24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

DESIGN OF NOISE CONTROL TECHNOLOGY IN SUBSTATIONS AND CONVERTER STATIONS

HU Sheng, CHEN Shaoyi, WU Xiaowen, Yang Jinchun, Peng Jiwen and LI Tienan

Hunan Electric Power Corporation Research Institute, Changsha, Hunan, China
email: hbhusheng@163.com

XIE Yine and Tang Qi

Hunan Xiangdian Testresearch Institute Limited Company, Changsha, Hunan, China

Noise-pollution Control is one of the most important projects of electric power corporation. For the noise problems in substations and converter stations, Noise reducing scheme in both indoor and outdoor substations and converter stations is proposed in this paper from two perspectives, which are controlling noise in the source and in the propagation process, respectively. Each noise reducing scheme is evaluated and the corresponding application case is given. The proposed scheme will give technical support in the noise controlling project of operating substations and converter stations, and in the noise optimizing of the substations and converter stations in the schedule of construction.
Keywords: substation, converter station, noise control

1. Introduction

With the rapid development of Chinese economy, the scale of urban electricity consumption is gradually increasing. Considering the reliability of power supply, the quality of power supply and the loss of power transmission, more and more substations need to be built in the city. In recent years, parts of substations in operation are gradually being surrounded by residential buildings because of the increasing speed of power grid construction and suburban urbanization. With the promulgation of National Environmental Policy Act (NEPA), the State intensified enforcement of law in environment protection, and the environmental protection conscious of the residents is gradually increased. Complaints and disputes caused by substation noise problems gradually increased, which exerted some negative impacts on the image of the Power Grid Corp. Therefore, designing rational noise control schemes for substations and converter stations has become the focus of environmental protection work in electric power company[1,2].

The design of noise controlling technology in substations and converter stations should be based on different reasons and specific conditions of exceeding standard and combined with the position of noise source and surrounding environment, one or more corresponding noise reducing schemes that is economically feasible should be established, and then compare and select the optimal noise reducing scheme.

In this paper, according to the characteristics of noise source, noise reduction schemes for substations and converter stations were put forward under indoor and outdoor conditions, besides, the noise reduction effects of each scheme were analyzed and the specific conditions of application were given. For outdoor noise sources, several measures can be taken to reduce noise based on different situations, including rectifying or replacing noise source equipment, setting sound barriers or

acoustic enclosure, installing vibration isolation devices or muffler. For indoor noise sources, in addition to the aforementioned measures, some other steps can be adopted, such as setting sound proof door or windows, installing indoor sound absorbing materials or other sound absorbing structure.

2. Outdoor noise source control measures

2.1 Controlling noise source

Noise source control is the prior measure as long as the condition of economy and technique is possible. The equipment, including transformers, converter transformers, reactors and fans, can be rectified or replaced to reduce the noise in substations and converter stations if the noise was caused by the equipment aging and failure[3].

For noise caused by the body of transformer, for example, if the transformer was used for a long time, which led to the overall high noise, and the cost of adopting noise reducing measures would be too high, in this case, replacing the transformer with new transformer that meet the requirements of noise control can be taken into consideration. Reforming the air-cooled transformer into self-cooled transformer or replacing low noise cooling fan if the noise in substation and converter station was caused by the cooling device[4].

2.2 Controlling the way of transmission

For substation noise source equipment which is arranged in outdoor, in addition to control the body noise, can also take measures to control the route of transmission so as to reduce the noise.

For air borne noise, the noise transmission path can be controlled by setting sound barriers and sound insulation covers. Generally speaking, the noise can be reduced by 5～15dB(A) by setting sound barriers and 15～25dB(A) by setting sound insulation covers. As for structure vibration noise, vibration isolation device can be installed, which have a good inhibiting effect on low frequency noise, in this way, noise can be reduced by 1～5dB(A). For airflow noise of fan, mufflers can be installed, which can reduce the noise by 15～30dB(A)[5,6].

2.2.1 Sound barrier

Setting up sound barriers is the most common measure for outdoor noise of substations and converter stations. On one hand, the materials of sound barriers are various, such as brick, steel structure, composite structure and so on. On the other hand, the sound barrier can be used flexibly, which can be set near the noise source separately and can also be set combined with the wall of the substation and converter station. In general, the sound barrier should be as close as possible to the noise source, the closer the distance from the noise source, the better the sound insulation effect of the sound barrier. Fig.1 and Fig.2 are the examples of the application of sound barrier to outdoor transform and converter transform.

(a) before (b) after

Fig.1 The sound barrier for outdoor transform

Fig.2 The sound barrier for converter transform

The insertion loss of sound barrier depends on the transmission, diffraction and reflection of sound wave on sound barriers, noise can be reduced5～15dB(A) in general. The specific acoustic design of sound barrier can refer to 《Norm on Acoustical Design and Measurement of Noise Barriers》(HJ/T 90), including determining the design target value, the position, the geometry, the shape, the insertion loss estimation and design adjustment of sound barrier.

If the background noise of boundary and sensitive target is equal to or lower than the environmental noise standard of this acoustic functional region, the target value of sound barrier can be determined by the predictive value or measured value of noise minus the value of environmental noise standard.

The main geometric shape of sound barrier include erect type, plate type and bending type, the specific type mainly based on insertion loss and the field condition. Therefore, the plate type of sound barrier is the most common in substation.

The insertion loss of sound barrier can be estimated according to the characteristics of noise source, the material and geometric size of the barrier and the relative position. The main calculation includes the attenuation amount of diffraction, the correction of acoustic transmission and reflection. The attenuation amount of diffraction mainly depends on the characteristic of noise source, the geometric size and relative position of sound barrier. The correction of acoustic transmission mainly depends on sound insulation performance of sound barrier material and the correction of acoustic reflection mainly depends on the sound absorption performance of the sound barrier and other reflector materials, as well as the geometric size and relative position of the sound barrier.

As for the design of sound barrier in substation and converter station, in addition to meet the above mentioned requirements of acoustic design, it should also meet the requirements of electrical safety, structural safety, service life, operation and maintenance, ventilation and landscape coordination.

2.2.2 Sound insulation enclosure

Sound insulation enclosure is a kind of noise reduction device which can inhibit the noise transmission by making the noise source closed completely in a confined space. The sound-insulating effect of sound insulation enclosure is better than sound barrier, which can make the noise reduced by 15～25dB(A). The noise source would generate heat when it was in operation, such as transformer, converter transformer and so on, which make it is necessary to set up a ventilation and cooling device with noise reduction effect for the sound insulation enclosure. Therefore, the sound insulation of sound insulation enclosure depends on the combination effect of sound insulation material and ventilation and cooling device. For example, Box-in, which is used for noise reduction of converter transform, is a detachable sound insulation enclosure with ventilation and cooling muffler. As shown in Fig.3, unlike sound barrier, equipment was placed in a totally enclosed space in Box-in measures. Fig.4 showed a specific application of noise control for the noise generated by the fan in main transform room in a certain substation using sound insulation enclosure.

Fig.3 Box-in for converter transformer

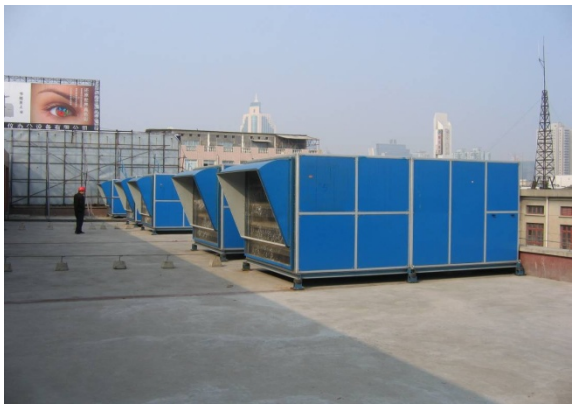

Fig.4 Box-in for the fan in main transform room

The specific acoustic design of sound insulation enclosure includes determination of the value of target design, ventilation rate, position, geometric size, the ventilation style, the sound attenuation design of ventilation channels, the insertion loss estimation and the sound insulation enclosure design adjustment.

2.2.3 Vibration isolation device

The noise-sensitive buildings that are close to noise source, are not only affected by airborne noise, but also affected by structure borne noise; The vibration isolation device can be installed to reduce this kind of noise, which have a good inhibitory effect on low frequency noise and the noise can be reduced by 1~5dB(A) by this measure. Therefore, it is possible to reduce the low frequency structure noise by installing the vibration isolation device at the bottom of the transformer, reactor and converter transformer.

The design of vibration isolation elements include the determination of vibration isolation target value, the selection of vibration isolation elements, the load, the determination of the size and number, the arrangement of the vibration isolation system and the computation check of vibration isolation effect.

1) The selection of vibration isolation elements, including vibration isolation cushion and vibration isolator, should comply with the following rules:

For the vibration with natural frequency of 1～8Hz, the metal spring vibration isolator and the air vibration isolator can be selected. For the vibration that the natural frequency is 5～12Hz, shearing rubber vibration isolator, rubber vibration pad with two to five layers or glass fibre with 50-100mm thick can be chosen. For the vibration with natural frequency of 10～20Hz, rubber vibration pad with one layer, metal rubber isolator and metal cotton isolator can be selected. For the vibration that the natural frequency is greater than 15Hz, cork and compressed rubber isolator can be selected. The variety and specification of vibration isolation elements can be determined according to the technical parameters of the products.

2) The arrangement of vibration isolation system should meet the following requirements.

The arrangement of vibration isolation system should be symmetrical, and the load of each pivot should be equal. If the unit does not constitute a whole, the public housing should be used to make the unit supported by isolator, what's more, the public housing units should have sufficient rigidity. If the natural frequency need to be reduced and the vibration isolation efficiency need to be increased, the vibration isolation elements can be used in series. The vibration isolation elements for small machinery equipment can be set on terrace and floor directly. It's not necessary to do equipment foundation and foundation bolt. For the machines that with a high center of gravity or have to bear accidental collision, horizontal stabilizer device can be adopted, however, a short circuit should be avoided.

3) The elastic connection should meet the following requirements:

Vibration isolation of certain piping system shall be carried out using elastic connections. For instance, for the vibration isolation of the blast pipe and return duct of the fan, canvas joint, rubber

hose and isolation hook can be adopted. For the vibration isolation of piping systems, such as pump, chiller and air compressor, rubber hose should be used. For piping system with high temperature of transmission medium, high pressure or chemical activity, metal hose should be used. For the electric line of electrical equipment, flexible line should be used. For pipe across the floor or wall, should be separated by elastic materials.

4) The vibration isolation frame is usually made of steel and concrete and should be set between vibration isolation element and machinery equipment. Steel frame should be used to make vibration isolation frame with light weight and easy to install. For vibration isolation frame with large amount of vibration isolation and good rigidity, meanwhile, the required vibration isolation have low gravity and low natural frequency, should be made of concrete. The weight of frame made of concrete should be 2 times the weight of the machine. For the reciprocator, the weight of frame should be 3-5 times of the machine.

2.2.4 The muffler for air inlet and outlet

The airflow noise of ventilation fan in substation and converter station can be reduced by installing muffler in air intake or air outlet of the fan. For the transformer noise mainly caused by cooling device, muffler can be installed in the vents of cooling device to reduce the noise of cooling fan. 15~30 dB(A) can be reduced by installing muffler. Fig.5 showed the muffler of the air outlet of the main transform room fan in a certain substation and Fig.6 showed the capacitor room fan muffler in a certain substation.

The design of muffler should base on the aerodynamic performance requirements, and the special requirements of moistureproof and high temperature resistance in air power equipment piping. For noise of ventilation fan that mainly in high frequency, dissipative muffler should be adopted. The model of muffler can be determined by the performance parameter of existing series muffler. Besides, it can be also design muffler that meet the requirements by oneself when it's possible.

For the noise of ventilation fan control, it is necessary to calculate air flow regeneration noise of each part of piping system in addition to consider the noise source and the noise attenuation of the muffler and each part of the fan. When the influence of air flow regeneration noise on the environment exceeds the noise limit value, the airflow velocity should be reduced, or the muffler structure should be simplified.

Fig.5 The muffler for fans in main transform room

Fig.6 The muffler for fans for the capacitor room

3. Indoor noise source control measures

3.1 Controlling noise source

As outdoor noise sources, within the scope of the economic and technical conditions permission, control measurements on the noise sources should be considered priority, for example noise caused by equipment aging or equipment fault, can be reduced through repairing or replacing of the corresponding equipment.

3.2 Controlling the way of transmission

For the indoor noise source, such as transformer, reactor, etc., the aerial noise emitted from them to the environmentally sensitive target,andmainly propagated through doors, windows or ventilation of the transformer chamber or reactor room; the structural (vibration) noise emitted from that into the environmentally sensitive target, mainly through the base, walls and other structures. Therefore, the air noise can be reduced by taking soundproof door or window, equipping indoor acoustical material or n sound absorption structure etc. The air flow noise in the inlet and outlet for ventilation can be reduced by equipping muffler, which generally has 15~30 dB (A) noise reduction effect. The structure (vibration) noise can be reduced by equipping vibration isolation device, which has good inhibition to low-frequency noise and generally has 1~5dB (A) noise reduction effect.

3.2.1 Sound proof door and window

For the substation and converter station with doors or windows, in order to reduce the spread of noise through a door or window, the area of the door or window should be reduced, at the same time the soundproof door or window of should be installed. Sound proof door or sound insulation window generally has 20~35dB (A) noise reduction effect.

In order to obtain good sound insulation effect, the lighting window for the noise chamber shouldn't be designed in principle. If the lighting window must be designed, single or multi-layer fixed window glass can be chosen based on sound insulation quantity target. At the same time, the size of the lighting window should be small as far as possible, the position of the window should try to avoid noise sensitive target.

In order to obtain good sound insulation effect, the full opening and closing big-sized door for maintenance shouldn't be designed in principle. A small-sized sound proof door can be designed to facilitate the daily maintenance of equipment and personnel access. When the transformer should be dragged out for overhaul, the wall on the side of door can be dismantled. When the transformer was reinstalled after the overhaul, then the wall can be restored. If the big-sized door for maintenance must be designed, the style of full opening and closing must be avoided. Otherwise, it is difficult to treat the crash of door and choose switching power. The fixed sound proof door with a small-sized maintenance door in assembling type is recommended, as shown in fig.7. The small-sizedmaintenance door is designed for the daily maintenance of equipment and personnel, and the fixed sound proof door is designed for transformer overhaul. The sound transmission loss of the door can be chosen based on sound insulation quantity target, at the same time the crash of door must be sealed. The position of the door should try to avoid noise sensitive target.

Fig.7 The fixed sound proof door with a small-sizedmaintenance door

3.2.2 Sound-absorbing material or structure

In the area with higher requirements for noise control, sound-absorbing material or structure can be adopted if the measurement of sound insulation or noise elimination can't accord with the noise

standard. Sound-absorbing material or structures generally has 3~8 db(A) noise reduction effect. The commonly sound-absorbing material or structure for the substation and converter station contains porous sound-absorbing bricks, slag expanded perlite acoustical tile and micro-perforated sound absorption board, etc. As shown in fig.8, an double layer sound absorbing structure of micro-perforated panel was installed for a main transformer room in the substation.

Sound absorption usually used to inhibit reverberation. If the room volume is not too big, sound absorption coefficient of the wall is small, the sound absorption treatment can obtain ideal effect.

The design of sound absorption include the noise characteristics, the sound absorption coefficient of the room to be processed, the target value of noise reduction, the type of sound absorption materials and sound absorption structure, the thickness and area of sound absorption material, etc.

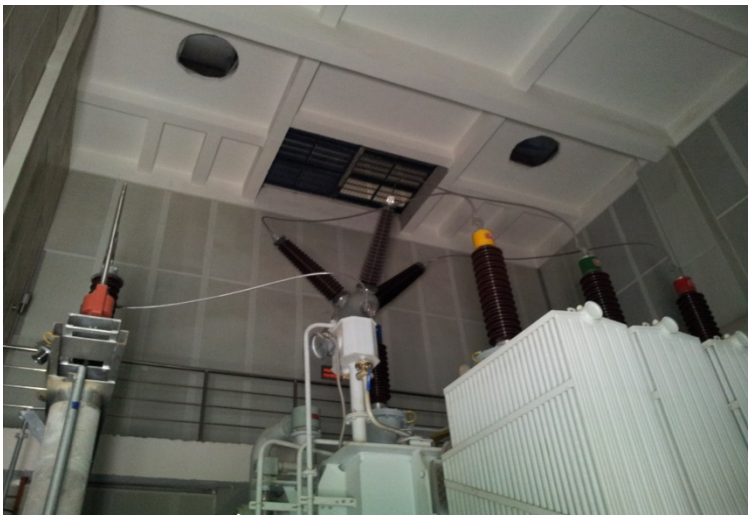

Fig.8 The microperforated panel for main transformer chamber

3.2.3 The muffler for air inlet and outlet

Different from the muffler for outdoor noise source, the style of the treatment to air inlet and outlet varies according to the ventilation way and the noise reduction target.

When the body and radiator of the transformer are an organic whole, the ventilation way of the transformer room should adopt mechanical ventilation. Therefore, the large ventilation air volume leads to the larger capacity fan with larger noise. In order to satisfy the large amount of noise elimination, the size of muffler for air inlet and outlet will be big, the fan also needsnoise reduction processing synchronization.

When the radiator of the transformer is separated from thebody, the ventilation air volume of the transformer room can be greatly reduced. So the size of ventilation opening and the capacity of fan can both be reduced thereupon. The muffler of air inlet can adopt silencing shutter or thermometer Screen, and the treatment way of air outlet and fan can be chosen according to different condition

The impedance compound muffler should be adopted for main transformer room or reactor room, which not only can reduce the low frequency noise produced by the main transformer, but also can reduce the high frequency noise produced by the ventilation fan. Generally, silencing shutter has 3~6db noise reduction effect, and the impedance compound muffler has 15~30db(A) noise reduction effect.

3.2.4 Vibration isolation device

Structure (vibration) noise emitted from that into the environmentally sensitive target, mainly through the base, walls and other structures. As shown in fig.9, a vibration isolation device was used for the indoor reactor in a substation.

(a) before (b) after

Fig.9 A vibration isolation device for the indoor reactor

4. Conclusions

Substation and converter stationare the main noise sources in the grid, andmuch attention had been paid to the noise problem. In this paper, noise reducing schemes in both indoor and outdoor substations and converter stations are proposed, including the specific way of noise reduction, equipment type and material selection, etc., and each solution effect of the noise control was evaluated. The proposed scheme will give technical support in the noise controlling project of operating substations and converter stations, which has a practical significance.

REFERENCES

1 Gu X. A., Shen R. Y., Xu J. T. Study on the vibration and noise control techniques in large power transformers, *Noise and Vibration Control*, 21(5), 7-11, (2001). (In Chinese)

2 Li Y. M., Wang Y. Q., Xu L. W. etc. Audible Noise Prediction and Simulation Analysis in Substation, *Electric Power Construction*, 34(7), 63-67, (2013). (In Chinese)

3 Zhang Q. B., Deng C.H., YU D. Y., etc. Study on the Noise Control Scheme for UHVDC Converter Stations, *Southern Power System Technology*, 3(5), 15-17, (2009). (In Chinese)

4 Chi F., Li L. H. Analysis of substation and transmission lines noise and its noise abatement summary, *Shanghai Electric Powe*r, 20(6), 580-586, (2007). (In Chinese)

5 Zhang J. S. Research on Comprehensive Treatment of HVDC Converter Station Noise, *Electric Power Construction*,28(8), 14-16, (2007). (In Chinese)

6 Zhou J. G. Li L. H. Du Y. Review on methods of noise reducing for equipment in substations, converter stations and transmission lines, *Electric Power*, 42(3), 75-78, (2009). (In Chinese)