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SOUND CONTROL FOR LARGE POWER TRANSFORMERS

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INTRODUCTION

To supply the ever increasing public demand for electric energy, more and larger power transformers must be installed as near the load centers as possible in rural, suburban and urban areas. The sound of energized power transformers, which may be heard outside of the station, is "noise" and must not exceed prescribed enforceable limits set by zoning ordinances. The noise problem for each location should be defined before the station layout and design is completed. This can be done by analyzing the pressure levels and frequency spectrum of the ambient sounds in the environment and the sound to be produced by the transformers. The latter can be measured at the factory at nominal cost. This will provide the basis for determining the amount and in what frequency range noise reduction is required to avoid transformer noise from being heard above the ambient sounds. Then the most satisfactory method or design for reducing the noise the required amount can be determined.

This paper describes a method of noise control for large EHV transformers by three-sided masonry wall enclosures utilizing acoustic block having high sound absorption as well as transmission loss characteristics that have proved satisfactory.

CONCLUSIONS

A three sided enclosure of masonry walls utilizing sound absorption block on the interior surfaces provides the reduction in transformer noise level required at two EHV stations of over 2000 MVA capacity. No change in standard cooling system was necessary, the transformers are accessible for inspection and maintenance, the structures are fireproof and can withstand 100 mph wind. The transformers are not visible from off site and the masonry structures are acceptable aesthetically. The cost was less than other methods considered.

DISCUSSION

The first large EHV transformer installation on the Baltimore Gas and Electric Company system was at Conastone Station in a quiet rural area. There are two banks of three 217 MVA, 500/230 kV single phase, NEMA standard 87 db maximum sound transformers. Each bank is capable of carrying in excess of 1000 MVA. The transformer design was established before the station site had been chosen. The six transformers cost $2,600,000. Lower guaranteed sound levels would have cost 1% of the transformer per db reduction below 87 db with a maximum reduction of 15 db obtainable. This would have provided at best 72 db units at an extra cost of $390,000, with a delay of several months in delivery. It would also have increased the size, weight and complexity of the transformers. If complaints developed after spending the $390,000, further substantial remedial costs would have been involved. The substation design included fire walls between transformers in each bank with sump pits under each unit to hold transformer oil and water from the fire protection systems in an emergency. The decision had been made to design the pit walls as grade beams to support sound walls, should they be required, and it was expected that they would be.

Sound level tests performed at the factory showed the transformers produced only 79 db, or 8 db below the 87 db guarantee, which is comparatively quiet for transformers of this size. Ambient sound pressure and spectrum analysis data obtained at the station site environment evaluated with similar factory test data for the transformers indicated that without some means of noise control, a public response rating of F - "justifiable complaint and likely group action" could be expected from the neighbors.

In the farming environment, during the summer, only crickets, frogs, cattle and an occasional tractor are heard by the inhabitants. It was certain that the 120 Hz hum and the psychological presence of the station and particularly the transformers would bring complaints.

The transformers were energized in late fall at which time sound level measurements and spectrum analyses were made during evening and daylight hours. These measurements verified the 79 db factory tests and the predicted F rating for the transformer noise in the environment.

Research into various materials available, experience and test data of others to guide us in the design of noise reduction means was continued. With the first signs of spring, open windows and doors and outdoor activity, we had complaints.

The sound problem was defined in this way: calculations showed that 12 db reduction in sound level was required 1200 ft. north of the transformers in the composite frequencies of 120 Hz and first four active bands to improve the F rating to B - "complainants would rarely hear the sound and thus, little public response", or possibly A - "sound inaudible to average listener and no observed reaction". Sound measurements taken at properties of neighbors to the south, east and west indicated a response rating of D - "individual complaint possible".

Some method of reducing the noise sufficiently to satisfy the complaint to the north and to a lesser degree to the east, south and west was the very minimum requirement.

The problem was discussed with consultants in the noise reduction field with manufacturers of various noise reduction materials and systems and this information evaluated. All would provide sound transmission loss and some claimed to have sound absorption characteristics. Technical data on comparative sound transmission losses for various materials showed that an 8 in. con-crete block wall with all hollows filled with mortar would provide about the transmission loss needed. Other materials such as fiber-glass, steel, aluminum, asbestos lead, etc. and combinations of same, depending on thickness would also meet the loss requirements, but require elaborate support systems, weatherproofing, painting and maintenance. The walls having to be 35 ft. high, fireproof and capable of withstanding 100 mph wind and ice made the use of these materials expensive and aesthetically unacceptable. The masonry wall was considered superior in all ways to the other materials investigated. It is acceptable in most every location and lends itself to variations in shape, texture and color and provides support for other equipment where needed.

A four sided masonry wall enclosure would require special external transformer cooling facilities, removable sections for maintenance and present electrical clearance problems for the 500 kV, 300 ampere bus leads. It would also present the problem of noise spillover at the top.

A three sided masonry wall arrangement would eliminate all of the above problems and cost less providing the interior side of the enclosure could be made to absorb sound and not reflect it through the open side.

Sound absorption became the real problem then, rather than transmission loss.

Among the noise reduction products and systems investigated was "SOUNDBLOX®", a two cavity concrete block 8 in. x 16 in. with the cavities open at the bottom only, with a narrow slot in the exposed face of each cavity which functions as a tuned Helmholtz resonator. This product, type A-1, has a sound absorption coefficient of 0.97 in the 125 Hz band, 0.44 in the 250 Hz band and 0.24 in the 500 Hz band. It also has approximately 38 db transmission loss at 125 Hz.

After investigating the manufacturer's claims and obtaining samples of this product, the decision was made to construct three sided masonry wall enclosures incorporating "SOUNDBLOX®" on the interior side with standard 8 in. concrete block on the outside and with wire fabric laid in the courses to tie them together. The inner surface of the walls are at least 6.7 ft. and not within one foot of multiples of 4.7 ft. from the transformers to avoid modes of increase in sound pressure level.

When the walls were completed, sound measurements were made as before with most gratifying results. A 13 db loss was obtained at the residence to the north, resulting in good, solid A rating. Similar results were experienced on the east and west sides and on the open side to the south, the rating was improved from a D to a quiet C - "some possible dissatisfaction". We have had no further complaints and do not expect any.

The 500 ft. of sound wall for the six transformers including reinforced columns cost $100,000. The additional cost for the pit walls installed as grade beam foundations for the sound walls was less than $80,000. The $100,000 cost for the masonry sound walls utilizing "SOUNDBLOX®" on the interior side was about one third of the estimated costs based on proposals and engineering cost estimates for barriers built of other materials. The cost of trans- formers with 15 db lower (the limit) than NEMA standard 87 db at 1% per db would have cost $390,000 for the two banks and would have provided 72 db transformers which we are certain would not have changed the public response rating of F to a rating of A. The fire walls were required even without sound walls and are not included in these cost figures.

We have since installed sound walls following the same sound measuring procedures and similar design on somewhat larger capability three-phase transformers at Waugh Chapel Station with equal success.

A third project now under construction at Coldspring Station, in Baltimore City, will have two 80 MVA, three-phase transformers in service next year and two additional 400 MVA three-phase transformers by 1980. The same method of environmental transformer sound analysis is being utilized and the same general design of sound wall will be installed, if and when required. Being adjacent to an Urban Development Project, the zoning stipulations as to noise will be more critical and enforceable than the County requirements. The sound level in db permitted at the property lines of the station site is spelled out. The values vary with zoning classifications of the station site and of adjacent properties.

REFERENCES

1. IEEE Transactions paper 60-175, June 1960, "Some Characteristics of Audible Noise of Power Transformers and Their Relationship to Audible Criteria and Noise Ordinances".

2. Zoning Ordinances of Baltimore City, No. 1051, amended by Ordinance No. 1202, 1971.