Transformer Noise – A Hot Problem?

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Abstract

Large scale conversions to Dairy Farming in the Canterbury region, and the associated irrigation requirements, are stretching the capacity of many local electrical substations. In an effort to extend the working life of existing transformers, fans are commonly used to force-ventilate their oil-filled cooling coils. Unfortunately, these fans can give rise to complaints from neighbours because of the noise they produce.

This paper discusses a recently installed system to reduce noise levels and improve the mechanical efficiency of the cooling system. Significant noise reductions have been achieved, and further performance can easily be obtained for critical situations.

The issue of transformer noise is also considered, with particular reference to the possible use of the cooling fans to mask the 100Hz pure tone which is dominant around transformer installations.

Introduction

With dairy farms now commonly milking up to 1200 cows, the supply of milk has become a big business. To ensure a regular flow of milk, a permanent irrigation system is essential in the normally dry Canterbury region. Some farms reportedly have 5 or 6 pumps each rated at up to 75 kW. On this basis, a single farm could require as much power as a residential subdivision of 50 houses. It is therefore hardly surprising that the resources of electricity supply companies are being stretched in rural areas.

Coupled with this, continuing urban creep means that substations which were previously only bothering sheep now have high class houses as neighbours.

The rated capacity of many large electrical transformers is given as two values; one for natural cooling and a higher one for forced cooling. Because of the high cost of new transformers, it is common to force cool and thereby extend the capacity of a substation. In many cases this forced cooling has been achieved by bolting an axial fan or fans directly to the cooling coils of the transformer. Figure 1 shows an example of such an installation.

Not only does this arrangement go against everything we are ever taught about designing for good airflow, the fans have no acoustic treatment and can result in complaints from neighbours about noise.

In this paper, an alternative system is examined, with measured results and possible further improvements discussed.

As It Was

The substations of immediate concern involve transformers of around 5-10 MVA, with residential properties within 50 metres of the transformer yard. Two substations were measured. Although the two substations use completely

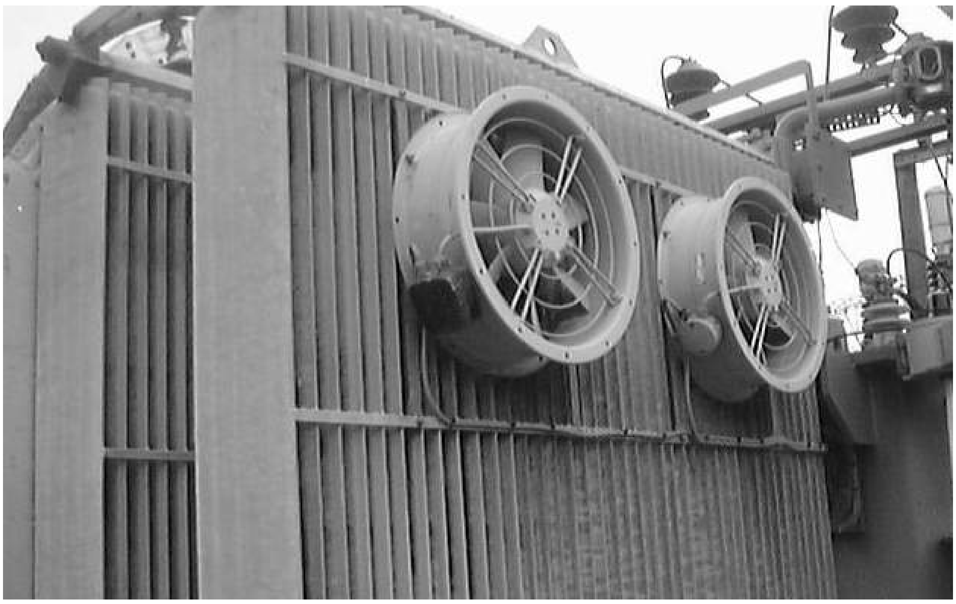

Figure 1: As it was

different transformers, the cooling fans were almost identical in both cases, and not surprisingly the measured noise levels were very similar. One substation produced a noise level of 76 dBA at a distance of 2 metres from the fans, while the other gave 78 dBA (also at 2 metres).

To put these levels in context, it is useful to extrapolate them to a typical residential boundary location of say 40 metres. Assuming "normal" behaviour, noise from sources such as this will reduce by 6 dBA for every doubling of distance. On this basis, the measured noise levels of 76-78 dBA at 2 metres would result in 50-52 dBA at a distance of 40 metres.

Most District Plans in New Zealand adopt the approach of NZS 6802:1991 *"Assessment of Environmental Sound"* which suggests that the upper limit of acceptability for night-time noise is 45 dBA, with noise sources such as transformers which contain "special audible character" penalised a further 5 dBA.

Moreover, many Councils specify 40 dBA for residential areas. The existing installations exceed the recommended night-time noise limits, and it is therefore not surprising that complaints have been received.

In addition, these fans operate on thermostats, and turn on and off suddenly. This rapid change in noise level tends to increase annoyance, particularly on a balmy summer evening during a relaxing outdoor barbeque.

The aerodynamic inefficiency of this system is easily illustrated by comparing the measured noise levels with the manufacturer's published data. The installed fans are producing 18-20 dBA more noise than would be expected from the catalogue. This is almost certainly due to both the extremely poor discharge conditions, and to having the fans rigidly mounted onto the steel cooling fins.

An Alternative Solution

The challenge in designing an alternative cooling system is that there is often very little available space around transformers. Required separation distances from high-voltage lines are such that several brilliant solutions were discarded out of hand by the client.

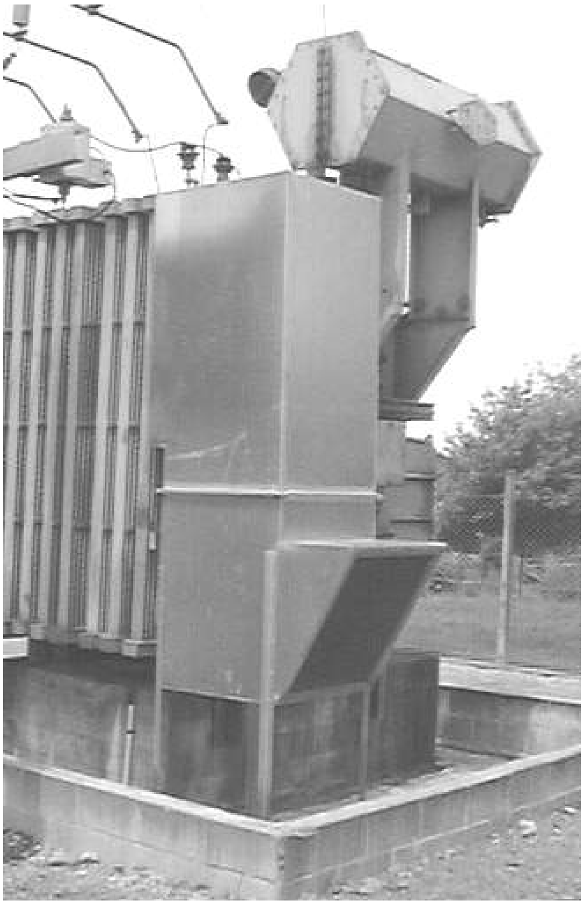

Figure 2: An Alternative Solution

In designing a new system, one aim was to provide more cooling than had previously been achieved. The need for this was determined by calculating the likely heat produced by a transformer assuming typical inefficiencies inherent in this type of equipment. The result of this increase was the need for larger fans, which in turn have the potential to create more noise.

A second consideration was the perceived need to draw air over the entire area of cooling fins in order to get efficient cooling. This proved to be almost impossible in light of the required acoustic treatment and space constraints, and hence the final design only draws air off the top half of the fins. This is, however, still a big improvement on the original system.

The agreed design consists of a "Z" shaped sheetmetal duct, internally lined with sound absorbing material, with the fan mounted at the mid point of the Z. The entire system is designed in such a way that the top half can easily be removed when fan maintenance is required. Smooth-Air Products Ltd of Christchurch were responsible for the engineering design, manufacture and installation of the system.

Figure 2 shows half of the first completed installation, with a second identical unit on the other side of the cooling fins off the left hand side of the picture. A single fan is used, whereas previously 2 smaller fans were used. The new fan is rated at 2.5 times as much air flow as one of the smaller original fans.

The noise level produced by this first alternative system has been measured at 66 dBA at 2 metres—10-12 dBA quieter than the original design. Initial comments by the client confirm that this system is giving significantly more

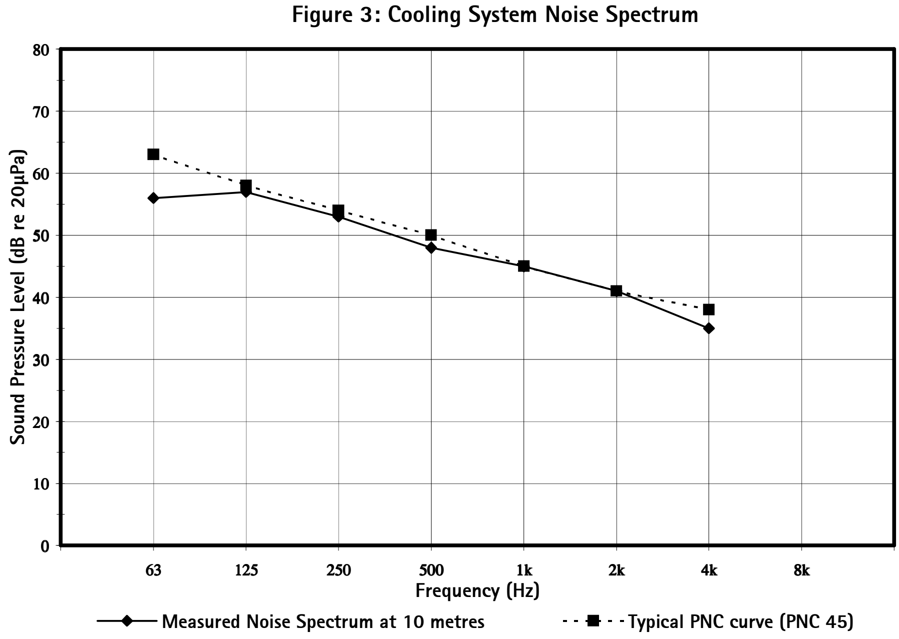

Figure 3: Measured Spectrum from Alternative System

cooling than previously, with the fans running less often, and the oil temperature reducing more quickly than before. This in turn means that the transformer will be able to handle even greater load safely.

Further Modifications

Astute readers of this paper will probably have looked at figure 2 and immediately decided that they could provide substantially lower noise levels by modifying the design. To ensure that this line of thinking doesn't lead to wondering if Marshall Day Acoustics really know what they are doing, consider the design aim. This particular substation is in the order of 45 metres from the nearest residential boundary. To comply with local authority night-time noise rules, the system was designed to achieve 40 dBA at this distance. Commissioning measurements show that the actual installation has resulted in a level of 38 dBA. At least the client cannot suggest that the system was over-designed!

In future cases, there will undoubtedly be substations which are either closer to houses, or require more fans. Each of these will require an individually tailored acoustic solution. At this stage, an additional 5 dBA noise reduction appears possible by extending the length of each leg of the "Z". Although super-quiet systems could also be developed from this same concept, there is unlikely to be a need for them because other considerations generally result in houses being kept 30-50 metres from the transformer yard.

Sound Masking

As an aside, the ever diminishing distance between houses and substations is also beginning to generate complaints about transformer noise—or more particularly the 100Hz "hum" which they produce.

On one recent project, a large transformer, with acoustic screening added, produced 32 dBA at a nearby rural house. This complied with the local authority night-time noise limit of 40 dBA even allowing for a 5 dBA penalty which is normally applied to noise sources with "special audible character". Nevertheless, the residents regularly complained about the hum.

The experiment which is currently being undertaken (not instigated by Marshall Day Acoustics) involves using an electronic noise masking system. The concept behind this is that a hum of 32 dBA is only audible because the background noise level in the absence of the transformer is so low. The same noise level would be completely inaudible within a typical urban area.

The electronic system uses loudspeakers and amplifiers to generate a well-controlled noise, which should sound neutral and hence not be noticed by the neighbours. Unfortunately, this type of system is not well accepted because there is something inherently abhorrent with the idea of generating noise to solve another noise "problem".

Fans, on the other hand, can be installed on transformers for cooling and therefore arguably serve a useful purpose. It is somewhat incidental that they also happen to produce noise. As a result, it would be possible to use these cooling fans as a sound masking source. To do this, the fans would need to run all night, and the noise spectrum would need to sound neutral.

The cooling system shown in figure 2 produced a noise spectrum shown in figure 3. Note that the noise measurements were made at a distance of 10 metres from the cooling system discharge. A reliable spectrum was not possible at the residential boundary because of traffic noise at this site. It is remarkable that the measured spectrum is an extremely close match to a "Preferred Noise

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combinations

- The contribution from the ceiling construction to IIC and STC
- The possibility of achieving IIC 55+ using non-carpet floor coverings

Tested samples were approximately 1000mm x 1000mm in size, with the exception of ceiling systems which were 3200 x 3200.

The concrete floor consisted of a steel Hibond system, with a concrete topping having a minimum thickness of 65mm. Figure 1 shows a view from underneath the slab, with the Hibond steel decking clearly visible. The average concrete thickness of this system is approximately 91mm.

The plasterboard used for the tests was 12.5mm thick "Gib® Plasterboard" as manufactured by Winstone Wallboards Ltd.

The following tables provide summarised results, outcomes and brief subjective assessments.

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Figure 1: Underside of floor showing Hibond Steel Decking with USG direct fix clip and steel batten ceiling suspension system.

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Criteria" (PNC) curve. In calibrating the electronic system described above, PNC curves have been found to provide a good neutral sound with good masking ability.

The challenge for future installations is to obtain a similar spectrum within the other constraints which exist.

Conclusions

Improved cooling has been achieved by designing an acoustically treated ducted ventilation system for medium sized electrical transformers. The design aim of 40 dBA at a distance of 45 metres has also been achieved.

There are options for further noise reductions if required for specific sites, and the system shows good promise for use as a sound masking system. ❑