Monitoring System of Substation Boundary Noise based on LoRa Communication Technology

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Abstract: The noise level of the substation is one of the important indicators to measure its environmental friendliness. In order to solve the wireless communication problem in the complex electromagnetic environment of the substation, this paper proposed a method of Online Noise Monitoring based on LoRa spread spectrum communication technology. The test results showed that the integrated system performed well on accurate monitoring and reliable transmission of substation boundary noise.

1. Introduction
With the rapid development of China's economy and the urbanization, the demand for social electricity consumption is increasing. The booming urban population makes the demand of electric power rise rapidly. As a result, some newly planned substations have to be located in the densely populated areas.

With the continuous improvement of living standards, people's requirements for the quality of surrounding environment are more and more stringent. However, while supplying power to the city, the substation in the central area of the city also has a certain influence on the surrounding environment----continuously producing noise. Normal life of residents will be affected by noise pollution, therefore, the excessive noise of substation become widely concerned.

The noise of transmission and transformation facilities not only brings adverse effects on the life of the surrounding residents, causes environmental disputes, but also brings legal risk to the State Grid Corp, which affects the normal construction and operation of the State Grid Corp. To reduce the impact of the noise on the environment and promote the construction of environmentally friendly substations (converter stations), the State Grid Corp is actively promoting the work of noise control in the substation.

However, noise measurement is an important basic means for noise evaluation, control and scientific research. Improving the accuracy of noise measurement, objectively and accurately reflecting the true level of noise, is very important for scientific and objective noise control.

In recent years, due to the requirements of the national environmental monitoring and development, some domestic noise equipment enterprises and scientific research units have gradually developed some outdoor noise monitoring systems, which serve in the public places, such as the city, the streets, the airport, etc. These fixed type large outdoor noise monitoring device are always complex and costly that hard to meet the requirements of micro and multi-point synchronous measurement in substation.
(converter station) scenario.

For State Grid Corp, manual measurement using hand-held instruments is the main means of substation boundary noise monitoring. However, artificial testing is easily affected by personnel quality, instrument stability, environmental conditions and etc. It is difficult to objectively and accurately reflect the true level of the long period of noise. Manual measurement cannot provide complete basic data for noise control, and that will influence the formulation and implementation of the related project. Therefore, it is necessary to carry out multi-point synchronous monitoring of substation boundary noise.

Considering the complex electromagnetic environment in substations and converter stations, LoRa technology based on spread spectrum communication is chosen as the main communication method [1-3]. For one thing, LoRa has the ability of channel interception and frequency hopping which brings a strong anti-interference ability; for another thing, the spread spectrum technology used by LoRa can accept very low signal to noise ratio, and can use very low RF power to achieve full station coverage, and reduce the interference to all the equipment in the substation.

Based on LoRa communication technology, this paper develops a continuous noise measurement system for substation scene. Using multi point synchronization monitoring, the real time analysis on the substation boundary noise is used to provide a more objective, efficient, and effective way to save the manpower and material resource. The noise monitoring system provides more accurate and scientific basic data for noise control projects, which is conducive to scientific optimization and decision-making of the governance scheme.

2. LoRa Communication Technology

LoRa is the most widely used technology for LPWAN (Low Power Wide Area Network) in the sub-GHz unlicensed band [4]. Due to the utilization of unlicensed band, LoRa network is open to customers without authorized by radio frequency regulations. Therefore, LoRa is easy to deploy and serves to customers at the cost of minimum investment and maintenance.

LoRa has made tremendous improvements to achieve the target [5]-[6]. The first one is LoRa modulation based on chirp spread spectrum (CSS) scheme that uses broadband linear frequency modulated pulses used for radar applications since the 1940’s. According to Shannon-Hartley theorem that showed as follows:

\[ C = B \lg(1 + \frac{S}{N}) \]  

(1)

Where, \( C \) is the channel capacity; \( B \) is the frequency bandwidth; \( S \) is the signal power; \( N \) is the noise power; and \( S/N \) is the signal to noise ratio;

It indicates that an increase of the transmission channel bandwidth is a way to overcome a poor SNR under a constant channel capacity.

Spreading spectrum is chosen for its inherent robustness to channel degradation mechanisms like multipath fading, Doppler-effect, and in-band jamming interference. As a result, the maximum coupling loss (MCL) for LoRa can exceed as high as 148 dB, 20dB greater than the existed sub-GHz communication which extends the coverage distance and increases the capacity of the network. LoRa modulation features six spreading factors (SF) resulting in the different data rates. This enables multiple differently spread signals to be transmitted at the same time on the same frequency channel with the adaptive data rate to the trade-off between communication qualities and distances.

The other improvement is LoRa network protocol which is optimized specifically for energy-limited sensors since for IoT networks the uplink traffic usually much exceeds the amount of downlink. Under the environment, the LoRa specification has defined three modes of different data receiving windows for different application scenarios. And the data encryption is also supported by LoRa to ensure the channel security by AES128-based public and private key pairs.

The modulation and demodulation mechanism of spread spectrum communication is shown in Fig.1. In the transmission system, user data to be transmitted are multiplied by the pseudo random sequence generated by the M sequence generator, and then transmitted to the emitter after high frequency carrier modulation and converted into electromagnetic waves through the antenna. In the receiving system, the signal can be demodulated according to the reverse operation of the modulation terminal. The sequential
logic and digital signal waveforms of each link are shown below. It can be considered that it is precisely because the M sequence has the same white noise spectrum characteristics that the LoRa signal inherits the excellent characteristics of anti-multipath fading.

Until now, LoRa has been widely tested in the demonstrations on smart meters, traffic tracking, smart appliances and smart healthcare over 56 countries [7]. The telecom operators of KPN in the Netherland and SK in Korea has deployed a LoRa network covering all over the country [8]. And LoRa Alliance with more than 300 members representing the different layers of an IoT ecosystem from chipsets, modules, devices, gateways to network and application servers is collaborating to define an open global standard for secure and carrier-grade IoT LPWAN.

3. System Architecture of Substation Boundary Noise Monitor
The substation boundary noise monitoring system is mainly composed of three parts, which includes the noise sensing system, the LoRa network communication system and the noise monitoring cloud platform.

The noise sensing system includes: capacitive microphone, spectrum analysis unit, communication and management unit, battery management module, SD card storage and so on as shown in Fig.2. Its main function is to complete the high precision sensing and acquisition of the noise signal, and analyze the sound level of the equivalent A/C/Z based on the embedded MCU, and output the spectrum analysis of the noise signal. At the same time, it responds to various instructions and parameter configuration of
cloud control platform, such as self-calibration, setting integration time, timing start stop and so on.

Figure 2. System architecture of substation boundary noise monitor

LoRa communication system includes: LoRa communication terminal and LoRa base station. The main functions are as follows: the noise signals collected by each noise terminal are sent to the LoRa base station through the LoRa communication terminal, and then further transmitted to the noise monitoring cloud platform shown in Fig.3. This part is to complete the information transmission and reliable interaction between terminal and cloud.

Figure 3. LoRa communication system architecture

The main function of the cloud monitoring platform is to monitor the noise level of the substation boundary in real time with GIS (geography information system). Through the historical data of cloud database, large data analysis including cluster analysis, correlation analysis, trend early warning and so on are carried out. The layout of the above system in substation is shown below:
Figure 4. Pilot scheme of substation boundary noise monitoring system

From the measured results, LoRa technology can transmit the noise data and local analysis results to the central node very steadily. Users can analyze and research large data based on the historical data of cloud database.

4. Conclusion

As the policy and public opinion are paying more attention to environmental problems, the power system will invest more resources in environmental problems such as noise pollution. Therefore, on-line monitoring of substation boundary noise will become an inevitable trend in the future. Aiming at the special environment of strong electromagnetic interference in substation, this paper uses LoRa technology based on spread spectrum communication to transmit the noise data in the substation. It makes full use of the characteristics of LoRa technology to resist multipath fading and flexible frequency hopping, and greatly improves the reliability of wireless communication at the expense of data rate. Finally, the system launched a pilot project in a 500kV substation, and the experiment shows that the substation boundary noise monitoring system performed a steady communication using LoRa.

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