Research Progress of evaluation method and control limit for Substation low frequency noise

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Abstract. At present, the low frequency noise control limit standards are only suitable for indoor structural noise control, and it is urgent to establish standards or specifications for substation low frequency noise evaluation and limit value. According to the theory of spectrum gauge weight, the equivalent continuous A sound level decays the low frequency part of noise greatly, only from the aspect of loudness, it only considers the feeling of human hearing to noise, and fails to fully consider the subjective feeling of people's annoyance to low frequency noise. The method of low frequency noise weight correction needs to be further studied. In this paper, the evaluation method of low frequency noise and the control limit standard are fully investigated, which can be used as a reference for the formulation of low frequency noise limit standard in our country.

1. Research status of low-frequency noise evaluation method

1.1. Evaluation method based on A sound level
At present, A sound level is the most widely used noise evaluation. However, the A weighted network has a lot of attenuation to the low frequency band noise, and it is not suitable for the evaluation of low frequency sound. Persson et al. The results show that for the low frequency noise with wide frequency band, when the unweighted sound pressure level reaches 65 dB, the A sound level should be compensated for 3 dB, and when the unweighted sound pressure level reaches 70 dB, the A sound level should be compensated for 6 dB. Kjellberg is equal to 1984 and draws a similar conclusion. When LC-LA > 15 dB, the A sound level needs to obtain a compensation value of 6 dB in order to reflect the subjective annoyance of the speaker (again, the prediction accuracy can reach 70.7%). In view of the large attenuation of the low frequency part of the sound by the A weight curve, Inukai et al proposed LF curve and LF2 curve, which are used to evaluate the low frequency noise of the low sound pressure level and the low frequency noise of the high sound pressure level, respectively. The LF curve and the LF2 curve reduce the attenuation of the low frequency component relative to the A weight curve, as shown in Fig. 1.
1.2. Evaluation method based on NR Curve
In 1962, the NR curves of Kosteen and Vanos reference to the degree of speech interference were proposed to evaluate the indoor noise. In 1971, the NR curve was formally accepted and extended by the ISO International Organization for Standardization. In 1978, the NR curve is not suitable for evaluating the low-frequency noise of the high sound pressure level, and the lower limit of the frequency of the NR curve is extended from 31.5 Hz to 16 Hz, and the NRM curve is established. In 1983, Broner and the like take the low-frequency noise of 10 Hz as the sound source. It is found that when the center frequency is between 35 Hz and 45 Hz, the subjective annoyance of the noise will appear a peak, so that the sound of the frequency band is more annoying than the sound of other frequency bands, while the BRONer and the like modify the NR curve according to the study result, and the LFNR (Low Frequency Noise Rating) curve is proposed for low-frequency noise.

1.3. Evaluation method based on NC Curve
In 1957, Beranek proposed the NC curve based on the isometric curve and the degree of language interference. The specific method is to analyze the octave of the noise, and then draw the spectrum diagram on the NC curve. The NC value of the noise is equal to the value of the highest NC curve in each doubling band sound pressure level. Because of the large frequency attenuation characteristics of low frequency noise, NC curve has defects in the evaluation of low frequency sound in frequency set. For this reason, Beranek proposed the noise evaluation PNC curve in 1971. In 1989, Beranek proposed the NCB curve. The curve extends the low frequency end of the NC curve and the PNC curve down from 31.5 Hz to 16 Hz. This is because in low frequency noise (such as air conditioning system noise), components below 31.5 Hz octave can not be ignored.
1.4. Evaluation method based on RC curve

Blazier has studied more than 200 cases of indoor noise measurement data and put forward RC curve, which has been recommended by (ASHRAE) of American Institute of heating, ventilation and Air conditioning Engineers as the basis of indoor acoustic environment design. Based on the RC curve, Blazier puts forward the RC Mark II curve (as shown in figure 3). From the point of view of spectrum balance, the concept of quality evaluation index QAI is put forward by calculating the energy average value of the difference between each frequency band and the RC curve. If $QAI \leq 5$, the noise is determined to be "neutral"; if $QAI > 5$, the spectrum energy distribution of the noise is determined to be unbalanced, if the LF is the largest, it is determined to have the characteristic of "rumbling", if the MF is the largest, it is determined to have the characteristic of "roar", and if the HF is the largest, it is determined to have the characteristic of "hissing". Blazier further proposes that when $5dB < QAI \leq 10dB$, the noise may cause people's discomfort. When $QAI > 10dB$, noise makes the vast majority of people feel uncomfortable.

![RC curve](image)

Figure. 3 RC curve

2. International status of low Frequency noise Control limits

2.1. Low-frequency noise emission limits in Sweden

In 1996, the Swedish National Health Bureau gave the recommended limit value of indoor low frequency noise, which stipulated the sound pressure level of 1/3 octaves each with the central frequency of 31.5~200Hz. Table 2 shows the specific limits, as well as the human hearing threshold (ISO 226). It can be seen from the table that the suggested limit is more strict, and the sound pressure level limit on the frequency band of 1/3 octave of 31.5Hz is lower than the human hearing threshold.
Table 1. Recommended limits for indoor noise in Sweden

| 1/3 octave center frequency (Hz) | daytime | night  |
|----------------------------------|---------|--------|
| 31.5                             | 56      | 56.3   |
| 40                               | 49      | 48.4   |
| 50                               | 43      | 41.7   |
| 63                               | 41.5    | 35.5   |
| 80                               | 40      | 29.8   |
| 100                              | 38      | 25.1   |
| 125                              | 36      | 20.7   |
| 160                              | 34      | 16.8   |
| 200                              | 32      | 13.8   |

2.2. Recommended limits for low frequency noise in Germany

In 1990, Piorr did a large number of investigations on the environmental impact of industrial equipment noise. Based on this, Germany gave the recommended limits of low frequency noise in 1997, as shown in Table 2. In the process of evaluation, LC-LA > 20dB is used as the evaluation standard of low frequency noise. Then, the sound pressure level of 1/3 octaves of noise measured in a specific time period is compared with the hearing threshold. For tuned noise, the limit value is based on the listening threshold. It can be seen from the table that the diurnal limit on the center frequency of 80 Hz and 100 Hz is 10 dB and 15 dB higher than the listening threshold, respectively, the diurnal limit values of the other 1/3 octaves are higher than the hearing threshold 5dB, while the night limits are all lower than the diurnal limit of 5 dB. For non-tuning noise, the equivalent continuous A sound level of 1/3 octaves exceeding the listening threshold needs to be calculated, and the diurnal limit of the equivalent sound level is 35 dB, and the night limit is 25 dB.

Table 2. Recommended limits in Germany

| 1/3 octave center frequency (Hz) | Listening threshold (dB) | Daytime limit for tuning noise (dB) | Night limit for tuning noise (dB) |
|----------------------------------|--------------------------|------------------------------------|----------------------------------|
| 8                                | 103                      | 108                                | 103                              |
| 10                               | 95                       | 100                                | 95                               |
| 12.5                             | 87                       | 92                                 | 87                               |
| 16                               | 79                       | 84                                 | 79                               |
| 20                               | 71                       | 76                                 | 71                               |
| 25                               | 63                       | 68                                 | 63                               |
| 31.5                             | 55.5                     | 60.5                               | 55.5                             |
| 40                               | 58                       | 63                                 | 58                               |
| 50                               | 40.5                     | 45.5                               | 40.5                             |
| 63                               | 33.5                     | 38.5                               | 33.5                             |
| 80                               | 28                       | 38                                 | 33                               |
| 100                              | 23.5                     | 38.5                               | 33.5                             |

2.3. Recommended limits for low frequency noise in Poland

In 2001, Poland proposed a set of low frequency noise control standards, whose evaluation range includes 1 ≤ 3 octaves of central frequency of 10 Hz~250 Hz. In this standard, a LA10 reference curve is proposed, and the influence of background noise is considered in the evaluation process. The evaluation consists of two parts: L1 is the difference between noise pressure level and LA10, L2 is the difference of sound pressure level between noise and background sound, and L2 is the difference of sound pressure level between noise and background sound. Noise is evaluated as annoyance when the following conditions are met: L1 > 0dB, and L2 > 10dB (for tuned noise) or L2 > 6 dB (for broadband noise).
2.4. **Recommended limits in America**

The main responsibility of noise control in the United States lies in state and local governments, and the federal government manages and controls commercial noise sources that require national unity. The noise control method in the United States Code revolves around the control of noise sources, including 42 USC 4904 main noise source identification, 42 USC 4905 commercial product noise emission standard and 42 USC 4914 low noise emission product development. Among them, the United States Environmental Protection Agency sets the following product emission standards in federal regulations: 1) construction equipment; 2) transportation equipment (including coaches and related equipment); 3) any motor or engine (including engines or any equipment for which motors are an integral part); and 4) electrical or electronic equipment.

3. **Control limit of low Frequency noise in China**

At present, there is no special emission standard for substation noise in our country. At present, the implementation standards of substation noise emission and impact assessment are as follows: the sound environment quality around the substation (including noise sensitive buildings) should meet the requirements of the sound environment functional area in the Acoustic Environment quality Standard (GB3096-2008), and the environmental noise emission from the substation plant boundary should meet the requirements of the Environmental noise Emission Standard for Industrial Enterprises (GB12348-2008).

| Functional areas of acoustic environment | Daytime | Night |
|-----------------------------------------|---------|-------|
| 0                                      | 50      | 40    |
| 1                                      | 55      | 45    |
| 2                                      | 60      | 50    |
| 3                                      | 65      | 55    |
| 4                                      | 70      | 55    |

For the fixed equipment located in the building can affect the indoor sound environment through structural transmission, China has specifically stipulated the indoor noise emission limit value of the fixed equipment for structural transmission in the Social living Environment noise Emission Standard (GB22337-2008). It can be seen from the table that the standard stipulates the limit value of the sound pressure level of each frequency doubling band with the center frequency of 31.5 Hz ~500 Hz, and the limit value is higher than that of other countries.

4. **Conclusion**

At present, the noise evaluation of substations in China is mainly based on the national standards GB 12348-2008 and GB 3096-2008. The existing national standards only put forward the control limits of low frequency noise in the room transmitted by fixed equipment noise, and there is no outdoor low frequency noise control limit standard (such as substation low frequency noise). Internationally, such as Sweden, Germany, Poland and other countries have also issued low-frequency noise control limit standards, but only applicable to the evaluation of indoor noise. At present, the low frequency noise control limit standards issued at home and abroad are only suitable for indoor structural noise control, but there is no outdoor low frequency noise control limit value. It is urgent to establish standards or specifications for substation low frequency noise evaluation and limit value, and to improve the noise evaluation technology system in our country.

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