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CONSIDERATIONS UPON THE NOISE GENERATED BY A POWER SUPPLY SUBSTATION

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Abstract

Power supply substations installed in the buildings generate noise that affects human beings’ life and activity. In the paper we investigate the noise generated by a power supply substation installed in a building. For achieving this, we investigate the noise sources from the power supply substation. We are also studying the propagation way and we determine the characteristic measures and its harmful effects. Finally, we establish some attenuation methods.

INTRODUCTION

The power supply substations are often installed within buildings. Consequently, they become sources of noise and vibrations which have aggressive effects upon man’s life and activity, having intensity levels and characteristic specters.

We identify the main noise sources from the power supply substations, the noxious generated noise, the propagation way, the measurement and evaluated methods, the admissible limits indicated in the standards and the attenuation methods.

NOISE SOURCES OF THE POWER SUPPLY SUBSTATIONS

Experience has shown that the electrical noise generated in the transforming station (electrical transformer) may reach the power supply substation instrumentation and control systems through the earth grounding system and the signal control cables.

The saturation of current transformer cores by excessive primary current (dc or ac) can induce very high voltages in the secondary windings and thus into the conductors attached to them. AC problems occur simply because of too much primary current while, DC problems are typically associated with the effects of lightning. The unwanted transient voltage appearing in the secondary consists of high-magnitude spikes having alternating polarity and persisting for a few milliseconds for the duration of the overcurrent condition.

Another source of noise for this objective is cable resonance. Without proper preventive design measures being taken, signal and grounding cables may become resonant to some frequency of radiated (far-field), coupled (near field), or conducted (galvanic) electromagnetic interference, and thereby subject the circuits connected to them to unintentionally high currents and / or voltages. The voltage will be maximum at one end of the conductor (with a current minimum), and the current will be maximum at the opposite end of the conductor (with a voltage minimum). As a result, the electrical components and insulation systems are stressed at one end of the path where the voltage is high and at the opposite end where the peak or rms current carrying ability of the components or conductors is stressed because the current is high.

Disorderly movement of charge carriers within every conductor leads to current fluctuations which appear as a thermal noise. This kind of noise can be heard in the proximity of the power supply substation. The typical environment in a power supply substation provides many sources of electrical noise such as the switching of large inductive loads, high fault currents, electric drives, and high-energy, high-frequency transients. The increasing use of solid-state equipment in these applications, introduces a number of specific concerns with respect to electrical noise control.

The electric noise is generated too by any unwanted voltages or currents appearing in a circuit which may or may not simultaneously contain desired signals, electrical power, or both. In this context, “noise” is generally agreed to have an impulsive character to differentiate it from harmonic waveform distortion that typically occurs on otherwise sinusoidal voltage and current waveforms.

The contactors represent another source of noise for this power supply substantion. A contactor is an electrical device used for controlling power flow. A contactor is activated by a control input which is a lower voltage / current for which the contactor is switching. Contactors come in many forms with varying capacities and features. A contactor is similar to, but different from an electrical relay. Although commonly both use a magnetic coil, a contactor differs because it is designed to "break" a high current load – although relays are designed for switching loads on or off as well they tend to be of much lower capacity and are usually designed for both Normally Closed and Normally Open applications.

THE NOXIOUS OF THE NOISE

The noise generated by the power supply substations is extremely injurious for human beings’ life and activity. Thus for the 65 dB equivalent noise level during the day, 45 % of the population in the polluted area is deranged. The noise affects human beings’ nervous system generating psychopsihological and blood circulation modifications and sleep disturbances. Also the visual function and endocrine gland are adversely affected. At the same time, the noise generates auditory tiredness and sonorous trauma.

In order to reduce the effects of the noise, we establish limit values which cannot be exceeded. These limits are characterized by the equivalent noise level and by the noise curves C_Z. The equivalent noise level correspond to an equivalent intensity which could be constant during the whole considered time and is defined by the relation

$$L_{ech} = 10\lg\left[\frac{1}{T}\int_0^T 10^{0,1L(t)}\,dt\right] \tag{1}$$

where L(t) is the instant acoustic level.

The noise curves C_z define the relation between the characteristic frequency of a sound and the proper pressure acoustic level in the conditions of a subjective equivalent sensation.

In this way corresponding to Romanian standard STAS 6156-86 “Protection against the noise in civil and socio-cultural buildings” were establish the admissible limits of the noise in the living and socio-cultural buildings. This standard establish that in classrooms and laboratories the admissible limit of the equivalent noise level is 40 dB respectively by the C_z 35 curve and for office buildings the admissible limit of the equivalent noise level is 45 dB respectively by C_z 40.

NOISE PROPAGATION

During the function of different sources the vibrations propagate in surrounding medium as spherical waves and cylindrical waves and at greater distance as plane waves.

The differential equation of the spherical waves in an elastic homogeneous and isotropic medium with the speed potential ϕ as parameter is

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

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 and if the perturbation 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 $f=\frac{\varpi}{2\pi}$ that travels from the source with the speed c and $k=\frac{\varpi}{c}$ is the wave number.

The acoustical pressure in a point of the acoustical field generated by these waves can be determined with relation

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

If we consider $A_c = Ae^{j\varphi}$ then, for studying the acoustical field, we can use the real part of the (3) solution and the acoustical pressure is

$$p=\rho_0\omega\frac{A}{r}\sin(\omega t-kr+\alpha) \tag{5}$$

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 sources 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

$$\frac{\partial^2 \phi}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial \phi}{\partial r} + \frac{1}{r^2} \cdot \frac{\partial^2 \phi}{\partial \varphi^2} = \frac{1}{c^2} \cdot \frac{\partial^2 \phi}{\partial t^2} \tag{6}$$

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

$$\phi = \left[AJ_m(kr) + BY_m(kr) \right] e^{-jm\varphi} e^{-j\omega t} \tag{7}$$

where A and B are constants, J_m is the Bessel function of the first degree and m range, and Y_m 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 becomes

$$p = A\left[J_0(z) + jY_0(z) \right] e^{-j\omega t} \tag{8}$$

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 (8) becomes

$$p = j\left(\frac{2A}{\pi} \right) ln(kr) e^{-j\omega t} \tag{9}$$

and at an important distance from the source

$$p = A\sqrt{\frac{2}{\pi kr}} e^{j\left[k(r-ct) - \frac{\pi}{4} \right]} \tag{10}$$

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 wave's propagation is p, then the level of the acoustical pressure is

$$L = 20\,lg\,\frac{p}{p_0} \tag{11}$$

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.

$$L_1 = 73 + 20\lg\frac{2f}{100} + 20\lg H + 20\lg\varepsilon \cdot 10^8\ [dB] \tag{12}$$

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

MEASUREMENT AND ESTIMATE OF THE NOISE

Having in consideration the huge number and variety of sources that have a part to play in generating the noise of a power supply substation, as well as the acoustic waves' nature produced by these, the acoustic field is extremely complex and its study is indicated to be of an experimental nature.

Consequently, the measurements for the noise level have been carried out using an NL-20 sound-meter, made in Japan, according to STAS 6161/1-89 "Noise level measurement in the civil constructions" and STAS 7150-77 "Means to measure the noise level in the industry".

Figure 1 illustrates the positioning of the measurement points when measuring the noise level for the power supply substation situated at first floor of the building. Figure 2 illustrates the positioning of the measurements points for the power supply substation number 2 situated at second floor.

We had also measured the global level of the noise on the moderating circuit A with a "fast" response.

All the measurements have been done for an electrical transformer having the following characteristics:

S_n [kVA]	U_n [kV]	U_n [kV]	Δp_{scn} [kW]	u_{scn} [%]	Δp_{gn} [kW]	i_{gn} [%]	lim. regl.[%]
1600	10	0.4	14.96	6	2.2	1.3	± 5

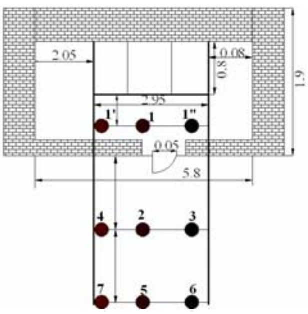

Figure 1

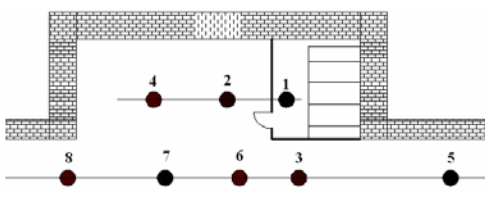

Figure 2

Measurements were taken during the day in two conditions: with the shut door and with the open door.

In table 1 are presented the measurement results for the power supply substation of the industrial house with doors shut and with doors open.

Table 1.1.

Measurement point	Value [dB]	Distance [m]	Place of measurement	Doors of the
1	72.5	0.5	Interior	Shut
1'	72.7			
1"	70.4			
1	75.3			Open
1'	73.7			
1"	77.2			

Table 1.2.

Measurement point	Value [dB]	Distance [m]	Place of measurement	Doors of the cells
2	54.2	1	Exterior	Shut
3	56.8			
4	58.2			
2	60.2			Open
3	53.1			
4	55.5			

Table 1.3.

Measurement point	Value [dB]	Distance [m]	Place of measurement	Doors of the cells
5	51.7	2	Exterior	Shut
6	50.1			
7	47.7			
5	59.6			Open
6	54.6			
7	56.8			

In table 2 are presented the measurement results for the main power supply substation (situated at second floor), with doors shut and with doors open.

Table 2.1.

Measurement point	Value [dB]	Distance [m]	Place of measurement	Access doors to the power supply substation
2	45.1	0.5	Exterior	Shut
3	47.2			
4	46.4 ---- 1 m			
5	49.7			
6	49.4			
7	46			
8	44.6			

Table 2.2.

Measurement point	Value [dB]	Distance [m]	Place of measurement	Doors of the cells
1	57	0.5	Interior	Shut
1’	58.2			
1”	58.9			
1	58.4	1		
1’	55.2			
1”	57.9			
1	59.8	0.5		Open
1’	61			
1”	63.3			
1	59.6	1		
1’	58.4			
1”	59.6			

SOME ATTENUATION METHODS

The electromagnetic contactors’ performances became very often insufficient, due to the increase of necessity frequency of commutation. The increase of commutation frequency leads to significant decrease of electromagnetic contactors’ operation life.

Thus, the new generation of commutation equipment Sirius furnishes contactors having a very log life time. The application domain is extremely wide, unlimited, these kind of contactors can operate in the heaviest environment conditions and under a great mechanical charge and in noise free environments.

Sirius family is specially designed for operation in industrial environment. These contactors are used for repeated commutations of resistive loads, for controlling the ventilation system, the engines. The most important characteristic for these contactors is the noise free commutation, so they are able to operate in office buildings and hospitals. The compact shape of Sirius family leads to an economy of space. Due to its facile assembling and installation, it can be done an economy from point of view of time and costs.

A method for reducing the noise generated by the power supply substation is to replace the old contactors with the new ones, having the same characteristics, but generating less noise. The contactors used in the power supply substation are monophase contactors (1 pole). By reducing the noise generated at each contactor, we decrease the noise generated by the entire power supply substation.

In figure 3 we present a contactor which can replace the old ones existing in the field.

I_n [A] = 16 ÷ 100 A; U_n [V] = 250 V; f = 50 Hz; Noise level: < 20 dB

I_n [A] = 63 A; U_n [V] = 250 V; f = 50 Hz; Noise level: < 20 dB

Figure 3 – Electrical contactors, furnished by Merlin Gerin

The electrical contactors presented in these two figures are modular contactors, with manual operating system. These modern contactors can be also equipped with auxiliary devices which can improve the productivity of work in that industrial house. Such as: contacts for signalling “open” or ”close” position of the main contacts of the contactor, auxiliary device for delayed control of the contactor, auxiliary device which acts as a filter, limiting the over voltages in the control circuit.

Another solution that can be applied consists in replacing the old contactors with hermetically sealed contactors (figure 4). This type of contactors has consistent contact resistance and quiet operation.

Figure 4 – Hermetically sealed contactors, furnished by Magnecraft & Struthers-Dunn

I_n [A] – up to 100 A. U_n [V] = 240 Vac; U_n [V] = 24 Vdc

Contactor is capable of carrying up to 500 A.

For reducing the noise generated by the electrical transformers, it can be used transformers that provide exceptional noise attenuation over a broad spectrum of frequencies (figure 5). Units are typically built in an enclosure with circuit protection and other components.

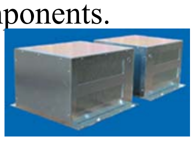

Figure 5 – Noise cut transformer 14.4 kVA

Resonance is related to the line constant ratio of the involved conductor and its associated electrical length expressed in terms of wavelength. In general, it is recommended that no conductor be allowed to have an electrical length that exceeds approximately 1 / 20th. of a wavelength (1 / 20λ or 0.05λ) at the highest frequency of the electromagnetic environment into which it is intended to be operated. This minimizes the effects of electromagnetic interference on the conductor since it cannot become resonant, so it doesn't generates noise anymore.

For reducing the noise generated by the power supply substation, we can also focus on cells existing in the power supply substation. At his moment, the walls of these cells are made of iron plate. There can be installed phono-absorbent barriers on the walls of the cells.

For the power supply substation installed in the inhabited centres, the problem of decreasing the noise 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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