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A Noise Monitoring System Used for Substation Boundary: Part 2 -- Noise Evaluation Method of Multi-Measuring Points

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Abstract: After the noise monitoring system of substation boundary is deployed, the monitoring platform can obtain a large number of original noise data. How to deal with the noise monitoring data and give the specific indicators to evaluate the noise radiation level need further analysis. In this paper, the distribution of long-term noise monitoring sequence values is discussed by means of noise distribution probability fitting. Seven mainstream distribution fitting functions are compared and analyzed, and it is found that burr distribution has better performance. The final evaluation mean value is given by the three parameters Burr distribution.

1. Introduction

At present in China, the assessment of substation radiated noise is mainly based on GB3096-2008: Environmental Quality Standard for Noise [1], GB12348-2008: Emission Standard for Industrial Enterprise Boundary Environmental Noise [2] and GB/T15190-2014: Technical Code for Division of Acoustic Environmental Functional Areas [3]. However, the noise collection stipulated in the relevant standards is based on short-term monitoring, and there is no reference to the evaluation method of medium and long-term continuous monitoring noise data, the fitting evaluation of noise measurement sequence value, particularly.

Some researches mainly focus on noise location [4-6], noise prediction [7-9], and few researches on the evaluation methods of multi-point noise measurement. In addition, it is necessary to consider other spectrum noise data, such as 1/3 oct spectrum data to provide technical support for noise impact assessment and pollution prevention and control of substations.

The noise radiation level of substation is closely related to its operation conditions, such as transformer type, real-time operation load capacity, the state of air conditioning and fan, etc. Generally, the operation condition of the substation does not change frequently. Therefore, the noise of the substation fluctuates near a stable noise value, and the fluctuation range is mainly caused by the interference noise, such as noise from air conditioning and fans, cars, birds, pedestrians, loudspeakers, etc.

In this paper, the overall distribution density of day and night noise is analyzed firstly. Secondly, the heavy tailed characteristics of noise distribution are discussed. Seven typical distribution functions are selected for data fitting. Finally, the maximum likelihood estimation index is used to compare the performance of various fitting functions under three typical noise, periodic noise, burst noise and



stationary noise, respectively. Burr distribution with better fitting performance can be used to evaluate the long-term noise monitoring sequence value.

2. Evaluation Method of Long-Term Measuring Noise

The noise radiation level of substation boundary is a continuous variable. However, the value measured by integrating statistical instruments in noise continuous monitoring system such as sound level meter is a discrete value. Numerical fitting is a common method to solve the mapping from discrete variable to continuous variable problems. By fitting the distribution characteristics of the discrete noise value, a continuous fitting function is constructed by using kernel function or other means to objectively depict the overall noise level.

The histogram of long-term noise monitoring value is shown in Figure 1. It can be seen that the noise at night is more stable than that during the day, and the noise component is less. During the day, the noise range is very wide, with a large number of noise distribution in the range of 38 dB to 56 dB. No matter in the day or in the night, the noise presents a similar normal distribution, that is, the larger and smaller noise components only account for a small probability of the overall noise distribution. Therefore, it is feasible to use the method of noise distribution probability fitting to evaluate the real noise radiation of substation reasonably.

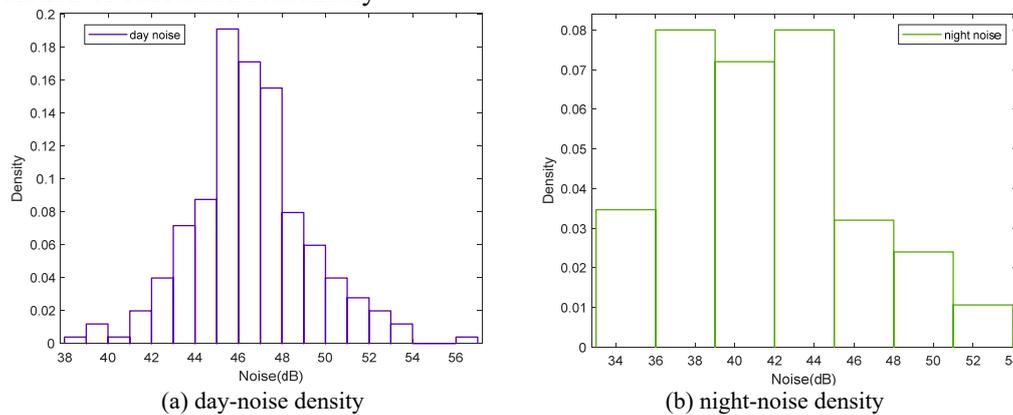


Figure 1. The histogram of long-term noise monitoring value

Burr distribution has the characteristics of strong adaptability, better data fitting performance and wide application, which can solve the problem of application limitation brought by simple distribution. The burr distribution of three parameters α , β , γ is widely used. Burr probability density function $f(x)$ and distribution function $F(x)$ are shown in Formula 1. The fitting performance of different fitting functions is concerned, so the derivation related to parameter estimation of three parameter burr distribution will not be discussed in this paper.

$$f(x) = \frac{\beta\gamma(x/\alpha)^\beta}{x[1+(x/\alpha)^\beta]^{\gamma+1}} \quad (1)$$

$$F(x) = 1 - [1 + (x/\alpha)^\beta]^{-\gamma}$$

Therefore, the standard burr probability density function $F(x)$ with three parameters can be constructed according to the fitted burr distribution function and probability density function, and the noise emission level under the mean value and different probability can be obtained.

3. Comparison of Different Probability Fitting Functions

The fitting performance of probability distribution function with seven heavy tailed characteristics, Birnbaum-Saunders, Burr, Gamma, Log-Logistic, Normal, Rician, Weibull, are compared and analyzed respectively. The smaller the absolute value of the log likelihood estimation and the smaller the fitting standard deviation, the better the fitting performance of the probability distribution. In addition, the distribution characteristics of noise data are evaluated by the method of log likelihood, and the mean value and standard deviation of the distribution are calculated.

All the noise data comes from the actual noise monitoring value of three 110 kV substation 1#, 2# and 3#. Each noise data is obtained by duration of one-minute and period of 20 minutes statistical measurement by noise monitoring system. The collected noise data include three types, namely, periodic noise, burst noise and stationary noise, respectively. The performance of Burr probability fitting is shown in the following comparison.

3.1. Periodic noise analysis

In substation 1#, there are 251 data points in the daytime and 125 data points at night. In Figure 2, it can be seen that the night noise monitoring curve shows significant periodic fluctuation, with high noise radiation level in daytime and low noise radiation level at night. Figure 3 shows the density distribution of periodic day and night noise under different fitting functions. During the day, the noise is mainly concentrated in 46 dB to 48 dB. However, noise at night ranges from 36 dB to 44 dB. That's because of the periodicity at night, the highest at 23:00 and the lowest at 03:00.

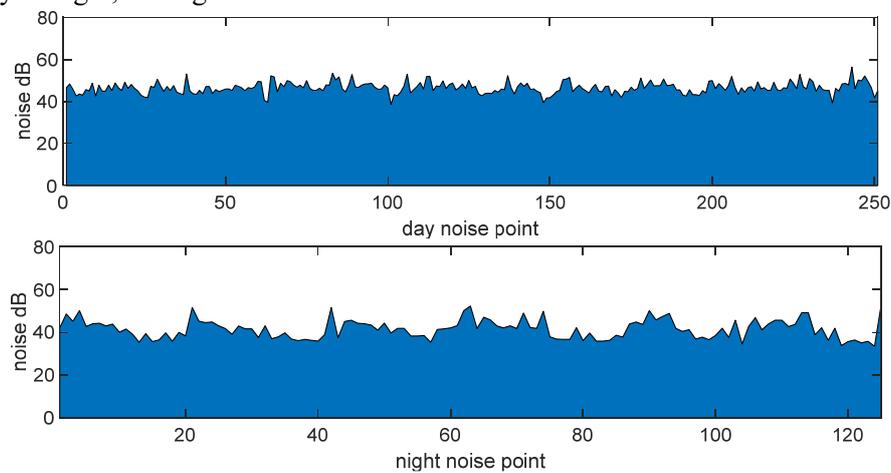


Figure 2. Original monitoring data of periodic noise

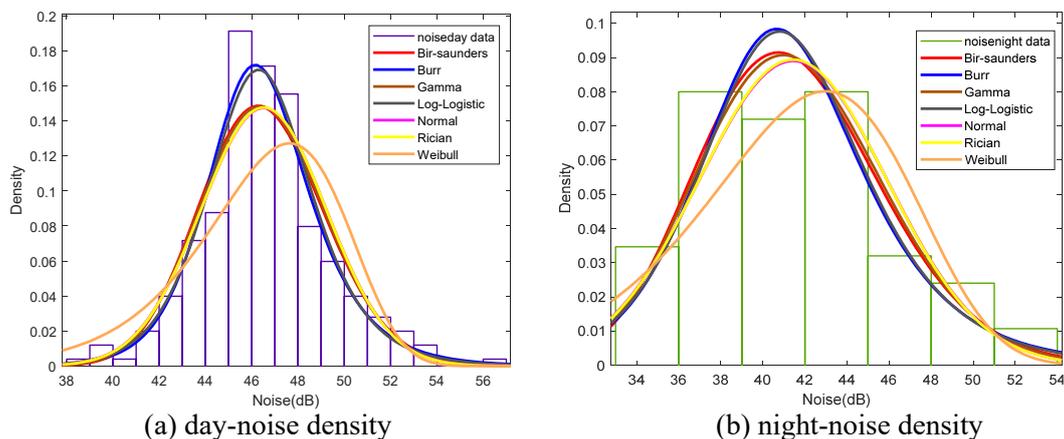


Figure 3. The density distribution of periodic day and night noise under different fitting functions

Table I shows the fitting results of different probability distribution in periodic noise data. It can be seen that the Burr function value of log likelihood has the better performance in seven distribution types. In contrast, Weibull distribution fitting is the worst. The mean value of daytime noise is 46.5173 dB and 41.4133 dB in night of Burr fitting is presented. In this case, most fitting functions perform well.

Table I. Fitting results of different probability distribution in periodic noise data

Noise type	Function (x)	Mean (dB)	Variance	Log likelihood
Day Noise	Birnbaum-Saunders	46.5124	7.26129	-604.334
	Burr	46.5173	7.40077	-600.751
	Gamma	46.5124	7.25309	-604.542
	Log-Logistic	46.4703	7.24665	-601.157
	Normal	46.5124	7.32325	-605.531
	Rician	46.5124	7.29407	-605.528
	Weibull	46.3034	11.9488	-631.832
Night Noise	Birnbaum-Saunders	41.4400	19.4958	-361.954
	Burr	41.4133	19.5083	-365.254
	Gamma	41.4400	22.5309	-365.570
	Log-Logistic	41.3864	22.3454	-365.282
	Normal	41.4400	20.0627	-364.296
	Rician	41.4400	19.9021	-364.281
	Weibull	41.2760	27.5783	-373.210

3.2. Burst noise analysis

In substation 2#, since the substation is close to the road, the noise measurement of the substation will be seriously disturbed by the honking of vehicles. In Figure 4, it can be seen that no matter in the daytime or at night, the noise curve appears obvious noise burst interference. Especially in the daytime, the number of burst noise interference is more frequent. Generally speaking, the noise at night is generally low, and the occasional noise interference is more obvious.

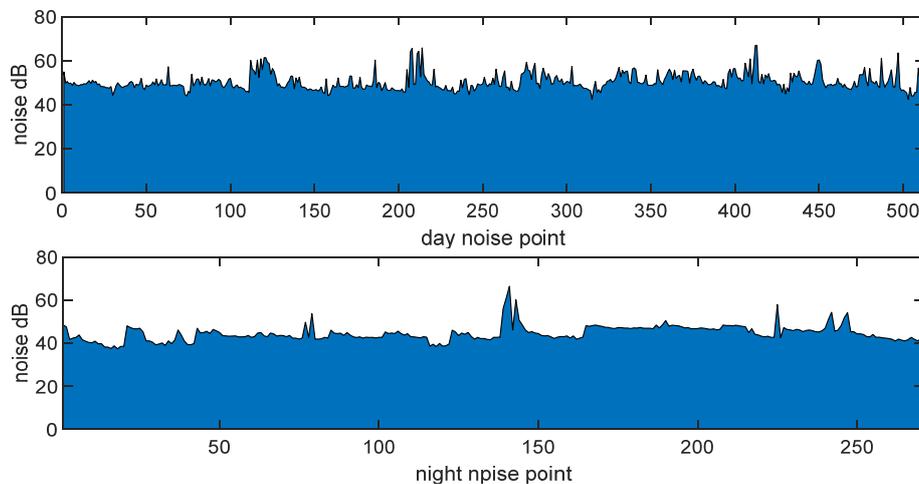


Figure 4. Original monitoring data of burst noise

Figure 5 shows the density distribution of aperiodic day and night noise under different fitting functions. From the image point of view, the fitting of noise distribution in day and night is similar, and the noise distribution probability in the mean value of noise in day is larger, while that in night is different. The fitted mean value can indicate the overall noise level to a certain extent if the variance is small. Table II shows the fitting results of different probability distribution in burst noise data. It can be seen that the Burr function value of log likelihood (-1337 in day, -705 in night) still has the better performance in seven distribution types. The mean value of daytime noise is 50.4122 dB and 44.5045 dB in night of Burr fitting is presented. In this case, Burr distribution also has good fitting characteristics.

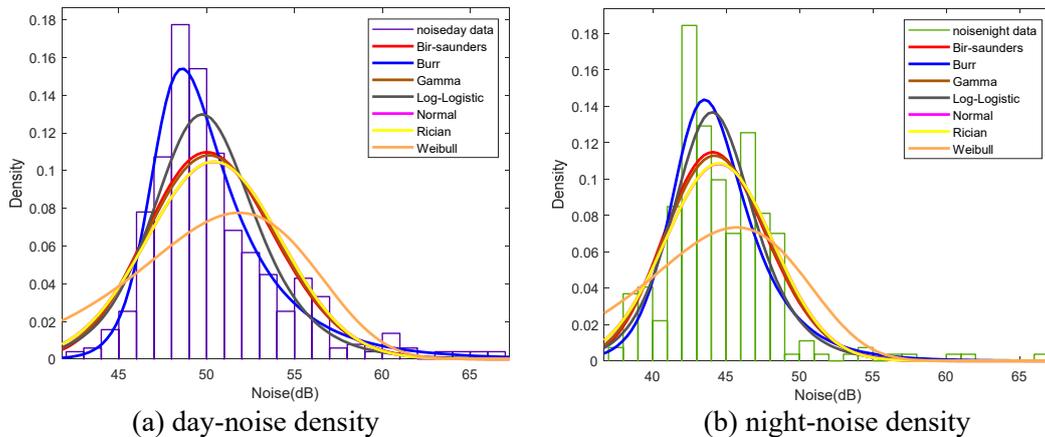


Figure 5. The density distribution of aperiodic day and night noise under different fitting functions

Table II. Fitting results of different probability distribution of burst noise data

Noise type	Function (x)	Mean (dB)	Variance	Log likelihood
Day Noise	Birbaum-Saunders	50.4045	13.3753	-1391.07
	Burr	50.4122	15.0161	-1337.83
	Gamma	50.4045	13.6831	-1398.04
	Log-Logistic	50.0164	12.3836	-1373.72
	Normal	50.4045	14.5368	-1413.98
	Rician	50.4045	14.5084	-1413.94
	Weibull	49.9451	30.2334	-1516.16
Night Noise	Birbaum-Saunders	44.5148	12.2532	-722.793
	Burr	44.5045	12.3679	-705.37
	Gamma	44.5148	12.5572	-726.814
	Log-Logistic	44.3347	11.1722	-709.027
	Normal	44.5148	13.535	-737.047
	Rician	44.5148	13.485	-737.01
	Weibull	43.8994	32.7351	-804.418

3.3. Stationary noise analysis

In substation 3#, the substation is located in the suburb, and there is no obvious noise interference source nearby. So, we increased the noise monitoring time. It can be seen from Figure 6 that the substation noise is very stable, almost no interference noise during the day and night. The baseline noise levels during the day and night are almost the same.

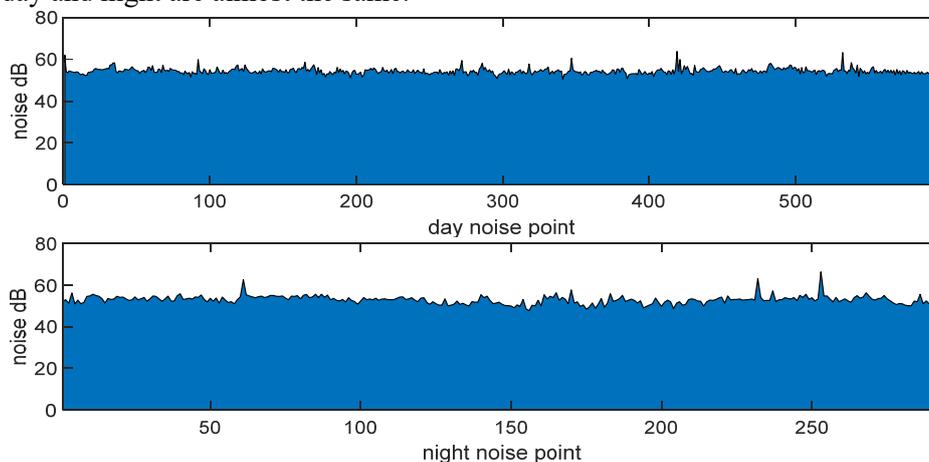


Figure 6. Original monitoring data of stationary noise

Figure 7 shows the density distribution of stationary noise at day and night under different fitting functions. Burr distribution is more significant for the probability at the mean value, while other distributions are almost the same density peak value and tail. Most of the distribution fitting are similar to normal distribution, which shows that it is reliable to evaluate noise level by using distribution fitting and given a confidence interval. Table III shows the fitting results of different probability distribution in stationary noise data. It can be seen that the Burr function value of log likelihood (-992.766 in day, -596.174 in night) still has the better performance in seven distribution types. The mean value of daytime noise is 54.3626 dB and 52.9272 dB in night of Burr fitting is presented. In this case, because the noise is relatively stable, the mean value of most distributions is same.

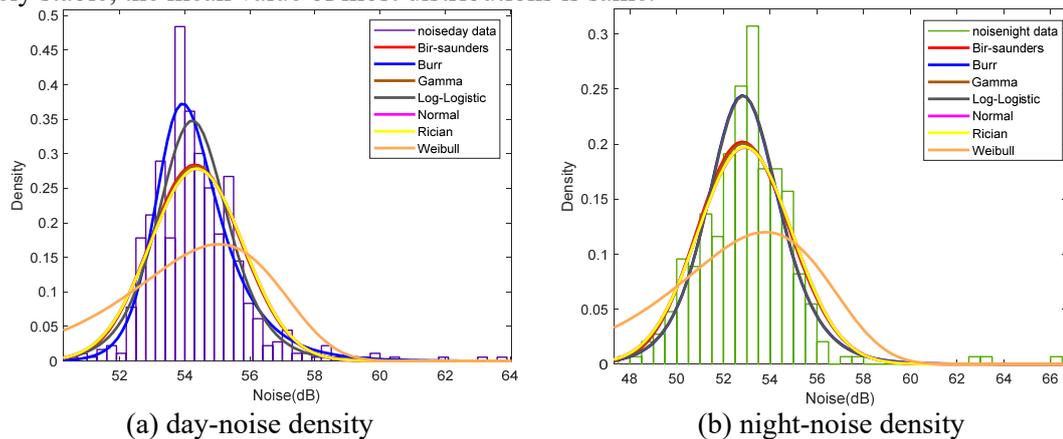


Figure 7. The density distribution of stationary day and night noise under different fitting functions

Table III. Fitting results of different probability distribution of stationary noise data

Noise type	Function (x)	Mean (dB)	Variance	Log likelihood
Day Noise	Birnbaum-Saunders	54.3643	1.97154	-1052.95
	Burr	54.3626	1.8641	-992.766
	Gamma	54.3643	1.99586	-1056.79
	Log-Logistic	54.2665	1.69932	-1010
	Normal	54.3643	2.05488	-1065.15
	Rician	54.3643	2.05144	-1065.15
	Weibull	53.9595	7.08066	-1275.32
Night Noise	Birnbaum-Saunders	52.9235	3.91146	-615.253
	Burr	52.9272	3.4914	-596.174
	Gamma	52.9235	3.96069	-617.256
	Log-Logistic	52.9177	3.46873	-596.213
	Normal	52.9235	4.10311	-622.07
	Rician	52.9236	4.08906	-622.065
	Weibull	52.3693	13.5192	-720.938

4. Conclusion

Compared with the traditional evaluation method of fixed threshold and single monitoring point, the data fitting method proposed in this paper can reflect the middle and long-term noise emission level more objectively, and support the noise evaluation of substation boundary more reasonably. We find that burr function performs best among all the noise fitting functions, whether periodic noise, burst noise or stationary noise. In the future work, we will consider how to fit the noise based on burr function in the application of noise data evaluation engineering.

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