A Noise Monitoring System Used for Substation Boundary: Part 1 -- Devices and Synchronized Measurement Method

Hou Guoyan¹, Li Shiping¹, Wang Jian²*, Lan Xinsheng³, Tang Ming², Zhou Yiqian³, Liu Tao³ and Liu Hongzhi¹
¹ State Grid SiChuan Electric Power Company, ChengDu 610041, China
² Sichuan Energy Internet Research Institute, Tsinghua University, Chengdu 610213, China
³ State Grid SiChuan Electric Power Research Institute, ChengDu 610072, China
*Corresponding author’s e-mail: jianwang16@foxmail.com

Abstract: Due to the interference of background noise, it is necessary to measure multi-point noise synchronously in the noise measurement of substation boundary. This measurement method not only increases the work intensity of measurement personnel, but also affects the reliability and accuracy of measurement data. In the long-term continuous noise monitoring task, there are still some problems, such as the data does not support online transmission, or cannot guarantee multi-point synchronous monitoring, or the standby time is insufficient. In order to solve the problem mentioned above, this paper provides a wide area synchronous noise measurement method and a continuous noise monitoring device. By deploying multiple sets of noise monitoring devices at the boundary of the substation and conducting wide area synchronous measurement, it can significantly improve the reliability of noise measurement data and improve the monitoring efficiency.

1. Introduction
Substation belongs to the power transformation link of the power grid, and plays an extremely important role in the power transmission. With the rapid development of economy and the continuous expansion of the city, some substations are in the central or densely populated area of the city. The noise generated by the operation of various electrical equipment in the substation will inevitably affect the staff, the residents nearby and the environment, especially during the peak power consumption period in summer, high load rate and serious noise are very significant.

In recent years, the residents' awareness of environmental protection and China's national environmental protection law enforcement are increasing. The environmental impact of substations, especially the substation noise, has attracted more and more attention, with the results that related complaints and disputes are increasing year by year, since 2015, the ministry of science and technology of State Grid has organized and formulated the work plan of science and technology, smart grid and environmental protection every year, requiring all provincial companies to strengthen the technical supervision of environmental protection in the whole process.

For example, carrying out noise monitoring and data filling during the operation period of substation (converter station), the number of substations (converter station) completing noise monitoring shall not be less than 25% of the total number in operation, and formulate treatment plans for substations (converter station) that are disturbed by noise exceeding the standard, so as to speed up the
implementation of treatment work.

In the aspect of substation noise analysis and measurement, scholars have done some work. In [1], an underdetermined blind source separation (UBSS) algorithm based on the sparse component analysis (SCA) was proposed to separate the mixed 220kV substation noise. In [2], a new acoustic mode of the transformers and reactors is built in ultra-high voltage substation. Using the Kirchhoff formula to solve the problem of closed cavity radiation noise with complex shapes in engineering practice in [3]. In [4], the author shared the data of a case study of noise measurement in 500kV substation of China Southern Power Grid. The sound array noise source identification and positioning method is tried to be applied in the actual substation noise test in [5-8].

However, from the actual noise measurement work, there are three main problems restricted the implementation of relevant work, such as uncertainty of noise measurement position, low efficiency of manual measurement and unreliable noise data. On the one hand, due to the measurement points selected by different personnel will also affect the accuracy of the measurement data, resulting in large noise deviation and the historical data cannot be compared vertically. On the other hand, multiple noise measurement devices cannot measure synchronously and cannot describe the noise radiation level at the same time.

In this paper, the synchronized measurement method and a feasible design of noise synchronous measurement terminal architecture is proposed. By using the technology of wide area synchronous time service (WASTS), it can ensure that multiple noise measurement terminals can perform measurement tasks synchronously, and accurately depict noise time-space section. The detailed synchronization timing mechanism is discussed. Besides, the advanced Internet of things (IoT) communication technology can ensure the data transmission reliably.

2. System Architecture and Noise Monitoring Devices

The developed noise monitoring terminal architecture is shown in Figure 1. Based on the B/S architecture, it is composed of device layer, communication layer and application layer. The communication layer is based on the mainstream internet of things communication technology, which enable the terminal monitoring data access network and ensure the reliable transmission in the complex electromagnetic environment of the substation.

The server side of noise monitoring system consists of application layer, service implementation layer and storage layer. The service implementation layer adopts various frameworks to support the system, such as Django, Nginx, Flask, Bootstrap3, Jquery, Layui, et al. The data storage layer uses MySQL database to provide data storage services. The application layer is built on the basis of the basic service layer to map out the specific application functions of the information platform. In addition, the application layer realizes data visualization, and enables multi-user web access to data and view real-time data and analysis results by authorized operation. Because of B/S architecture, it unifies the client, centralizes the core part of the system function to the server, and simplifies the development, maintenance and use of the system. Therefore, users only need a browser to access the noise data.

Narrow band internet of things, NB-IoT, is used as the data transmission mode in the noise continuous monitoring architecture mentioned in this paper. NB-IoT occupies a very narrow bandwidth, only needs about 180 kHz, and uses the license band. It can be directly deployed in the GSM, UMTS or LTE network, i.e. 2/3/4 G network, taking advantage of the advantages of multiplexing with the existing network, so as to reduce the deployment cost and upgrade smoothly. The noise monitoring device directly uploads the data to the NB-IoT base station to improve the transmission efficiency.
Figure 1. Structure diagram of noise monitoring system at substation boundary

Figure 2 shows the components of each module inside the noise monitoring device. The device layer adopts the latest embedded processor (MCU) and the sound level meter with class I accuracy to monitor the original noise. The uplink data to the server mainly includes the equivalent sound level, 1/3 octave band noise data, station information, equipment status, calibration and electricity quantity and so on. GPS is used for positioning and wide area timing of each noise monitoring point to ensure the synchronization of monitoring time. The noise measurement device is powered by 3.7 V lithium-ion battery, which can guarantee the normal operation of the equipment for up to 15 days. Figure 3 shows the noise monitoring device prototype appearance. In order to adapt to the complex environment of field installation and deployment, there are two types of devices mounting models, plane and convex, respectively.

Figure 2. Schematic diagram of internal modules of noise monitoring device
3. Synchronized Noise Measurement Method

In a wide area synchronous measurement system composed of multiple noise monitoring devices, the running time of each measuring terminal must be the same. In the actual measurement work, each noise measurement terminal usually works independently, which cannot guarantee to measure the real noise and eliminate the background interference noise in strict synchronization time. Therefore, it is very important to ensure that each terminal performs the measurement task in a unified measurement sequence and accurately depicts the noise emission level at the same time.

In fact, the continuous noise measurement task can be further subdivided into many steps. Depending on the measurement period, it can be divided into periodic and repetitive noise measurement sub steps. In the wide area noise synchronous measurement system, each noise monitoring device will perform each noise measurement sub step in turn and automatically according to a synchronization time. The decoupling of noise measurement tasks is shown in Figure 4.

The synchronization time is generated by an accumulator with the minimum time unit (ms), and used to keep the system synchronized by using the accumulated value of the accumulator. In addition, the
synchronization time also obtains the wide area timing information periodically. It calibrates and updates the value of the accumulator according to the time value extracted from the timing information. The flow chart of synchronous measurement method is shown in Figure 5. The method includes the following steps.

Figure 5. The schematic diagram of noise measurement task decoupling

**Step 1:** Initialize the synchronization time in milliseconds. The system timer and synchronization time are built. When the timing arrives, the synchronization time performs the auto increment 1 operation.

**Step 2:** Set a synchronization period and acquire the time of wide area timing periodically. When the value of the synchronization time is an integral multiple of the value of the synchronization period, the wide area timing information is read, and the wide area timing time is parsed out from it. Positioning and timing information is obtained by GPS module.

**Step 3:** In the synchronization cycle, it will calibrate and update the system synchronization time according to the obtained wide area time service time.

**Step 4:** The noise continuous measurement process is decoupled into four sub steps, such as, startup step, measuring step, measurement duration step and task stop step. And the corresponding sub steps are matched according to the synchronous time. In detail, it includes the following steps.

**Step 4-1:** Startup step. This sub step is the first step. When the synchronization time is calibrated for the first time, it will check whether the synchronization time is the preset measurement time for the noise devices startup. If it is, the process goes to the **Step 4-2**; otherwise, it will wait until the time arrives.

**Step 4-2:** Measuring step. In this sub step, it is detected whether the synchronization time reaches the periodic measurement point. It will continuously measure the noise according to the preset measurement duration parameters.

**Step 4-3:** Measuring duration step. Ending this noise measurement after the preset measurement duration is reached, and perform the next step.

**Step 4-4:** Task stop step. Checking whether the synchronization time is the preset end measurement task time. If not, it will repeat **Step 4-2** after the end of the current measurement cycle period and start a new noise period measurement task when the next measurement cycle period starts. When the preset stop time of noise measurement is reached, all measurement tasks are killed and exited.
Table I. Synchronized noise measurement algorithm

| Input: | \([\text{sStartTime}_d, \text{sStartTime}_h, \text{sStartTime}_m, \text{sStartTime}_s], \)  
|        | \([\text{sStopTime}_d, \text{sStopTime}_h, \text{sStopTime}_m, \text{sStopTime}_s], \)  
|        | \([\text{Duration}_h, \text{Duration}_m, \text{Duration}_s], \)  
|        | \([\text{Period}_h, \text{Period}_m, \text{Period}_s]\); |
| Parameters: | \([\text{Hour}, \text{Min}, \text{Sec}], \text{sStartTime}, \text{sStopTime}, \text{Duration}, \text{Period}\), \ INT \ N, \ INT \ M ; |
| Callback: | \text{Restart}[\text{val}], \text{ParseGlobalTimeInfo}[\text{val}], \text{Cacul}[\text{val}], \text{MeasureData}[\text{val}], \text{Exit}[\text{val}] |
| Run: | \text{WHILE}(\text{True}) |
| Step1: | IF SysmsTimerout THEN  
|        | \text{SyncTime}++;  
|        | \text{Restart}[\text{SysmsTimer}]; |
| Step2: | IF \text{SyncTime} = N * \text{SyncPeriod} THEN  
|        | \text{ReadGlobalTimeInfo};  
|        | \text{[Hour,Min,Sec]} = \text{ParseGlobalTimeInfo}[\text{GPS}]; |
| Step3: | IF \text{ParseDone} ? \text{True} : \text{False} THEN  
|        | \text{SyncTime} = \text{Update}[\text{Hour,Min,Sec}];  
| Step4: | \text{sStartTime} = \text{cacul}[\text{sStartTime}_d, \text{sStartTime}_h, \text{sStartTime}_m, \text{sStartTime}_s];  
|        | \text{sStopTime} = \text{cacul}[\text{sStopTime}_d, \text{sStopTime}_h, \text{sStopTime}_m, \text{sStopTime}_s];  
|        | \text{Period} = \text{cacul}[\text{Period}_h, \text{Period}_m, \text{Period}_s];  
|        | IF \text{SyncTime} >= \text{sStartTime} THEN  
|        | IF \text{SyncTime} = M * \text{Period} THEN  
|        | \text{MeasureData}[\text{Duration}_h, \text{Duration}_m, \text{Duration}_s];  
|        | IF \text{SyncTime} >= \text{sStopTime} THEN  
|        | \text{Exit}[\text{ALL}]; |

Table I shows the synchronized noise measurement algorithm. The input parameters mainly include \text{SyncStartTime}, \text{SyncStopTime}, \text{DurationTime}, and \text{PeriodTime}. Among them, taking the \text{SyncStartTime} parameters for example, the specific parameters of \text{SyncStartTime} at the first start-up measurement time are \text{sStartTime}_d, \text{sStartTime}_h, \text{sStartTime}_m, and \text{sStartTime}_s, which means the noise monitoring equipment does not enable the periodic noise measurement function until \text{SyncStartTime} is arrived.

4. Conclusion
The ideal noise monitoring equipment should be able to ensure the extremely convenient measurement process, extremely efficient measurement, accurate and reliable data, and has the functions of light weight, portable, wireless transmission, no external power supply, online real-time observation and common analysis of noise data, et, al. Compared with the noise monitoring equipment already in service, the noise continuous monitoring device designed in this paper has the obvious characteristics of light weight, convenient, wireless and wide area synchronous measurement. At the same time, the wide area synchronous measurement method can be further extended to other systems that need synchronous measurement to achieve more intelligent wide area synchronization.

References
[1] Liu H, Zou L, Wu J, et al. Underdetermined blind source separation algorithm of 220kV substation noise based on SCA[C]// 2016 IEEE International Conference on High Voltage Engineering and Application (ICHVE). IEEE, 2016.
[2] Jingzhu H, Dichen L, Qingfen L, et al. Analysis of substation noise prediction based on equivalent source method[C]// Power & Energy Engineering Conference (PEEC). IEEE, 2015.
[3] Lusheng X, Fengqiang G, Shan H, et al. Application of Kirchhoff formula in prediction of noise level of substation[C]// Anti-counterfeiting, Security, and Identification (ASID), IEEE, 2017.
[4] Hualing L, Li L, Kai Z, et al. A case study of noise pollution and its control in an Eco-friendly 500 kV substation[C]// Power System Technology (POWERCON), IEEE, 2018.
[5] Xuan C, Yong C, Xuelei Z, et al. Research on Noise Source Location of 110KV Outdoor Substation Based on Acoustic Array[C]// International Conference on Automation, Electronics and Electrical Engineering (AUTEEE), IEEE, 2018.
[6] Kun Z, Bin L. Sound source localization system based on microphone array[J]. Machinery & Electronics, vol. 35, no. 10, pp. 26-30, 2017.

[7] Thomas T, Sgard F, Doutres O, et al. Acoustic source localization using a polyhedral microphone array and an improved generalized cross-correlation technique[J]. Journal of Sound & Vibration, vol. 386, pp. 82-99, 2017.

[8] Chunzhen S, Enli C, Shaopu Y, et al. Experimental study on vehicle noise source identification based on acoustic array technology[J]. Journal of Vibration and Shock, vol. 28, no. 6, pp. 171-174, 2009.