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Influence of the Noise Generated by the Electrical Transformers upon the Environment

Often, the electrical transforming stations are located in the proximity of inhabited areas.The electrical transformers from the stations generate noise that affects the residents of these areas.In this paper we will present the results obtained by identifying the sources of noise from the electrical transformers and their typical levels. We will also approach the methods of reducing the acoustic pollution which is generated as a result.

1. Introduction

The noise has, for the human beings and for the environment, a harmful effect, which can vary depending on the intensity and the spectral component of the noise, the length of exposure to it during a workday and the whole length of exposure to it during the lifespan [1]. The noise generates on the human organism a range of various effects physiologically, as well as psychologically speaking, that culminates with lesions of the hearing organ.

Various scientific researches have proved that, in case its level surpasses by 40 dB the audibility threshold, noise generates several important changes in the state and performance of many organs and tissues.

Unlike harmful action of the noise concerning the man that we find is in full process of production, the noise action in the resting periods become more disturbing and with more serious following effects, even if the noise level is lower.

The transformers installed in the inhabited neighbourhoods or in their proximity have a large part to play in creating the background noise during the night.

On the world scale, the problem of reducing the noise generated by transformers has moved to the forefront during the past ten years. In our country, up till now, it has not been looked upon with a particular consideration. In view of that, one must study the causes and sources of noise in the transformers, the means of measurement and analysis of the noise, as well as the means of diminishing the noise generated by the transformers.

It is very important to determine the noise level generated by the electrical transformers for realising the acoustic maps which represents a condition for admission to the U.E.

2. The sources of the noise

The noise from the transformers is due to the magnetostriction of the magnetic circuit, to the magnetic forces that occur at the joining of the armature core discs, to the constructive particularities of the fastening of the core and to the mechanical reverberation of all these elements. Additionally, one must not overlook the influences exercised by the props and by the positioning system in the cuve, by the assembling method of the transformer and by the area where the transformer is set to work. For large transformers, there have been detected other sources as well, of impermanent nature, such as fans and oil pumps, used to induce cooling, switches for adjusting the work of the transformers and the electrodynamic effort of the coils as a direct result of the load and its degree of dissymmetry.

The noise generated by the transformers depends also, to a great extent, on their electromagnetic and mechanical sizing.

The main cause of the noise in the transformers is found in the vibrations of the core, as a consequence of magnetostriction, that depends as much on the induction, as on a variety of physical and structural parameters of the core discs.

3. Theoretical considerations

When the electrical transformer is working, its vibrations and the vibrations of the accessories, propagates as spherical and cylindrical waves.

The differential equation of the spherical waves, with the speed potential ϕ as a parameter, is

$$\frac{\partial^2 \phi}{\partial t^2} = c^2 \left[\frac{\partial^2 \phi}{\partial r^2} + \frac{2}{r} \cdot \frac{\partial \phi}{\partial r} + \frac{1}{r^2 \sin\theta} \cdot \frac{\partial}{\partial \theta} \left(\sin\theta \frac{\partial \phi}{\partial \theta} \right) + \frac{1}{r^2 \sin^2\theta} \cdot \frac{\partial^2 \phi}{\partial \varphi^2} \right] \tag{1}$$

where r, θ , φ are the spherical coordinates which are positioning the volume element; c – the travel speed of the wave.

If we only take into consideration the motion on the length of the vector radius, the (1) equation becomes

$$\frac{\partial^2}{\partial t^2}(r\phi) = c^2 \frac{\partial^2}{\partial r^2}(r\phi) \tag{2}$$

which is analogue to the one-dimensional equation of the plane wave.

If the perturbations that generate the waves are expressed through harmonical functions, the solution of the exponential equation that takes into account only the divergent wave is

$$\phi = \frac{A_c}{r} e^{jk(ct-r)} \tag{3}$$

where A_c is the complex amplitude of the spherical wave, at the frequency $f = \frac{\omega}{2\pi}$ that travels from the source with the speed c and $k = \frac{\omega}{c}$ is the wave number.

The acoustical pressure in a point of the acoustical field generated by the electrical transformer can be determined with relation [1]

$$p = -\rho_0 \frac{\partial \phi}{\partial t} = -j\rho_0\omega\phi \tag{4}$$

If we consider $A_c = Ae^{j\varphi}$ then, to study the acoustical field, we can use the real part of the (3) solution, expressed as following

$$\phi = \frac{A}{r} cos(\omega t - kr + \varphi) \tag{5}$$

and the acoustical pressure is

$$p = \rho_0\omega \frac{A}{r} sin(\omega t - kr + \varphi) \tag{6}$$

This expression allows us to determine the acoustical pressure in any point of the generated acoustical field.

In the same time, taking into account that some parts of the electrical transformer have cylindrical shape, because of their vibrations, there are produced cylindrical waves. If all the points of the environment travel on a direction perpendicular to the source, these cylindrical waves are characterized by the differential equation

$$\frac{\partial^2\phi}{\partial r^2} + \frac{1}{r}\cdot\frac{\partial \phi}{\partial r} + \frac{1}{r^2}\cdot\frac{\partial^2\phi}{\partial \varphi^2} = \frac{1}{c^2}\cdot\frac{\partial^2\phi}{\partial t^2} \tag{7}$$

where ϕ has the known signification; r and φ are the cylindrical coordinates of the volume element.

One solution for this differential equation can be obtained by using the variable separation method. It has the following form

$$\phi = \left[AJ_m(kr) + BY_m(kr)\right]e^{-jm\varphi}e^{-j\omega t} \tag{8}$$

where A and B are constants, Jm is the Bessel function of the first degree and m range, and Ym is the Bessel-Neuman function of the second degree and m range.

Heaving in mind that the waves appear due to the radial and uniform vibrations of the source and knowing the expression of the potential of speed, it is possible to determine the expression for the acoustical pressure. In case of the waves that travel uniform, m = 0 and the acoustical pressure can be written

$$p = A\left[J_0(z) + jY_0(z)\right]e^{-j\omega t} \tag{9}$$

where $z = kr = \frac{\omega}{c}r = \frac{2\pi}{\lambda}r$, J_0 and Y_0 are respectively the Bessel and Neuman functions of zero degree and λ is the wavelength.

Taking into account the approximation of the J_0 and Y_0 functions, for small values of the z variable, the expression (9) becomes

$$p = j\left(\frac{2A}{\pi}\right)ln(kr)e^{-j\omega t} \tag{10}$$

and at an important distance from the source

$$p = A\sqrt{\frac{2}{\pi kr}}e^{j\left[k(r-ct)-\frac{\pi}{4}\right]} \tag{11}$$

Propagation of the spherical and cylindrical waves is causing the variation of the pressure in a point of the acoustical field.

If we consider that the pressure at a moment of the waves propagation is p, then the level of the acoustical pressure is

$$L = 20\,lg\frac{p}{p_0} \tag{12}$$

where $p_0 = 2\cdot 10^{-5}\left[N/m^2\right]$ is the reference acoustical pressure.

For the regular constructed transformers, after identifying the sources and causes of the noise, there has been established an empiric equation to determine the acoustical level L_1 of the first harmonic of the noise [3].

$$L_1 = 73 + 20\,lg\frac{2f}{100} + 20\,lg\,H + 20\,lg\,\varepsilon\cdot 10^6\ [dB] \tag{13}$$

where f is the network frequency [Hz], H – the height of the column [m], ε – the relative lengthening of the armature core disc used.

4. Experimental investigations

Considering the huge number and variety of causes and sources that have a part to play in generating the acoustical field of an electrical transformer, one realizes that the field is extremely complex and its study is indicated to be of an experimental nature.

Consequently, the measurements for the level of noise have been carried out using an NL-20 sound-meter, made in Japan, according to STAS 7150-77 "Means to measure the noise level in the industry". Thus, the measurement points have been established at distances equal with twice the largest dimension of the transformer and, vertically, at half the height of the cuve of the transformer.

Figure 1 illustrates the positioning of the measurement points when measuring the noise level for one single transformer, while figure 2 illustrates it for two transformers.

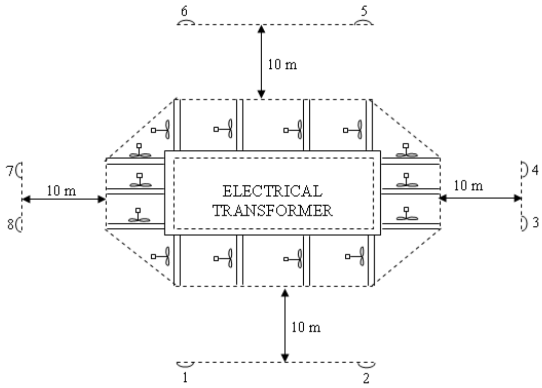

Figure 1.

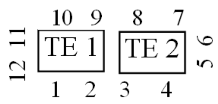

Figure 2.

The noise level in the controlling room of the transforming station was also measured. In this case, the microphone was positioned near the electrician's ear in work position.

The global level of the noise on the moderating circuit A with a "fast" response has been measured.

All the measurements have been done for two electrical transformers having the following characteristics:

ET 1: $S_n = 40MVA, U_n = 110\ kV / 10kV, I_n = 210\ A / 2099A, u_k = 18{,}57\ \%, Y_0\Delta - 11$

ET 2: $S_n = 25MVA, U_n = 110\ kV / 22kV, I_n = 131{,}5\ A / 655A, u_k = 10{,}9\ \%, Y_0\Delta - 11$

Measurements were taken during the day, in two different conditions: when the fans were working and when the fans were stopped.

In tables 1 and 2 are the measurement results in case of a single transformer. Table 3 presents the measurement results in case of two electrical transformers.

Table 1.

Measurement point		1	2	3	4	5	6	7	8
L [dB] (A)	Working fans	76,5	77,2	74,1	72,2	74,5	70,6	72,5	73,1
	Fans stopped	57,8	60,5	58,7	59,4	55,5	59,8	58,8	54,4

Table 2.

Measurement point		1	2	3	4	5	6	7	8
L [dB] (A)	Working fans	69,4	69,3	70,1	75,4	82,9	82,7	80,3	70,8
	Fans stopped	57,1	55	56,8	60,1	59,5	58,2	61,3	

Table 3.

Measurement point		1	2	3	4	5	6	7	8	9	10	11	12
L [dB] (A)	Working fans	75,6	76,7	72,2	71,3	71,7	76,1	81,5	83,1	78,9	77,9	70,9	71,3
	Fans stopped	58,9	61,2	55,6	54,6	55,1	55,5	56,6	56,1	55,3	61,4	55,4	55,1

As the measurements have been done in open field conditions, the medium level of noise generated by the transformer may be found with equation [2]

$$L = 10\,lg\frac{1}{n}\sum_{i=1}^{n}10^{0,1\cdot L_i} \qquad (14)$$

where L_i is the level of the noise in the i point and n is the number of measurement points.

If the maximum deviation between various L_i values is less than 5 dB, the medium L level equals the arithmetical average of the levels of noise.

Using the values given in tables 1, 2 and 3 has been obtained for the medium level of noise the values presented in table 4.

Table 4.

Working status	Electrical transformer 1		Electrical transformer 2		Two transformers	
	Working fans	Fans stopped	Working fans	Fans stopped	Working fans	Fans stopped
L [dB] (A)	74,3	58,5	78,4	58,5	77,5	57,4

In table 5, we present the noise level values measured inside the controlling room of the transforming station.

5. Means of decreasing the noise upon the environment

The transformers used for measurement are installed in the proximity of an inhabited centre and near the building were it is the command room of the transforming station. That is why, it would be sensible for the peoples from the inhabited centre not to be an intolerable source of noise.

According to STAS 6156-86, the tolerable limit of the level of noise in an occupied room is 35 dB (A). It is stipulated that, in an occupied room, the level of noise, to guarantee the optimum state of tranquility, must not rise above 25 dB (A), although it is advisable to drop to 20 dB (A).

Taking into account that most of the inhabited areas are in the proximity of the electrical transforming stations, noise generated by the electrical transformers has a large part to play at the overtaking the level of 50 dB near the buildings according to STAS 10009-88.

In this way, some measures must be taken to reduce the effects of noise generated by the electrical transformers.

The magnetostriction is the main source of noise generated by the electrical transformers.

To reduce the noise generated by magnetostriction, it is crucial to reduce the induction in columns and yokes.

The sources of noise generated by magnetic forces that emerge at joints may be removed by using exclusively homogenous armature core discs, with identical magnetic and mechanic properties. The iron plate must have a uniform thickness on its entire surface, without any ripples or any other kind of distortions, including bends ensued during manoeuvring or during the work process.

An important decreasing of noise in transformers may be attained by positioning the decuvable part on elastic sets that will not allow the vibrations to travel from the core to the cuve.

Introducing phono-absorbent barriers inside the cuve is another means of diminishing the level of noise.

Apart from the phono-absorbent barriers, at the low-power transformers, the reducing of the level of noise may be achieved by using SF_6 as the cooling agent. At such transformers, the cuve has an important function as a phono-absorbent case, whereas the SF_6 has phono-absorbent properties.

The means of reducing the sources of noise in transformers are extremely effective, but they are also awfully expensive.

As a result, the reduction of noise generated by transformers via external means is much more used. Such external means offer ingenious solutions like compensating the generated noise or installing cuves and phono-absorbent rooms or acoustical screens, accordingly to the desire to eliminate the resonance. It is also indicated to realize an area of green grass and trees.

One of the most efficient means of decreasing the noise of the transformers is the use of phonic insulating cases, with steel walls, that cover the cuve of the transformer. As a result, one would achieve a cuve with double walls, between which a phono-absorbent material is introduced.

If the transformers are installed in large open areas, the noise decreasing in certain directions can be achieved through acoustic screens.

The most efficient means to reduce the noise of the transformers is attained through the use of completely sealed rooms, with massive walls. Such rooms are able to decrease the noise by 30-40 dB, but they are not easy to design and to accomplish as one faces the problem of eliminating the losses of the transformers and absorbing the noise by the walls of the room and the execution of the access doors.

For the transformers installed in the inhabited centres, the problem of the noise decreasing is acutely pondered, leading to the endorsement of the most adequate solution, technically and economically speaking, of all those mentioned above.

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