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DEVELOPMENT OF A SILENCER FOR ACOUSTIC ENCLOSURES OF LARGE TRANSFORMERS

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Abstract

An acoustic enclosure is widely used to reduce the sound pressure level propagating from the noise source. However, the performance of acoustic enclosure is decreased by its inherent limitations such as temperature rise or acoustic pressure which is built up inside the enclosed space. In this study, a silencer is installed to overcome these limitations, for large amount of air should be move through it. For this purpose, a parallel baffle-type duct silencer with acoustic resonators is studied to reduce the transmitted noise from a transformer. By using the silencer, the high-frequency components of the transmitted noise above 360 Hz can be effectively absorbed by the parallel baffles and the harmonic components such as 120 Hz and 240 Hz can be reduced due to the presence of Helmholtz resonators. As a result large sound attenuation is achieved by applying the silencer to large transformers in an actual electric substation.

INTRODUCTION

Although the large transformer in a substation is essential to supply electricity to users, it often brings about civil petitions due to its high noise level. Recently, these types of civil petitions are expected to be rapidly increased since more substations need to be installed around the downtown areas and the residential areas are expanded, thus approaching to nearby the existing substation. Until now, countermeasure plans for resolving these problems have caused a lot of economic and even human losses. Thus, it is important to develop the noise control device for the noise reduction of large transformers, which can suppress the environmental noise of residential areas and

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make it possible to supply electricity effectively without public complaints.

An easy and simple way to reduce the transformer noise is using the enclosure around the transformer, which has been widely used to isolate sound propagation from the noise source. Specifically, in case of the transformer, it can be used as a safety barrier for blocking broken pieces due to the explosion. However, the presence of the enclosure cause a high temperature rise of the inner space by restricting the air movement and the noise level would be amplified due to the resonance of the space. In this study, a silencer is designed to effectively reduce sound radiation from the transformer with maintaining natural air flow by attaching it to the transformer enclosure.

A lot of silencer types are widely used in many application fields in order to reduce the noise by using the principles of absorption, reflection, and interference of sound. The basic concept of noise reduction in low frequency region can be explained by the reactive wave arising inside the expansion chamber associated with the geometric configurations of the inlet/outlet locations, and the area expansion of the jacket. In case of the high frequency region, it is more effective to use the absorption materials to attenuate the propagating noise.

In this study, the frequency range for noise control is divided in two regions such as low frequency band below 240 Hz, and high frequency band above 240 Hz. Considering the performance for absorption material with a thickness of 50 mm, absorptive parallel baffles are used for the noise reduction of the frequency range above 240 Hz. And acoustic resonators are used for low-frequency components, especially 120 Hz and 240 Hz. Attempts are made to reduce the transformer noise installed in an actual substation by using the silencer which is designed to reduce both low and high frequency noises.

SILENCER FOR ACOUSTICS ENCLOSURE

Transformer noise is caused by a phenomenon called as “magnetostriction”. It can be explained as following. If a piece of magnetic sheet steel is magnetized, it is extended itself. When the magnetization is taken away, it goes back to its original position. A transformer is magnetically excited by an alternating voltage and current so that it becomes extended and contracted twice during a full cycle of magnetization. Because of this phenomenon, the transformer generates harmonic noise with the fundamental frequency at 120 Hz that is double of the electrical frequency of 60 Hz.

A noise spectrum measured at 1-meter distance from a transformer of 154 kV-grade is depicted in fig. 1. This shows that MTR (main transformer) noise come from the radiation of the harmonic frequency component. The level of transformer noise varies with the measurement location, but the spectrum has the similar shape regardless of the locations. This means that if the harmonic components could be reduced, the transformer noise should be controlled to be small.

In general, the acoustic enclosure for the large transformer has the shape shown in fig. 2. Partial or total enclosures can be installed depending on transformer’s shape and installed conditions.

The silencer designed for the acoustic enclosure need to satisfy three main roles. Firstly, it provides airway to discharge unwanted heat created from the transformer. Secondly, it weakens the possible acoustic resonance in the low-frequency region due to the enclosed acoustic field. The volume velocity by the transformer vibration at 120 Hz corresponds up to several ten liters per second, thus there are strong possibility of resonance in the low-frequency region by structural-acoustic coupling between the enclosure and the inner space.

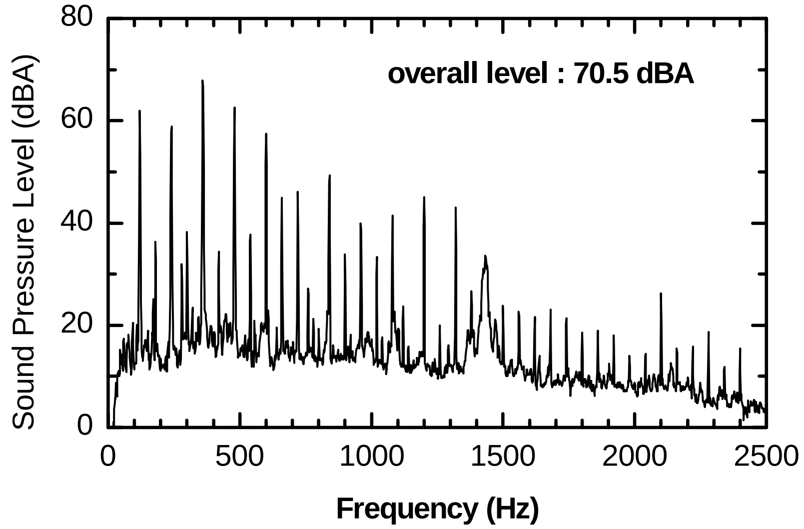


Fig. 1. Typical noise spectrum of a large transformer in substation.

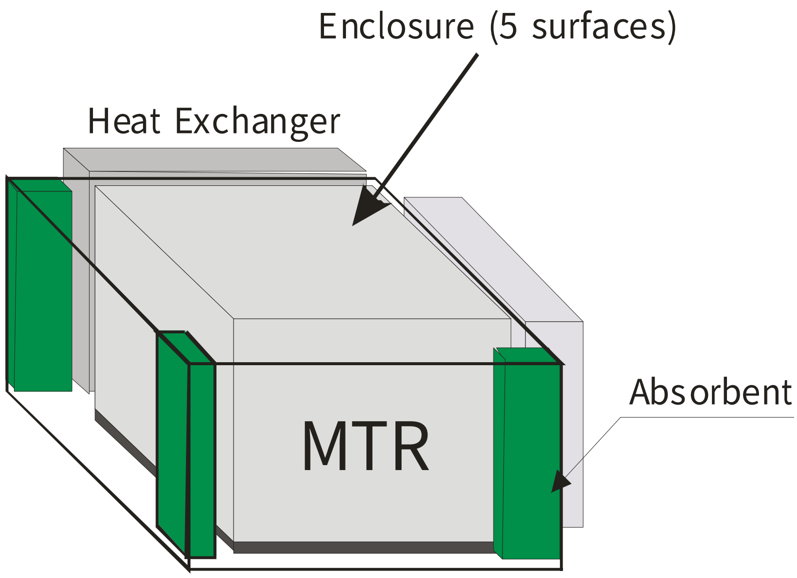


Fig. 2. Schematic diagram of enclosure

Moreover, the air way provided by the silencer is more economical to avoid resonance than reinforcing the enclosure structure. Lastly, if there is no air way, a structural damage of the enclosure would occur by the lift force induced by a strong wind like as typhoon.

For above reasons, the silencer, a parallel baffle-type duct with acoustic resonators, is attached to the transformer enclosure as shown in fig. 3. The silencer is developed with a standardized size to dispose the silencer modules appropriately for the required acoustic performance under given on-site condition.

In the developed module, the absorption materials are located both at left and right sides of the air-way and array of the acoustic resonators are mounted on the bottom side of air-way. Because most of transformer noises consist of the identified pure tones, the resonator is designed to reduce the low-frequency components (120Hz, 240Hz) and the absorptive parallel baffles reduces the high frequency components above 360 Hz.

The resonator has the shape of Helmholtz resonator as shown in fig. 3. In some cases, the predicted tuned frequency of the resonator is little bit different from the measured one due to the coupling between the acoustic field and the structure of silencer. This phenomenon happens more often when the tuning frequency moves to the low-frequency region. For this reason, it is required to tune the resonance frequency exactly by performing the performance tests such as insertion loss measurement.

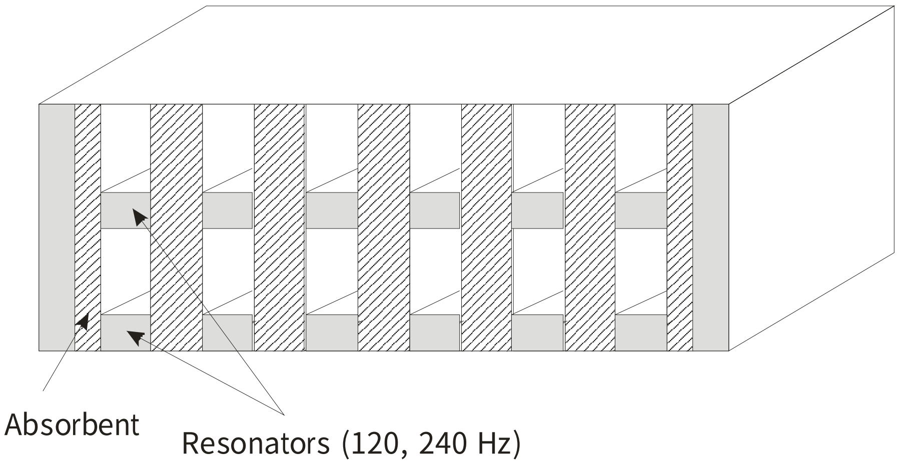


Fig. 3. Schematic diagram of a silencer

The experimental setup for insertion loss measurement of the silencer module consists of a sound source, a test duct, a microphone and a dynamic analyzer as depicted in fig. 4. The insertion loss can be calculated from pressure difference between the cases with and without silencer. In this test, the test duct has the area dimension of 450 mm x 450 mm and the location for the pressures measurement is located at 1.5-meter apart from the resonator with the angle of 45^{o} from the parallel line of test duct.

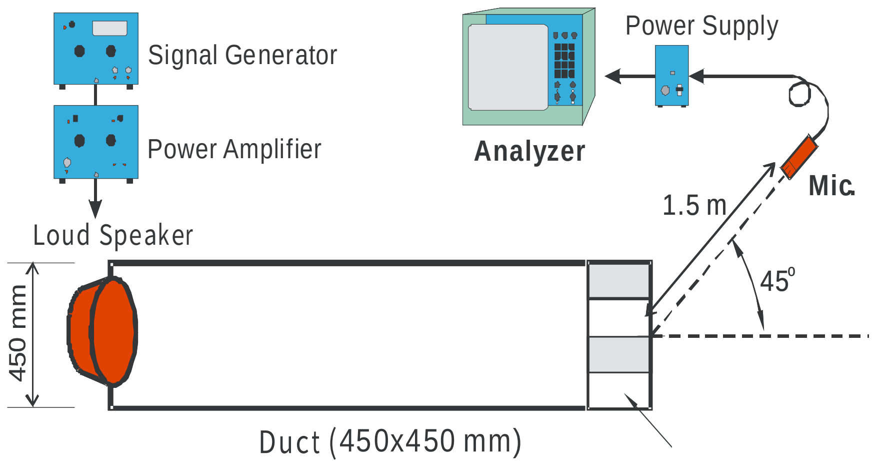
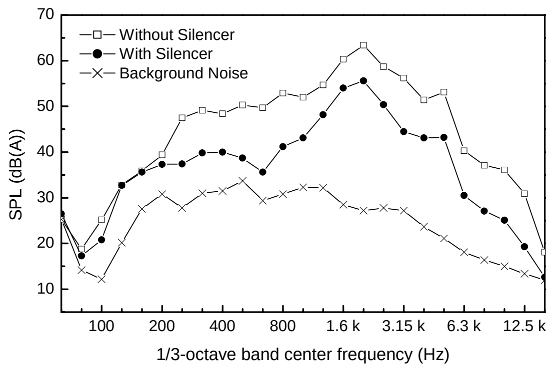
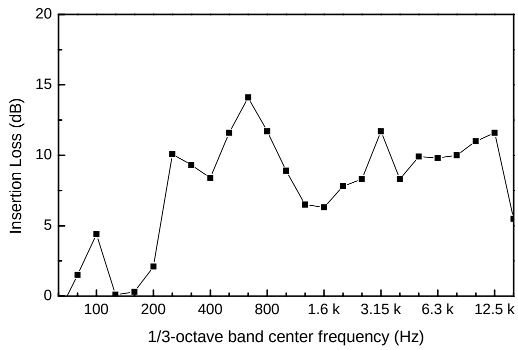


Fig. 4. Schematic diagram of testing apparatus

Fig. 5 shows the measured sound pressure level and the insertion loss of the silencer module. In this result, it can be noticed that the noise reduction is achieved not only at 120 Hz and 240 Hz by the resonator, but also in the high frequency range above 200 Hz by the absorptive baffle.



(a) Experimental results of sound pressure level



(b) Experimental results of insertion loss

Fig. 5. Experimental results

APPLICATION

Fig. 6 shows the layout of a substation where four main transformers are normally operated at the same time. Recently, since a new apartment has been constructed nearby the substation area, the inhabitants have raised civil appeals for the high level noise.

Based on the investigation of the noise measurement, the transmitted noise generated by #4 MTR needs to be reduced more than 12 dB to meet the noise regulation-level, 45 dBA, provided by environment law in Korea. To reduce the radiation noise, a partial enclosure depicted in fig. 7 is designed considering on-site condition because the clearness between the heat- radiator and the transformer is too short to make total enclosure. The open area of the enclosure is located in the opposite direction of the apartment and the silencer located in the apartment direction make a smooth airway

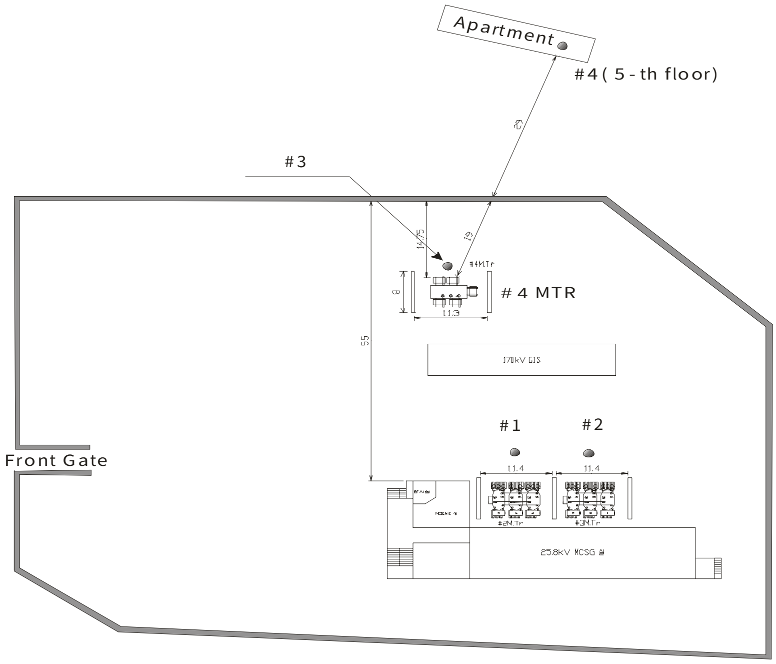


Fig. 6. Layout of a substation

Fig. 7. Installation of Partial enclosure

CONCLUSIONS

A silencer is developed to complement the drawbacks of an acoustic enclosure such as temperature rise and acoustic pressure build-up inside the enclosed acoustic field. The performance of sound attenuation is verified in laboratory test. By using the developed silencer, the low frequency components of the transformer noise, such as 120 Hz and 240 Hz, are reduced by using the Helmholtz resonator and the broad-band components above 200 Hz are effectively absorbed by using the absorptive parallel baffle. As a result, large sound-attenuation is achieved by applying the silencer to the large transformers in an actual substation. It is expected that the concept of the developed silencer can be utilized for other machineries as well.

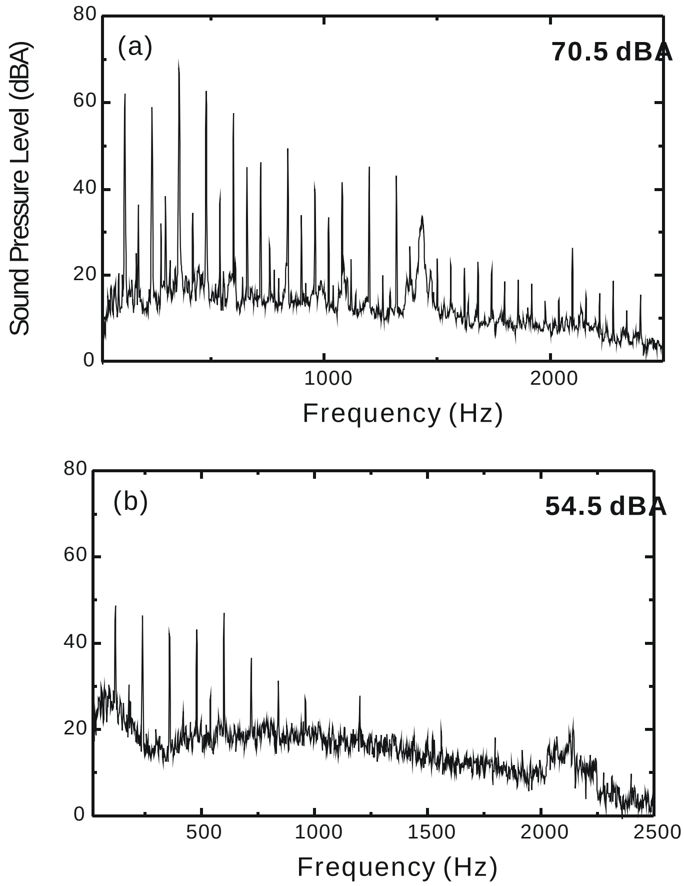


Fig. 8. Comparison of noise level before and after acoustic enclosure

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