Jacketing solution for noise control of transformers

ABSTRACT

This article discusses solutions to acoustic noise problems in transformers. Details of the noise origin and noise measurement are presented. In addition, we analyze the jacketing method for noise reduction, and its advantages over conventional solutions are given for the transformers' and reactors' applications.

KEYWORDS:

Noise, Acoustic Material, Jacketing, Noise Measurement, Acoustic Analysisbolt, Duval's triangle method

Pechom guarantees noise reduction for transformers with its acoustic solutions

Transformers and reactors tend to generate noise due to the structure of their cores, fans, pumps, oil, and air flows

1. Introduction

Rapid industrialization has led to an increase in demand for electrical machinery, equipment, and appliances, resulting in higher energy consumption. Growing global energy demand and usage also increase the need for energy distribution. In densely populated cities and areas with small land areas but high population density, energy distribution stations are situated closer to residential areas. Lately, Pechom has encountered numerous requests from transformer manufacturers for decibel limitations at energy distribution stations. Noise measurement is of great importance for occupational safety, daily living conditions, and the environment. Objective measurement of sound levels is essential for environmental noise protection programs. Jacketing made by accurately measuring transformer noise and selecting appropriate materials for acoustic data of a transformer creates an affordable noise reduction solution for manufacturers.

2. Transformer noise and noise measurement

2.1 Transformer noise

Transformers and reactors tend to generate noise due to the structure of their cores, fans, pumps, oil, and air flows. Noise can even arise from the harmonics of power circuits. Transformer noise is generally known to be primarily caused by the core. Core noise is the result of pressure changes created by small variations in the dimensions of silicon steel laminations due to magnetization.

2.2 Professional approach to noise measurements

Noise measurements of power transformers are conducted in accordance with the BS EN-60076-10:2016 standard. Measurement standards define the way noise is measured, which parameters should be considered, and under what conditions measurements should be taken. Pechom adheres to all measurement standards.

Sound levels are often not constant while measured, so an average value is typically used. Leq, known as the "Equivalent Sound Level," is a measure of the average energy of varying sound levels and a fundamental average parameter in standards.

Noise measurement standards

Microphone locations are determined at intervals of 1 meter along the distance line according to transformer type (ONAN, ONAF). Depending on tank height (h), microphone heights are located at (1/2)h, (1/3)h, and (2/3)h.

Transformer noise is generally described as a stable sound. Noise frequencies of a transformer are required to generate solution proposals. Class 1 type devices that can perform frequency-based measurements, calculate weighted averages, and provide high accuracy are preferred.

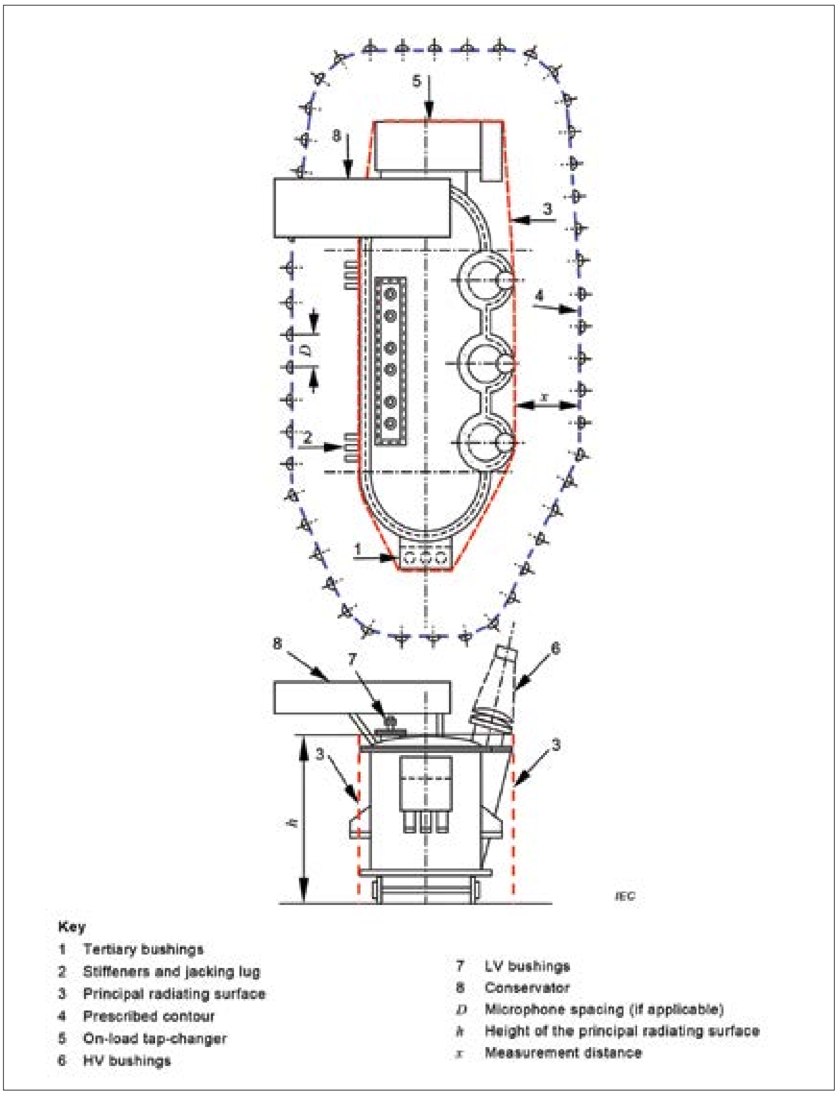

Figure 1. Measuring line in power transformers [1]

Pechom can perform frequency-based sound measurements with its professional devices – only a 30-second measurement is sufficient to determine average sound levels

Pechom can perform frequency-based sound measurements with its professional devices. Due to the stable sound characteristics of transformers, a 30 second measurement duration is sufficient to determine average sound levels.

Correct environment, correct measurement

It is essential to choose an environment for measurement with minimal acoustic reflection. An environmental correction factor can be calculated to compensate for sound reflections:

$$(K).K = 10Log(1+(4/(A/Sv))) \quad (1)$$

(A=α.Sv, α: is the average acoustic absorption coefficient, Sv: is the total surface area of the test room (walls, ceilings, and floors) in square meters.)

Potential confusion from background noise

The impact of environmental noise on outdoor measurements, represented by the K factor, is near 0. Variables such as temperature fluctuations, changes in wind, precipitation, or humidity can affect measurements; measurements cannot be conducted under extreme meteorological conditions. Indoor measurements may represent not only sound emitted from a transformer but also reverberation. In addition to transformer noise, environmental noise from sources such as human voices, wind noise, and noise of other machines operating at a distance also contribute to sound levels. To identify the source sound, we need to subtract background noise from the total sound level.

$$Lp_{result} = 10Log(10^{(Lptotal/10)} - 10^{(Lpbackground/10)}) \quad (2)$$

If the difference is less than 3 dB below transformer noise, background noise is considered high for an accurate measurement: efforts should be taken to reduce background noise. If the difference is measured to be more than 10 dB below transformer noise, the background noise is less critical.

Variables such as temperature fluctuations, changes in wind, precipitation, or humidity can affect noise measurements

Acoustic sound insulation materials are non-flammable (flame retardant) and water repellent (hydrophobic), which makes the materials preferable in practice

2.3 Noise measurement evaluation

Equivalent sound pressure levels in the A band (LAeq) taken point by point from the field are examined. The logarithmic average of these values determines the dB(A) value of the transformer. However, details are hidden in a sound pressure vs. frequency graph of the transformer. With this graph, a roadmap during the development of the solution method, we can see at which frequencies sound harmonics are at their highest level and at which frequencies they are ineffective. The graph in Figure 2 is one example.

In the given graph, we can see sound peaks at 100 Hz, 250 Hz, and 315 Hz. Acoustic materials that will perform well at these frequencies and meet the necessary specifications are selected for the intended sound reduction application. This process constitutes another step in the project.

3. Acoustic material and performance measurement

3.1 Let's get to know acoustic materials

Acoustic sound insulation materials are non-flammable (flame retardant) and water repellent (hydrophobic), which makes the materials preferable in practice. The material may have these properties due to its structure, or these properties can be added to the material later. These features are more common in certain sectors for which occupational safety is primary and long lifetimes are secondary.

Temperature ratings of acoustic materials selected for use in transformers are well above the maximum tank temperature. In this way, tank temperature does not have a negative effect on acoustic materials in terms of physical properties or noise reduction.

The basic features of acoustic materials are sound transmission loss and sound absorption. Apart from these, characteristic properties of an acoustic material include porosity, airflow resistance, density, tortuosity, shape factor, thermal

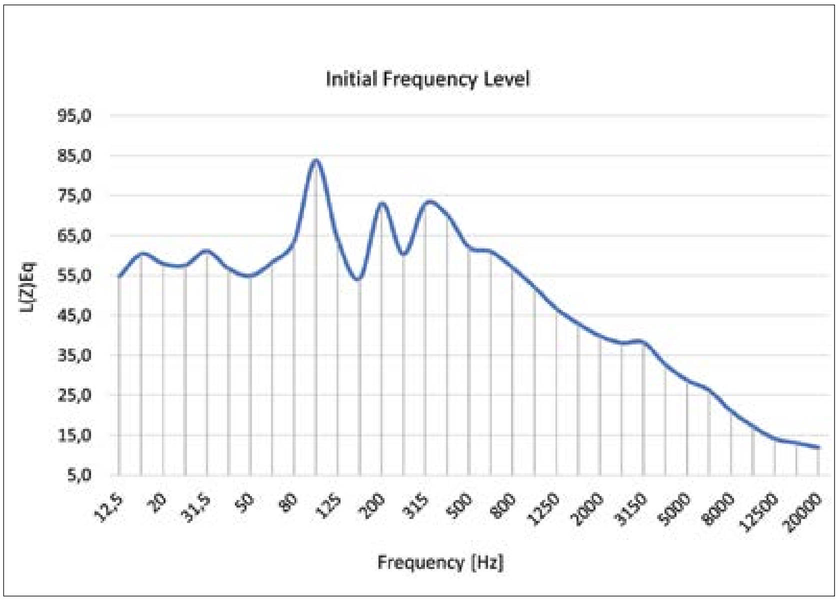

Figure 2. Z Band frequency graph

With material libraries created based on experience and test data, material selection can be accelerated by taking into account parameters specific to a given project

characteristic length, and viscous characteristic length.

The literature for measurement of values states that tests be performed in acoustic chambers, in alpha cabins, or in impedance tubes. Among these, tests performed in impedance tubes provide the fastest and most practical solution for single or combined materials.

3.2 Impedance tube measurements

The impedance tube is an important system used in acoustic testing and acoustic engineering at Pechom. Sound waves can be tested over a wide spectrum, and material behavior is examined as a function of frequency.

The system used to obtain sound absorption coefficients is shown in Figure 3. Sound absorption coefficient tests are performed in accordance with ASTM-E1050 [2].

The system used to obtain sound transmission loss value is shown in Figure 4. Sound transmission loss value tests are performed in accordance with ASTM E2611 standards [3].

3.3 Now we can choose the material

With impedance tube measurements, it is possible to test individual or layered materials. This is used as a roadmap to create a combination that will provide the expected sound performance in desired frequency ranges by using materials that provide high performance therein. Materials can be combined to match specific low, medium, and high frequencies. Transformer noise generally has a frequency graph with a peak at 100 Hz followed by peaks at the 1st harmonic 250 Hz and 2nd harmonic 315 Hz. A multilayer combination selection will be made for this source determined in low-frequency ranges.

With material libraries created based on experience and test data, material selection can be accelerated by taking into account sound frequencies, special material requests, intended sound reduction, and other similar parameters specific to a given project.

The transmission loss curve of the material selected after the measurement evaluation (Section 2.3) is shown in Figure 5. It is seen that this material, which was chosen to provide the desired performance at 100 Hz, 250 Hz, and 315 Hz, is more effective than expected at high frequencies. However, providing sound performance at low frequencies is quite difficult compared to high frequencies in terms of both sound absorption and transmission loss. The main reason for this is that low-frequency wavelengths are larger than high-frequency wavelengths. To achieve this performance at low frequency, it may be necessary to ignore inefficient performance at high frequency.

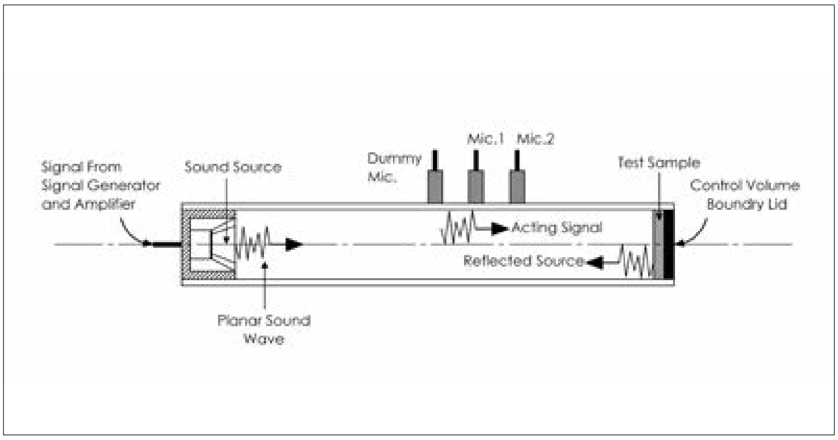

Figure 3. Sound absorption coefficient measurement system

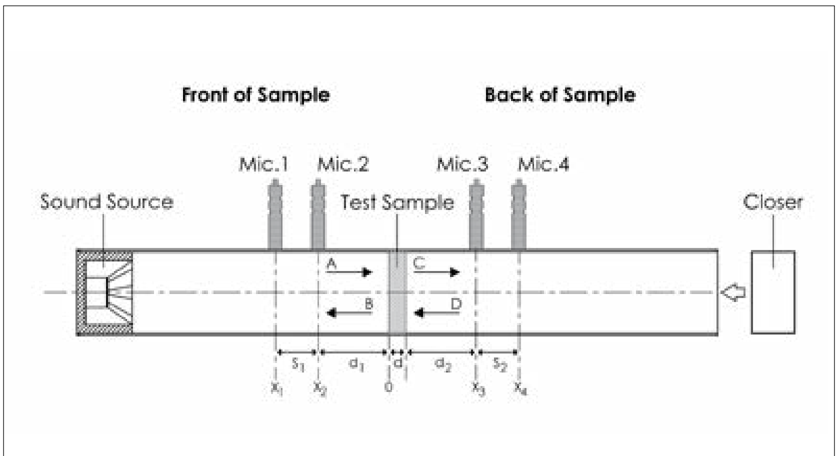

Figure 4. Sound transmission loss measurement system

4. Acoustic design and acoustic analysis

It is necessary to thoroughly understand the current situation in order to examine and define the behavior of sound and to offer appropriate solutions. Analyzing

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the complex structure caused by variables in field conditions requires specific studies as well as theoretical knowledge. Elements such as equipment, devices, and technology support theoretical knowledge. Professional acoustic measurement devices and compliance with standards enable necessary data acquisition from the field. Acoustic software is needed to process information and produce a solution.

For example, consider a static analysis study. The load dependence of a steel plate is determined by graphics. However, acoustic analysis was also carried out, just like static analysis studies, to examine complex situations. For this purpose, reflecting areas and surfaces, sound propagation parameters depending on temperature and humidity, and the effects of background noise on the environment are considered.

A solution system is designed around 3D data in line with information and requests (specifications) received from the customer and sound data received from the field

4.1 Acoustic design

Acoustic design is the first phase that allows us to simulate field conditions in 3D. At this stage, information about transformers, supporting equipment, reflective surfaces, obstacles, and environmental (closed volume, open volume) conditions are obtained, and a 3D model is created. A solution system is designed around 3D data in line with information and requests (specifications) received from the customer and sound data received from the field.

Figure 6 is an example of a transformer jacketing application. Yellow, green, and turquoise regions are the areas where acoustic material will be installed. Solution methods to be applied are processed on 3D data, and the second stage begins.

When all conditions are taken into consideration, the acoustic material determined as the relevant solution is checked for desired sound reduction

4.2 Acoustic analysis

Acoustic analysis is the second phase that allows us to simulate field conditions in 3D. At this stage, the initial sound level input of the system, microphone definitions (as shown in Figure 7) for measurement conditions of the system (BS EN 60076-10 in Power Transformers), acoustic value inputs of all surfaces in the 3D environment, and environmental conditions (open air, closed volume) are defined. Background sound level, ambient temperature, and humidity data are entered. After characterizing the current situation, the proposed solution is simulated. When all conditions are taken into consideration, the acoustic material determined as the relevant solution is checked for desired sound reduction. After the solution is simulated, differences between initial and final sound levels allow a guarantee of sound reduction.

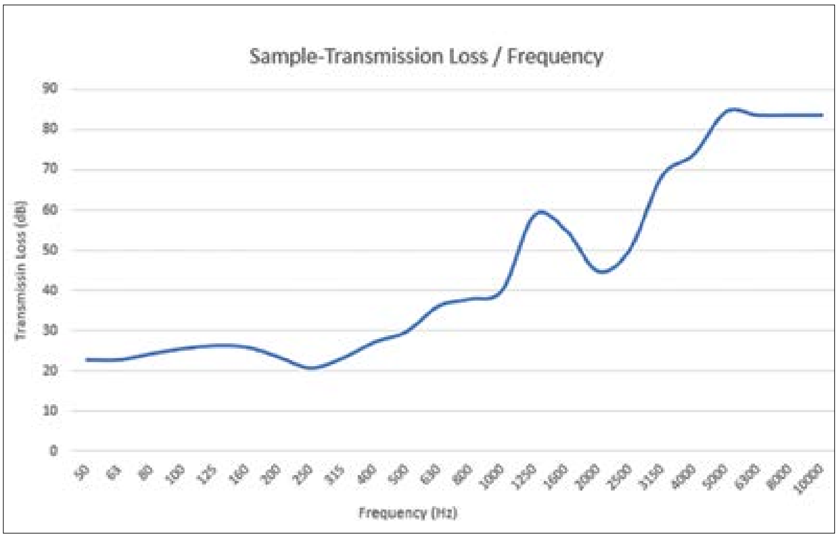

Figure 5. Acoustic material combination transmission loss graph

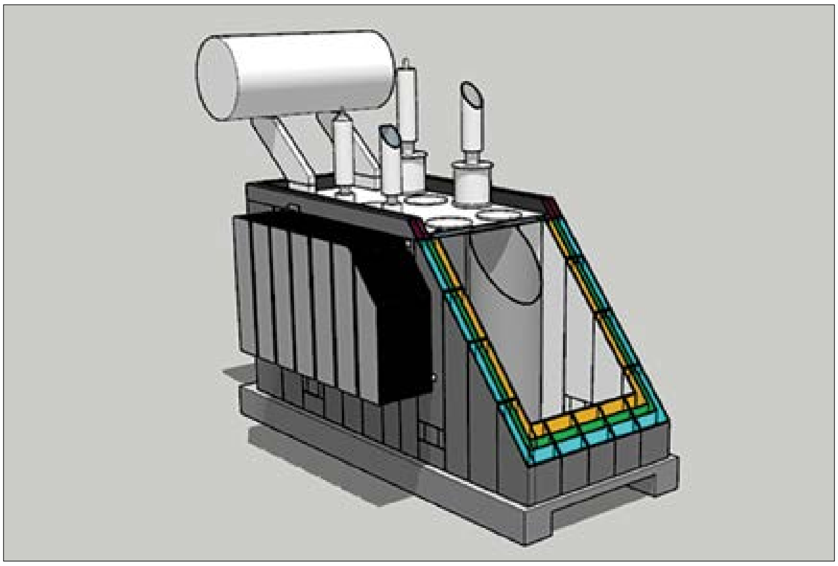

Figure 6. Power transformer acoustic design cross-section

By using specially selected vibration-dampening materials between sheet metal plates and the cage structure, noise and damage that may occur due to mechanical vibration are prevented

Frequency results can be examined from the assigned microphone positions. At the same time, grid maps can be created that allow tracking the movement of sound along a specified surface in the field. A previously solved grid map is shown in Figure 8.

Pechom's special noise reduction "jacketing" and its advantages

Special jacketing systems are developed by Pechom to control noise in transformers and reactors.

Jacketing means placing a combination of materials specifically selected for the project on tank surfaces. Materials are placed between stiffener spaces without using adhesives. For placement, it is preferred that stiffeners be type T or I. To fix transformers that cannot have T or I stiffener type, small pins can be requested from the manufacturer to be pinned to the transformer tank surface.

Acoustic materials are mounted only on a transformer tank. They do not interact with hot oil in the transformer tank. After material placement, the materials do not have any connection with the internal parts of the tank. For this reason, acoustic materials are compatible with environmental materials.

We encounter situations where stiffener depth is insufficient to achieve the desired sound reduction. In such cases, stiffener depth is increased, or a cage system holds together the material structure that extends past stiffener tips.

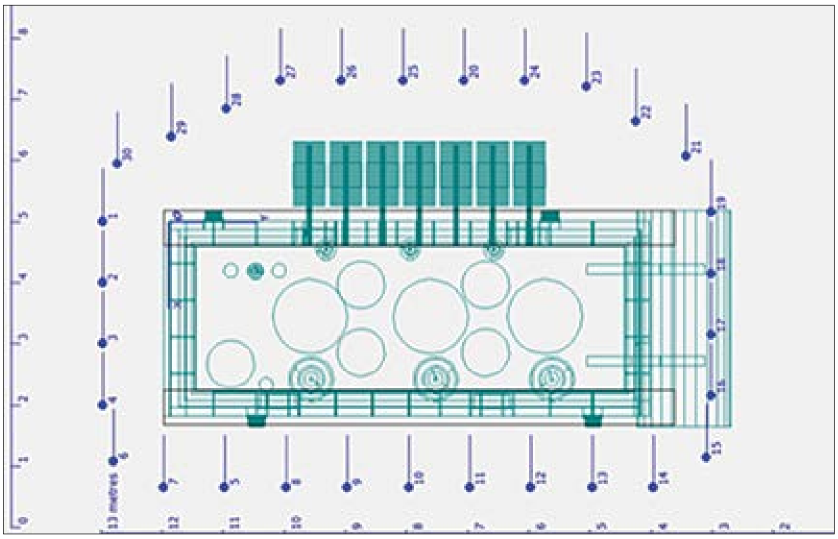

Figure 7. Microphone placement in accordance with BS EN 60076-10:2016

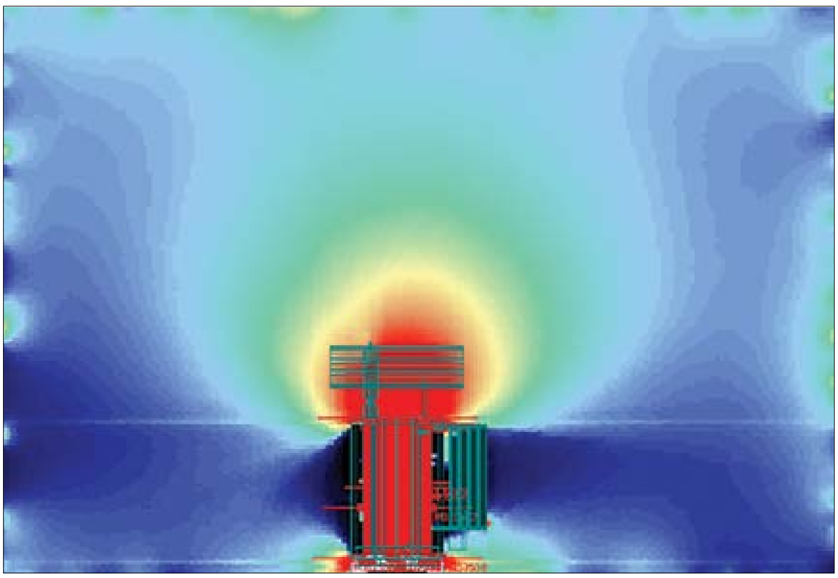

Figure 8. Grid solution map

After placing composite acoustic materials, they are covered by sheet metal. The sheets are mounted on mechanical connection legs at stiffener ends, leaving acoustic materials completely enclosed. These connections must be added by the manufacturer during transformer design. By using specially selected vibration-dampening materials between sheet metal plates and the cage structure, noise and damage that may occur due to mechanical vibration are prevented. Thus, the entire lateral surface of the transformer tank is covered by acoustic composite materials. Thanks to the closed sheet metal plates, damage to acoustic material from external factors is prevented. At the same time, sheet metal plates also have a positive effect on acoustic insulation performance.

Acoustic composite materials are pre-sized and delivered to a customer's site. For dimensioning, a 3D model of the transformer is needed before the project. Combinations are sized in line with measurements taken from 3D data. This entire process is carefully carried out and inspected by expert teams.

Sound levels are determined by noise measurements made before and after jacketing. This specially designed jacketing system can reduce sound by up to 10-12 dB in transformers and reactors. As mentioned in previous sections, sound reduction is quantified and guaranteed by prior analysis. As a result, noise control of transformers is possible with the special jacketing system developed at Pechom.

Noise enclosures or noise walls, conventional methods of noise control for transformers and reactors, have long been in use. Pechom has implemented jacketing studies for many years, resulting in successful outcomes that stand out compared to conventional methods:

- 10–12 dB(A) noise reduction can be achieved
- Does not take up space around the transformer
- Integrated with transformer, does not require maintenance
- Installation can be done at the factory where the transformer is produced
- Installation takes less time than that for an enclosure or noise wall
- Does not require transportation separate from the transformer
- Cost is 40% less than other solutions

Bibliography

[1] BS EN 60076-10:2016 Power transformers. Determination of sound levels

[2] ASTM E1050 Standard Test Method for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones and a Digital Frequency Analysis System

[3] ASTM E2611-09 Standard Test Method for Measurement of Normal Incidence Sound Transmission of Acoustical Materials Based on The Transfer Matrix Method

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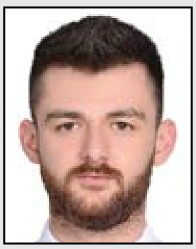
Noise control of transformers and reactors is possible with the special jacketing system developed at Pechom

Author



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