This paper presents a simple and speed implementation prediction method without complex parameter detection and calculation process, which synthesized four point source prediction model and five point source model based on the near field noise values for far-field noise. According to the horizontal distance, the different forecasting models was chosen to calculate the far-field noise value of the transformer. The difference between the predicted values and the measured values is less than 1dB (A), which indicated that the prediction method can get very good results.

Keywords: Substations, noise, far-field, prediction model

1. Introduction

The transformer is one of the main noise sources in the substation. The technical protocol put forward by our transformer manufacturers show that the control values of the transformer noise are near-field noise values, which is usually 1m or 2m away from the transformer shells. Therefore, the sound power value of the transformer can not be precisely given and it has important significance to grasp the far-field noise prediction model based on the transformer of near-field noise for the noise control of the newly established substation and the noise treatment of the operating substation [1]. Although many studies have been performed both at home and abroad, but no far-field noise prediction of the transformer model has been commonly recognized yet [2-4]. This paper has established a simplified far-field noise transformer model with five-point resources, compared with the measured values and far-field noise transformer model commonly used both at home and abroad and verified that the model can accurately predict the far-field noise of the transformer.

2. The attenuation model of the radiation noise of the transformer

2.1 The far-field noise model commonly used at home and abroad

2.1.1 The point source model

The point source model simplifies the transformer into only one point source and the basic formula of the spherical irradiation is as following formula (1) [5]:

\[ L_{WA} = L_{A(r)} + 10 \lg \frac{4 \pi r^2}{K} \]  

In the formula (1):
“r” represents the distance between the shell of the transformer to the test point, m;
“\(L_{WA}\)” is A weighted sound power of the transformer, dB(A);
“\(L_{A(r)}\)” indicates A weighted sound power of the transformer when the distance between the shell of the transformer is \(r\), dB(A);
“K” represents the directional coefficient and the value for the half-free space (outside substation is 2);

Deriving Formula (2) from formula (1):
\[
L_{WA} = L_{A(r)} + 10\log 2\pi r^2 = L_{A(r)} + 20\log r + 8
\]

So:
\[
L_{A(r)} = L_{WA} - 20\log r - 8
\]

The formula that can speculate the far-field noise based on the near-field noise of the transformer is as following formula (4):
\[
L_{A(r)} = L_{A(r_1)} - 20\log \frac{r_2}{r_1}
\]

“\(r_1\)” represents the distance between the shell of the transformer to the near field point, m;
“\(r_2\)” represents the distance between the shell of the transformer to the far field point, m.

### 2.1.2 The empirical formula

European countries usually adopt the following formula (5) to calculate the attenuation of the noise of the transformer\(^6\):
\[
\Delta L = 4.4 + 20\log \left(\frac{D'}{\sqrt{WH}}\right)
\]

In the formula (5):
“\(\Delta L\)” represents the noise attenuation caused by the increase in the distance away from the wall of the tank, dB;
“W” represents the width of the fuel tank, m;
“H” represents the height of the fuel tank, m;
“\(D'\)” indicates the distance between the monitoring points and the wall of the tank, \(D' > \sqrt{WH}\) m.

The predictor formula of the far-field noise is as following formula (6):
\[
L_{A(r_2)} = L_{A(r_1)} - 20\log \left(\frac{D'}{\sqrt{WH}}\right) - 4.4
\]

“\(L_{A(r_2)}\)” represents the noise level of \(D'\) monitoring point, dB(A);
“\(L_{A(r_1)}\)” indicates the noise level measured in the near field, dB(A);
“s” represents the total surface area of the four walls of the transformer tank, m\(^2\).

### 2.2 The improvement of the far-field noise model

The far-field noise model is improved and the four-point-source model is adopted to speculate the noise value when the predicted distance(r) is no more than two times of the maximum size of the transformer\((r_0)\). The five-point-source model is adopted to speculate the noise value at the pre-
diction site when the predicted distance is larger than two times of the maximum size of the transformer. The schematic diagram of the model is shown as below Fig.1:

![Schematic diagram of the model](image)

**Figure 1:** The schematic diagram of the model

### 2.2.1 Five-point-source model

The vibrating radiation noise at the bottom of the transformer is neglected. Five-point sources are distributed on the four lateral surfaces and the upper surface of the transformer and the formula to calculate the far-field noise of the transformer is as following formula (7):

$$L_{d(r)} = L_{d(r)} = 20 \log_{10} \frac{r_2}{r_1} + 10 \log_{10} 5 = L_{d(r)} - 20 \log_{10} \frac{r_2}{r_1} + 7$$

### 2.2.2 Four-point-source model

In consideration of the little effects of the lateral surface at the back of the predicted position, the vibrating radiation noise originating from the bottom of the transformer and the lateral surface at the back of the predicted position can be neglected. Four points sources are distributed on three lateral surfaces and the upper surface of the transformer. The formula to calculate the far-field noise of the transformer is shown as below formula (8):

$$L_{d(r)} = L_{d(r)} - 20 \log_{10} \frac{r_2}{r_1} + 10 \log_{10} 4 = L_{d(r)} - 20 \log_{10} \frac{r_2}{r_1} + 6$$

### 3. Comparisons of the predicted results of all models

#### 3.1 Three-phase transformer

![Layout of predicted position for three-phase transformer](image)

**Figure 2:** Layout of the predicted position for three-phase transformer
The 110kV substation is equipped with a 50000kVA main single-phase transformer with 6m x 6m x3m size. The layout of predicted position is shown in Fig.2. The comparison between the measured noise attenuation values of the transformer and the predicted values of all models is performed and the results are shown in Fig.3. In the improved far-field noise model, when the predicted distance is no more than 12m, the four-point-source model will be adopted to calculate the noise value at the predicted position and the five-point-source model will be used to calculate the noise value at the predicted position if the predicted distance is more than 12 meters. Results of Fig.3 have showed that the deviation in the point-source model is the biggest while the empirical formula and improved model can predicate the noise attenuation of the three-phase transformer well. Results of Table 1 have showed that the maximum deviation of the far-field noise values over 10 meters away in the improved model is 0.5 dB(A), which is smaller than that in the empirical formula.

![Figure 3: The results of varies predict models for three-phase transformer noise](image)

<table>
<thead>
<tr>
<th>Predict models</th>
<th>The deviation values(dB(A))</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Test values</td>
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<tr>
<td>The point source model</td>
<td>/</td>
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<td>The empirical formula</td>
<td>/</td>
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<td>The improvement model</td>
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### 3.2 The single-phase autotransformer

The 500kV substation is equipped with three ODFPS-334000/500 model single-phase autotransformers with 8m x 8m x5m size. The layout of predicted position is shown in Fig.4. The comparison between the measured noise attenuation values of the transformers and the predicted values of all models is performed and the results are shown in Fig.5. In the improved far-field noise model, when the predicted distance is no more than 16m, the four-point-source model will be adopted to calculate the noise values at the predicted position and the five-point-source model will be used to
calculate the noise values at the predicted position if the predicted distance is more than 16 meters. Results of Fig.5 have showed that the deviation in the point-source model is the biggest while the empirical formula and improved model can predicate the noise attenuation of the three-phase transformer well. Results of Table 1 have showed that the maximum deviation of the far-field noise values over 10 meters away in the improved model is 0.5dB(A), which is smaller than that in the empirical formula.

Figure 5: Layout of the predicted position for single-phase transformer noise

Figure 4: The results of varies predict models for single-phase transformer noise

Table 2: The deviation values between test and predict models for single-phase transformer noise

<table>
<thead>
<tr>
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<td>1m</td>
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<td>Test values</td>
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4. Conclusions

This paper has simplified the model and established the five-point-source far-field noise model, made comparisons between the measured values and the far-field noise models of the transformers commonly used both at home and abroad and found that the predicted deviation is the smallest. Deviations between the noise predicted values and measured values of the three-phase transformer and single autotransformer are within 1dB(A). The method needs less parameters, the models are simple and the predicted results are accurate.

REFERENCES


