of many learned papers for at least two generations. It has come to prominence again, mainly because transformers are placed closer to the populace—in high rise office buildings, apartments, shopping malls and in their gardens. It is becoming even more necessary to locate these units carefully and some planning, preferably ahead of time, is needed.

The remedies we use to counter possible objections to transformer noises are varied and in some cases, expensive, because we cannot produce a blanket remedy to cover all situations. It is absolutely necessary to consider each case on its merits, to apply the general rules of acoustic technology and to be familiar with the causes of transformer noise. The techniques can be explained simply enough for anyone to understand and the rules are, in the main easy to apply.

The BEST RULE however is to PLAN AHEAD. Finding out you have a noise problem (or vibration problem) after the placement of the unit is costly, time consuming and frustrating.

WHAT MAKES A TRANSFORMER HUM?

Transformer 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. When the magnetization is taken away, it goes back to its original condition. A transformer is magnetically excited by an alternating voltage and current so that it becomes extended and contracted twice during a full cycle of magnetization.

A transformer core is made from many sheets of special steel. It is made this way to reduce losses and to reduce the consequent heating effect. If the extensions and contractions described above are taking place erratically all over a sheet, and each sheet is behaving erratically with respect to its neighbour, then you can get a picture of a moving, writhing construction when it is excited. Of course, 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.

The act of magnetization by applying a voltage to a transformer produces a flux, or magnetic lines of force in the core. The degree of flux will determine the amount of magnetostriction (extensions and contractions) and hence, the noise level.

REDUCING TRANSFORMER NOISE AT THE SOURCE

The obvious question is why not reduce the noise in the core by reducing the amount of flux. Why? Because it is not that simple.

Transformer voltages are fixed by system requirements, and the amount of magnetization, by the ratio of these voltages to the number of turns in the winding. The decision on what this ratio of voltage to turns will be is made for reasons, mainly economic. It means that the amount of flux at the normal voltage is invariably fixed, thus setting the noise and vibration level. Also, increasing (or decreasing) magnetization does not increase or decrease the magnetostriction by the same amount. In technical terms, the relationship is not linear. Therefore, when we are asked, as we invariably are, – "can you reduce the noise level at the source?" – The answer is that it can be done, at a cost and for not much improvement in noise level.

TRANSFORMER NOISE FREQUENCIES

We have established that the transformer hum is caused by the extension and contraction of the core laminations when magnetized. Under alternating fluxes, we can expect this extension and contraction to take place twice during a normal voltage or current cycle. This means that the transformer is vibrating at twice the frequency of the supply, i.e. for 60 cycles per second supply frequency, the noise or vibration is moving at 120 cycles per second. This is called the "fundamental noise frequency."

Nothing in this world is ever perfect and so it is with transformer cores. Since the core is not symmetrical and the magnetic effects do not behave in a simple way, the resultant noise is not pure in tone. The noise or vibration produced is not only composed of a 20c/s frequency, we find from practical work that transformer noise is made up of frequencies of odd multiples of the fundamental known as 1st, 3rd, 5th and 7th harmonics.

This means we get noise frequencies of 120 (1st), 360 (3rd), 600 (5th), 840 (7th) cycles per second. They are not equally important for we find that the first and third harmonics predominate and produce most of the transformer sound.

It is important to know this because, with this knowledge, we can measure the amount of noise at these frequencies and determine whether amongst a number of other noises, we really are picking up a transformer noise.

WHAT ABOUT A TRANSFORMER ON LOAD?

It is usually asked – "what proportion of the transformer noise is contributed by the windings and does the noise increase as the load increases?" There are, of course, mechanical forces existing between individual conductors in a winding when the transformer is excited. These forces will produce a vibration and a noise, but only one which is pure in tone, i.e. at twice the exciting frequency –120 cps. This, however, is swamped by the fundamental and harmonics produced by the core. The difference between no load and full load, at constant flux density is usually no greater than 1 or 2 dB. An exception to this is when special flux shields are placed inside a transformer tank to reduce stray flux effects.

VIBRATION-DON'T FORGET IT

It has been explained that the noise from a transformer is caused by mechanical movement of the individual lamination of the core under magnetization. The pulsation will cause not only air disturbances, thus producing noise, but also physical vibration of the core structure and everything attached to it. The vibration will have similar frequencies to those measured in the noise analysis.

Reducing (attenuating) these mechanical pressure pulsations is vital to noise and vibration control and consequently, isolating the core and coils of a transformer, either in the tank or through a tank, or just as the core and coils, is important. Baffling transformer noise and forgetting to isolate the vibrations will only lead to a disappointing result and is something which should not be done.

Remember noise is usually air borne. Vibration is ground borne. They are very much connected.

LET US STOP AND SUMMARIZE

- Transformer noise is produced by the core.
- The amount of noise is generally fixed by the design of the transformer.
- Adjustments to a design to reduce the noise level can be made at cost but don't expect a large reduction in the noise level.

• Loading a transformer has little effect on the noise level.
• Vibrations are produced as well as noise and these are just as important as the noise.

TRANSFORMER TYPES

We have established that the core and coils of a transformer will, when magnetized, produce a hum (noise) and mechanical vibrations, but, the transformer category will also have an effect on what happens once the noise and vibration is produced.

There are three basic categories currently in use:
• Those immersed in liquids - oils, silicones, etc.
• Those immersed in vapours and gases – nitrogen, fluro-carbons, etc.
• Those mounted in air.

A basic statement can be that irrespective of how transformer core and coils are surrounded, noise and vibration will still be transmitted. Oil is incompressible, and gas and air, we know, transmit sound very effectively. Until we put units in absolute vacuums, we have to accept that they will transmit sound almost as if all were in air.

However, each type requires special consideration and treatments, and it is important that these are understood. Transformer size, requirements, and it is important that these are understood. Transformer size, requirements and applications will determine more exactly where and how a transformer is placed, but there are certain treatments which are common to all types. First, let us consider how transformer noise is measured.

MEASURING TRANSFORMER NOISE

We talk about dB's (decibels) 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. These decibels will vary according to the frequency of the noise, but this is taken care of in the noise level meter.

We refer to dBA. The "A" part refers to a position on a sound level meter which more closely follows the human ear. It is important when taking measurements to specify if the noise level was taken on the "A" weighted scale.

Since the transformer is not necessarily symmetrical, we cannot take one reading of noise level from a sound level meter and call the noise level of the unit. It is necessary to take many readings around the transformer and to average them. The resultant will become the transformer noise level.

Standards are laid down on how this should be done. The main ones are ANSI Standard C57-12-90 or NEMA Standard TRI-2-068-1954.

What happens is that you imagine a string following the contours of the transformer. You step back 1 foot from that contour line with the unit excited at the normal voltage, and record a measurement. You take these measurements at 3 foot intervals along the imaginary string. The measurements are totalled and then averaged. The result is the transformer noise level.

To measure amounts of noise in each frequency range you need a frequency analyzer. This is a worthwhile acquisition.

It is always necessary to measure the background (ambient) noise level before you start and when you finish the tests. There has to be a difference between the ambient reading and the average noise level of 7dB or better, for it to be valid, otherwise you could be increasing the actual reading of the transformer. This sometimes makes night owls of the testers!

SO NOW WE KNOW WHERE THE NOISE COMES FROM AND HOW TO MEASURE IT. WHAT CAN WE DO ABOUT IT?

First of all, accept that there is a noise and you are stuck with it. 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.

We have both noise and vibration to worry about and as we have said NOISE is usually air borne, VIBRATION is structure borne.

METHODS OF CUTTING AIR BORNE NOISE

• Put the object in a room in which the walls, floor are massive enough to reduce the noise to a person listening on the other side. Noise is usually reduced (attenuated) as it tries to pass through a massive wall. Walls can be of brick, steel, concrete, lead, etc.
• Put the object inside an enclosure which uses a limp wall technique. This is a method which uses two thin plates separated by viscous (rubbery) material. The noise hits the inner sheet – its energy (some) is used up inside the viscous material. The outer sheet should not vibrate.
• Build a screen wall around the unit. This is cheaper than a full room. It will reduce the noise to those near the wall, but the noise will get over the screen and fall elsewhere (at a lower level). Screens have been made from wood, concrete, brick and with dense bushes (although the latter becomes psychological).
• Do not make any reflecting surface co-incident with half the wave length of the frequency. What does this mean? Well, every frequency has a wave length. To find the wave length in air, for instance, you divide the speed of sound, in air (generally reckoned as 1130 feet/second) by the frequency.

If a noise hits a reflecting surface at these dimensions it will produce what is called a standing wave. Standing waves will cause reverberations (echoes) and an increase in the sound level. If you hit these dimensions and get echoes you have to apply absorbent materials to the offending walls (fibreglass, wool, etc.).

METHODS OF CUTTING STRUCTURE BORNE VIBRATION

- Isolate the core and coils of the transformer from the ground. In air cooled dry types this means to isolate the core and coil from its support on the ground. For an oil filled unit it means to isolate the core and coil from its tank base, and isolate its tank base from the supporting ground.
- Use isolating materials guaranteed to eliminate transformer frequencies (at 120 cps upwards). This is important. Not many materials can do this. Seek advice on the best anti-vibration pads to use.
- Make sure all connections to a solid reflecting surface are flexible. This includes incoming cables, busbars, standoff insulators, etc. Any solid connection from the vibrating transformer to a solid structure will transmit vibration.
- Make sure shipping bolts are removed so that they do not short circuit anti- vibration pads.
- Additional information is given in ANSI C57.94, Section 4.10.

WHAT CAN THE MANUFACTURER DO?

The manufacturer must first insure that they achieve the noise level as specified by the appropriate specification. If something unusual is required by way of a very low noise level then there should be discussions and agreement between the manufacturer and the user, as to what steps to take. Remember the only course left to the manufacturer is usually to lower the flux density and this means increased cost. There have to be trade-offs between cost and noise annoyance or treatments.

If the manufacturer is only supplying core and coils, then what happens next is in the hands of the user, assuming all noise level requirements have been met. If the core and coil is mounted in a containing cabinet then the manufacturer has some precautions to take.

They must insure that the core and coils are correctly resiliently mounted. If they are not, the noise level will increase. The stiffness of the mounts must be such that they do not weaken the installation by being too soft or spoil their attenuation properties by being too hard.

The choice of the resilient must be carefully considered. It has to absorb transformer frequencies which, by most commercial shock absorber systems are very low. "Shore" hardness (resilience), ability to withstand the environment and stiffness sufficient to carry the unit, are all important design parameters.

Busbar or other connections to the core must not transmit vibrations. Flexibility is the key. Ventilators must be carefully positioned. The core must be designed to avoid transformer frequencies of half wave-length dimensions, or multiples of these dimensions. If this cannot be achieved, then consideration of damping material applied to the case is required. This is an added cost and must be part of the arrangement with the user.

Now comes the interface with the user. For shipment purposes, it is often necessary to "block out" the core and coils against the case, to avoid shipping damage. This can include holding down bolts which if left in a fastened condition, can short circuit the anti-vibration effects of the resilient mounts. The manufacturer draws attention to these bolts by marking them and advising his customer to remove all such marked bolts before use. All other blocking and wedging, not part of the design, should be carefully removed since these might interfere with the vibration isolation. The user should be made aware of any of these requirements. After this, it is up to the USER!

WHAT CAN THE USER DO?

The user thinking should start at the conceptual stage. If he can, he must consider if he has a noise problem before he specifies his transformer. If he does, a noise survey including frequency analysis would be advisable. If for instance, a building is only in the conceptual stage, then a little thought beforehand will make sure that transformers are not placed in small reverberant rooms next to a proposed board room, sleeping areas, study areas or other occupied areas where the normal sound level is low. Closets under stairs are very popular for dry type transformers – but are usually acoustically bad. Some discussion with the manufacturer is useful at this point.

A word of warning here. The noise level as measured and given by the transformer manufacturer is usually for the core and coils inside a cubicle. There is no way that the manufacturer can assess the effect on the transformer noise level by the location in which the unit will be place. It is advisable that if a user wants to maintain a particular noise level in a particular environment they should work backwards.

First of all, assess what level is tolerable (say 65dBA). Allow for the effect of the room (say 3dB). Allow for the efficiency of all the connections (say 2dBA) and as a result ask for a transformer to meet 60dBA! This will ensure that the required noise level is met. Advice on how to assess these corrections is available within Federal Pacific.

The design of the room to house the transformer is the next consideration. Avoiding half wave-lengths of transformer noise, or multiples thereof, is advisable. This includes dimensions in all directions, including the ceiling. If these dimensions cannot be avoided, then damping treatment is required remembering that transformer frequencies are involved. This is a caution against using acoustical treatments which are only effective for speech frequencies. Choose damping materials for the noise frequencies to be damped.

Isolation of the transformer from the ground is vital.

Installation instructions must ensure that nobody tightens down shipping bolts – but removes them. Connecting cables must be as flexible as possible. Ventilation ducts must be placed in positions where these are effective thermally without affecting the acoustic performance.

After taking all the precautions, a noise survey after installation, with the transformer excited might be useful.

The most profitable thing a USER can do is 'THINK AHEAD!"

Save money, time and future headaches by considering where to put a transformer and if necessary consult the manufacturer for advice. Do that even if it is only to warn the manufacturer of an impending problem. It will avoid conflicts later on.

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