Design of Low-Noise Power Transformer with the Noise Effect Survey on the Resident

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Abstract: - This paper characterizes the noise impact due to power transformer setup over the population living in the vicinity area. In order to reduce the noise level caused from the transformer, certain improvement on the electromagnetic design and mechanical structure are introduced. The noise effect from the transformer can be investigated with the simulation of acoustical mapping along with the on-site measurements. In this paper, an extreme low noise power transformer is designed and implemented. The designed power transformer with the capacity of 20MVA is installed in the Kiama city, Austria. To evaluate the real noise level in the neighborhood of the transformer, noise levels are measured and analyzed. According to the standard of comfortable living, the designed low-noise power transformer indeed provides the low noise level as desire.

Key-Words: - Power transformer; Noise; Acoustic; Design; Electromagnetic

1 Introduction

In recent years, the cities of acoustical comfort relate with resident people have been arisen continuously increasing this issues. The noise source can be summarized as follows. Some noise was increasing in resident live place, and another coming mainly from traffic, but with some noise was occurred by man-made components [1-3]. Especially, some other noise sources are also important as they act within very closely areas in a city. This research analysis focus on equipment of power transformer was achieved. Some of them are located in city with this equipment side, and most of them do not have enclosed transformers.

Therefore, both of electromagnetic design and transformer mechanical structure improving for power transformer was seriously considered in detail. Application of this reducing noise occurred by power system equipment effect on nearby resident people is very important issues. The research focus on improving core joint structure for transformer used to reduced noise level is present [4,5]. Developed calculation scheme for the computer modeling of the noise of oil-insulated three-phase power transformers is presented by FEM [6]. Therefore, there is proposed a few way of concert, such as electromagnetic design and mechanical structure improving for transformer was considered. This product was going to setup nearby people living. The city of the kiama is located in eastern-Southern areas, Australia. In this paper, this city is mainly application and discussion about noise effect on resident people condition. The noise has been continuously increasing, affecting more and more people in this environment area. Therefore, it is important to improve occupancy live evolution in the city and compare the data with the settlement of power equipment.

This paper is organized as follows. In Section 2, the noise and improving objectives was defined in detail. The low noise electromagnetic and mechanical structure design for power transformer is Section 3. The methodology was defined in Section 4. Both of measurement and simulation noise results were analyzed in Section 5. The concluding remarks are given in the Section 6.

2 Noise definitions and improving objectives

Table 1 summarizes some common noise levels around real lives. For measured noises, it was possibly occurred in fluctuations condition, the measured results of noise data should be within a certain period. In order to summarize all the fluctuations, due to non-constant noise should be set because the fluctuations may occur as that time. This constant noise level has the same amount of energy as the actual measured noise over than period considered in the measurement, therefore, it is also defined that equivalent continuous sound level was obtained. Table 2 carry out the noise emission limits for the resident areas where the power transformer are located, both for day period and night period. The measured noise of zoon floor (ZF) stands for Residential Zone, ZF-n ranging from 1 to 2. For transformer of the silicon steel, its spectral analysis shows that such as common high noise response has a dominant frequency with 120 Hz double ratio will be observer. Fig.2 and Table 4 bring a typical noise spectrum of a transformer, obtained by Rodrigues (Rodrigues, 1998) in a substation situated in Belo Horizonte city.

In this paper, the objectives of this research are described as following:

a. Characterize the resident of power transformer in Kiama to their noise emission levels.
b. Characterize the acoustical discomfort the power transformer bring to the neighborhood people.

In order to achieve obviously the objectives, acoustical mappings have been recorded for the power substations and around with resident building. Application of the software sound model has been used for this project, where the sound models of noise disturbance between power transformer and nearby residences relationship have been recorded. When tracing the acoustical maps around the power substations, where traffic noise has not been considered, however, it was considered in the discussions.

3 Electromagnetic and mechanical structure design for low-noise power transformer

In this paper, a power transformer with the capacity of 20MVA is design and implemented, where the rated primary and secondary voltages are 33 kV and 11 kV, respectively. The main parts of the power transformer include the core, winding, and shell. To reduce the induced noise level from the power transformer, improvements on the electromagnetic design and mechanical structure will be discussed in the following.

3.1 Reducing magnetic induction of the core

It is popularly known that transformer operated with smaller value of magnetic inductance will induce less noise level. However, the scenario of operating with small magnetic inductance will lead to the increasing of core size and the cost will be increased as well. In this paper, the transformer core is made by silicon steel, where the saturation induction can be achieved about 2.0 (T). Practically, the operating condition of magnetic inductance for the designed power transformer is set as 1.3 (T). Under the aforementioned circumstance, the calculated noise level is about 50 (dB) without no including shelling. The cross section area of central limb (cm^2) can be derived as

$$A_C = \frac{10^4}{4.44 \times f \times B_m \times \delta} \cdot \frac{V}{N} \tag{1}$$

where f is the operating frequency (Hz), Bm is the magnetic flux (T), δ is the stacking factor 0.96, and V/N is voltage per turn ratio.

Table 1 Some common noise levels [1, 2]

Noise level (dB)	Activity
0	Threshold of hearing
38	Library
40	Living room
58	Conversational speech
66	Business office
80	Average street traffic
100	Pneumatic chipper
120	Firecrackers
140	Jet take-off (20m) and threshold of pain

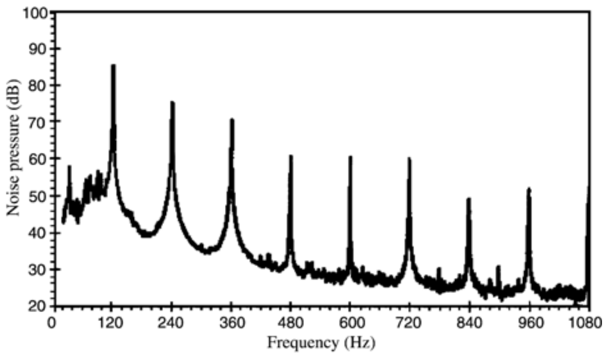


Fig. 1. Typical noise spectrum of a transformer [1, 2].

Table 2 Typical noise spectrum of a transformer obtained by Rodrigues [1, 2]

Frequency (Hz)	Sound pressure level (dB)
120	86.0
240	75.5
360	70.5
480	61.0
600	60.5

3.2 Core stacking with multi-step lap

The magnetic circuit induced from the induction fluxes around the transformer core can be defined by the electromagnetic theorem. It is also known that the distribution of induction intensity will be influenced by the stacking joint structure of the core. In this paper, a multi-step lap pattern is adopted for the core stacking, such that the core loss due to magnetic induction suddenly change and magnetostriction variation in the core joint side can be reduced.

3.3 Increasing thickness of transformer shell

As the assembly of the core and winding, the original thickness of shell is 10 mm. To enhance the noise isolation purpose, the thickness of shell is increased to 20 mm. According to the measurement results, the noise level can be reduced about more than 5 dB.

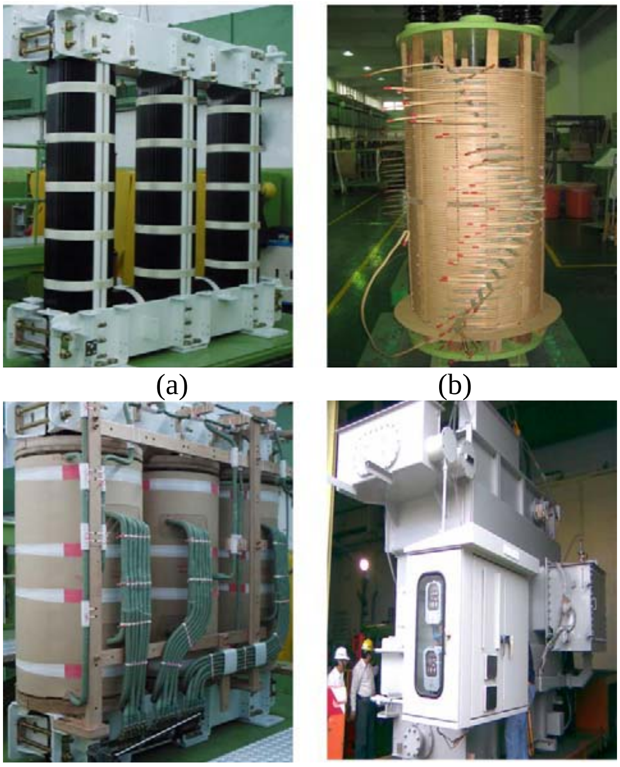
3.4 Equipment for the vibration prevention

The major source of the noise is actually occurred by core. The other factors cause noises are the resonance vibrations of windings, fans, and conductors. In this paper, to prevent the vibration, additional equipments are considered, such as spacer, spring and support seat. The complete design and assembly procedures are shown in Fig. 2. Based on the aforementioned scenarios, in an noise-isolated experimental room, the measured noise level of the designed power transformer is only 48 (dB).

4 Acoustical simulation method

The measured results have been carried out around transformer in a distance of 2 m, and the distance along the direction each house. With the noise levels obtained from the measurement results, it is possible to calibrate the models and generate the correct acoustical maps for simulation guidelines. It is noted that the measurements are carried out without the consideration of background noises. Although the surrounding walls protect the traffic noises to some extent, all of the measured results are carried out during the full traffic flow intervals. In order to construct the simulation models, several factors need to be addressed in detail, such as terrain modeling, insertion of the noise sources (transformers and streets), and material properties of the walls.

The simulation models contain the position of the transformers, firewalls, walls surrounding the power transformer, the command house, and some houses and buildings surrounding the substation. The transformer is modeled as a punctual noise source. With this, the calculations could be conduced by the software, generating acoustical maps for the day and night periods. Although the transformer noise is maintained constant working every day, the traffic flow changes can cause a change in the noise perceived by the residents.



(a) (b) (c) (d)

Fig. 2. Manufacture and assembling of 20 MVA power transformer: (a) Iron core, (b) Winding, (c) Assembled power transformer, (d) Transformer transportation.

5 Results

5.1 Noise measurement in a noise-isolated room

According to designed low-noise power transformer, the measured results of a single core and transformer can be obtained. In fact, the environment for noise measurement is specially built up in a noise-isolated room, where the measured environment noise is only 32 (dB). The measured noise levels corresponding to the operational inductances are shown in Fig. 3. From Fig. 3, the noise level of the designed power transformer, operated with inductance 1.3 (T), is less than 48 (dB), which is acceptable for comfortable living environment. With the previous confirmation, the next stage is to install, operate, and test the power transformer at the designated location in the Kiama city, Austria.

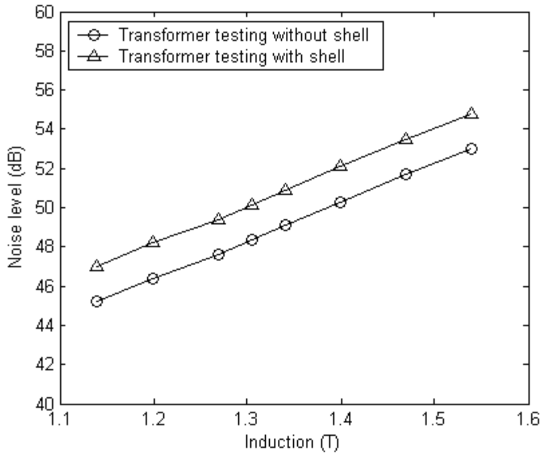


Fig. 3 The measured results of the noise level.

5.2 Acoustical map analysis

The on-site measurements of the noise levels in the neighborhood of the installed power transformer are shown in Fig. 4 and Fig. 5 for day and night, respectively. In this paper, these maps present the noise mapping only due to the transformers. The noise derived from the streets is not considered in these maps. It is possible that intensive traffic during the day will tend to cover the source of the transformer noise. The map clam range around the transformer distance is about 5 to 10 (m). It is obviously that the noise affecting on resident people is about 48 to 52 (dB). In a short distance from the transformer, the induced noise could make the resident people feel uncomfortable. In addition, it is obviously that the transformer clam range of induced noise level during a day is higher than nearby house due to the traffic noise. The traffic noise tends to induce more acoustical noise than the sole transformer noise. Therefore, the areas of nearby resident people will feel uncomfortable due to power transformer is working a day. Consequently, about noise level effect on resident people cause by power transformer, it should be strictly considered the noise level specification by each government in the word.
Consequently, according to the measured results in the daytime, due to intensive traffic in Brown street and Gipp street, the noise level induced from the adjacent road is higher than 50 (dB). From the measured results, it can be seen that the houses numbered 1 and 2 suffer from higher noise disturbance compared with other houses. Additionally, most of noise levels during the night are small than 40 (dB). However, the number 1 and 2 houses still have higher level of noise because that the two houses are near to the power transformer. Considering other adjacent roads, the measured results for Princes Highway are 63 (dB) and 49 (dB) for the day time and in the night, respectively. Because that the Princes Highway is far away from the resident people, the induced noise is smaller than the part caused from the transformer. The measured noises inside the buildings during the day and night are shown in Table 3.

6 Conclusion

This paper investigates the noise impact due to the power transformer installed in the Kiama city, Austria, over the population living in their neighborhood. To reduce the induced noises, several improvement strategies have been considered such as low magnetic inductance, multi-step lap core stacking, and the increase the thickness of shell. In addition to the acoustical mapping analysis, on-site measurements are also provided to analyze the noise affecting on the resident in the vicinity of the position of power transformer. The efficiency of reducing the noise pollution the designed low-noise power transformer can be verified from the simulation and measurement results.

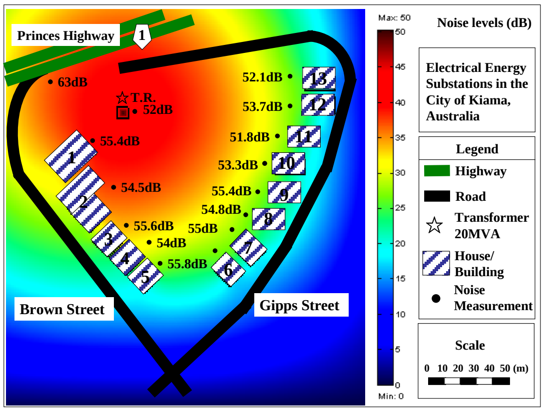


Fig.4. Acoustical mapping of Kiama power transfomer and its surroundings in the daytime.

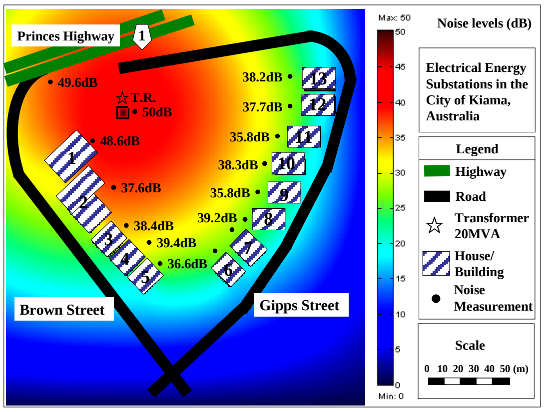


Fig. 5. Acoustical mapping of Kiama power transfomer and its surroundings in the night.

Table 3 The noise measured results during day and night inside the buildings.

Category	Total noise level (dB)	
	Day	Night
House 1-3	55	34
House 4		
1 floor	53.4	33.2
2 floor	55.7	34.1
House 5, 6	51.8	34.7
House 7		
1 floor	52.2	33.9
2 floor	53.5	37.1
House 8	52.8	35.1
House 9		
1 floor	50.1	29.8
2 floor	52.6	31
House 10	50	33.7
House 11	51.6	32.5
House 12	49.9	34.1
House 13		
1 floor	52	30.6
2 floor	51.7	31.1

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