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The power grid monitoring promotion of Liaoning December 14th accident

Zhi Zhou¹, Ziji Gao, Xiaoyang He, Tie Li, Xiaoming Jin, Mingkai Wang, Zhi Qu and Chenguang Sun
State Grid Liaoning Electric Power Co., Ltd., Shenyang 110006, China.
¹zhouzhi12321@163.com

Abstract. This paper introduces the main responsibilities of power grid monitoring and the accident of Liaoning Power Grid 500kV Xujia transformer substation at December 14th, 2016. This paper analyzes the problems exposed in this accident from the aspects of abnormal information judgment, fault information collection, auxiliary video monitoring, online monitoring of substation equipment, puts forward the corresponding improvement methods and summarizes the methods of improving the professional level of power grid equipment monitoring.

1. Introduction
With the full completion of "Large Operation" of State Grid Corporation of China, the intensification of human resources, finance and material resources has become an inevitable trend of development. Monitoring information in substations is uniformly linked up to dispatching and control center, dispatching and control center monitors need to handle accident, abnormality, over limit and deflection information which is required within the monitoring area, power grid equipment monitoring work is facing a completely new working model. Therefore, it is urgent to ensure the safe operation of power grid equipment and improve the professional working ability of monitoring profession.

In recent years, the research on power grid real-time monitoring service mostly focuses on the optimization of monitoring system information[1-4]. When substations occur a wide range of accidents, the reliability of dispatching monitor system will reduce, monitors need to adopt other methods to monitor power grid equipment multi-dimensionally, combine equipment operation conditions with the abnormal information, use intelligent algorithms to judge the equipment failure[5-7]. The method of dealing with large-scale accidents in power grid and the suggestions for power grid dispatching management are studied in literature[8,9], but research on the impact of large faults caused by power transmission and transformation equipment is devoid.

The tank of the high voltage reactor of 500kV Xujia substation Feng-Xu Line #1 burst at December 14th, 2016. The blackout of 500kV system of Xujia substation was caused by the accident. This paper analyzes the problems exposed in this accident from the aspects of power grid equipment monitoring, puts forward the corresponding improvement methods, and summarizes the methods of improving the professional level of power grid equipment monitoring.
2. “12.14” Accident profile

Xujia substation is located in the northeast of power grid of Liaoning province, it is an important hub substation in Liaoning Province. Xujia substation is connected with Jilin power grid through Feng-Xu Line #1 and Feng-Xu Line #2 which are important link lines between provinces as shown in Figure 1.

![Diagram of 500kV system of Xujia substation](image)

**Figure 1.** 500kV system diagram of Xujia substation.

At 14:31 December 14th, 2016, The tank of the high voltage reactor of the B phase of 500kV Xujia substation Feng-Xu Line #1 burst and oil injected acutely with the fire broken out. Meanwhile, Feng-Xu Line #1, Feng-Xu Line #2, 500kV Bus Ⅰ and 500 kV Bus Ⅱ tripped sequentially. The accident caused 500kV power system of Xujia substation to shut down, and the blackout range was large. During the accident, effective accident alarm information shown in the power grid monitoring system is shown in Table 1.

| Serial Number | Fault Information                                                                 |  |
|---------------|------------------------------------------------------------------------------------|---|
| 1             | Xujia substation /500kV Feng-Xu Line #1/ The first set of protection/ Main protection action |  |
| 2             | Xujia/500kV Feng-Xu Line #1/ The second set of protection/ Main protection action   |  |
| 3             | Xujia substation /500kV Feng-Xu Line #1 reactor/ Ontology protection /Heavy gas protection action |  |
| 4             | Xujia substation :500kV Feng-Xu Line #1 reactor/ The second set of protection / Differential protection action |  |
| 5             | Xujia substation /500kV Feng-Xu Line #1 reactor/ The first set of protection / Differential protection action |  |
| 6             | Xujia substation /500kV 3rd string /5031 switch/opening                           |  |
| 7             | Xujia substation /500kV 3rd string /5032 switch/opening                           |  |
| 8             | Xujia substation /500kV Feng-Xu Line #2/ The first set of protection/ Main protection action |  |
| 9             | Xujia substation /500kV 4th string /5041 switch/opening                          |  |
| 10            | Xujia substation /500kV 4th string /5042 switch/opening                          |  |
| 11            | Xujia substation /500kV 4th string /5041 protection /Reclosing action            |  |
| 12            | Xujia substation /500kV 4th string /5041 with closing                          |  |
| 13            | Xujia substation /500kV Feng-Xu Line #2/ The first set of protection/ Accelerated protection action |  |
| 14            | Xujia substation /500kV Feng-Xu Line #2/ The second set of protection/ Accelerated protection action |  |
| 15            | Xujia substation /500kV 4th string/5041 switch/opening                          |  |
| 16            | Xujia substation /500kV 1 bus/The first set of protection/ Differential protection action |  |
| 17            | Xujia substation /500kV 1 bus/The second set of protection/ Differential protection action |  |
| 18            | Xujia substation /500kV 1st string /5011 switch/opening |  |
| 19            | Xujia substation /500kV 2nd string /5021 switch/opening                          |  |
| 20            | Xujia substation /500kV 5th string /5052 switch/opening                          |  |
| 21            | Xujia substation /500kV Ⅱ bus/The first set of protection/ Failure protection action |  |
| 22            | Xujia substation /500kV Ⅱ bus/The second set of protection/ Failure protection action |  |
| 23            | Xujia substation /500kV 1st string /5013 switch/opening                          |  |
| 24            | Xujia substation /500kV 2nd string /5023 switch/opening                          |  |
| 25            | Xujia substation /500kV 3rd string /5033 switch/opening                          |  |
| 26            | Xujia substation /500kV 4th string /5043 switch/opening                          |  |
| 27            | Xujia substation /500kV 5th string /5053 switch/opening                          |  |

Table 1. Effective accident alarm information of "12.14" accident.
Technical support system for Liaoning smart grid dispatching (hereinafter referred to as the monitoring system) and auxiliary video monitoring system about Xujia substation are broken down at 14:38. After the station using electricity restored, the monitoring system about Xujia substation has been recovered at 15:37 (But the 500kV remote control function had not been recovered, so the 500kV operation is carried out locally), the auxiliary video monitoring system about Xujia substation was recovered at 15:50.

3. Problems exposed from 12.14 accident

3.1. Some frequent abnormal alarm information was not paid enough attention to
In the power grid equipment monitoring work, there is often some alarm information that can be automatically reset after action, the alarm information is often ignored by the monitors.

The information of "Xujia substation 500kV Feng-Xu Line #1 reactor light gas relay protection action/non-electricity protection device alarm and lock "appeared 5 times on the monitoring system during 9:33 to 14:31, This signal had not been paid much attention by the monitor on duty. The monitors only notified the field operation and maintenance personnel to check the equipment. Field operation personnel found that the gas in the B phase reactor of Feng-Xu Line #1 was nonflammable and told the result to monitors on duty, the duty monitor did not take immediate action. The monitor informed the field operation personnel to contact the maintenance personnel and oil samples were further tested to confirm if the equipment could continue to run. Reactor failure occurred in the process of oil sampling test by waiting personnel.

During the operation of transformer (reactor), light gas alarm occurs frequently, part of which is false alarm. In order to avoid the transformer (reactor) mistakenly shutdown, so the analysis and confirmation of light gas alarm process is long. But this accident exposes that light gas action may soon develop into serious fault, especially in the analysis and confirmation process, when there are personnel working in the surrounding, and that may cause personal injury.

3.2. The auxiliary monitoring means of field equipment was single
During the "12.14" accident, the monitors only relied on the alarm information of the monitoring system to judge the fault of the equipment on the spot, lacked monitoring means for the change of equipment operating conditions. When the alarm information occurred, the equipment may be seriously damaged, that caused the monitor cannot judge the equipment condition. At the same time, the reactor tank burst, caused the cable loss, power loss of station using electricity that made Xujia substation signals on the monitoring system interrupted and monitors lose surveillance of Xujia substation. The monitors on duty could not have a grasp of the operation condition of equipment and the degree of fault development.

3.3. The amount of alarm information was large when the accident occurred
When the accident occurred, the amount of alarm information was large, which affected the collection and analysis of fault information by monitors. A large amount of alarm information was poured into the monitoring system during the accident. Liaoning Dispatching and Control Center received nearly 300 kinds of alarm information just in 5 minutes, nearly one hundred kinds of alarm information produced was useless such as accompanying information and total accident information when the circuit breaker was switched off, it seriously interfered with the fault information collection and accident judgment of the monitor and had a serious impact on the accident treatment of the power grid.

3.4. Unstable auxiliary video monitoring system
At present, the video monitoring system produced by Easion Technologies Inc. is used in Liaoning power grid for remote monitoring 500kV substations. The video terminal and cameras need the station using electricity to keep running. If the station using electricity loss, power cable burning and other
circumstances happen, signals of the auxiliary video monitoring system will disappear and the monitors cannot monitor the actual situation of the substation through the video monitoring system. When the "12.14" accident happened, about 100 cables such as power cables, control cables, DC power cables and so on, were all burnt out, that directly influenced on power supply of video monitoring terminal and cameras and signals of Xujia substation in the auxiliary video monitoring system disappeared. During the time, the monitors could not monitor the actual situation of Xujia substation and peripheral equipment damage through the video monitoring system.

4. Solution

4.1. Paying attention to frequent abnormal alarm information

According to the principle of typical monitoring information processing management issued by the National Dispatching and Control Center, the disposal principle of frequent alarm information is analyzed. Combined with the actual situation of Liaoning power grid, we suggest paying high attention to frequent alarm information, once it is found it should be dealt with immediately and if necessary, in the case of conditions permitted, power failure disposal should be taken. Particularly the frequent alarm information such as light gas alarm, When the transformer and reactor with light gas alarm happened satisfy N-1 condition, the transformer and reactor can be stopped first, then analyze and judge whether the information is false, thus the transformer and reactor burst, fire and other serious faults can be effectively avoid.

4.2. Optimizing information and improving efficiency

The traditional alarm information of power grid monitoring system adopts the way of time sequence, All the information is displayed one by one in chronological order at the alarm window, that makes the monitoring personnel must judge the importance of signals from a large number of complex signals, and that makes monitors to work heavily and prone to mistakes. This paper proposes a method to optimize the monitoring information to improve the monitoring efficiency of the monitoring work, so as to improve the speed of accident processing and ensure the safety of the power grid, which is shown in Figure 2 and Figure 3.

![Logic flowchart of alarm folding processing](image1)

**Figure 2.** Flowchart of alarm folding processing.

![Flowchart of delayed uploading function of interferential alarm information](image2)

**Figure 3.** Flowchart of delayed uploading function of interferential alarm information.
At present, all the information of 500kV substations in Liaoning province has access to the monitoring system, including accident, abnormality, over limit and switching information, monitor information processing capacity is great. This includes a lot of frequent information, including frequent information of old equipment, frequent information of circuit breaker operation and frequent information of equipment repair and debugging. Liaoning Dispatching and Control Center research countermeasures to solve the problem, develops the function of frequent alarm information folding display and interferential alarm information delayed uploading. At the same time, monitors place "Jianxiu" label on maintenance equipment timely. The above measures effectively reduce the frequent interferential information.

After optimizing the monitoring information, the monitoring efficiency of the alarm information of the monitoring system increases from 13.71% to 85.78%, that greatly improves the work efficiency of the monitors. Some equations are defined as follows:

\[ me = \frac{e}{t} \times 100\% \]  
\[ t = e + i \]  
\[ i = f + in + fa \]

where: \( me \) means monitoring efficiency; \( e \) means effective alarm information quantity; \( t \) means total amount of monitoring alarm information; \( i \) means invalid alarm information quantity; \( f \) means frequent alarm information quantity; \( in \) means interferential alarm information quantity; \( fa \) means false alarm information quantity.

4.3. Monitoring power grid equipment multi-dimensionally

Power transmission and transformation equipment status online monitoring system as an important auxiliary method of daily work of monitors should play a role in daily monitoring work. For better application, State Grid Liaoning Dispatching and Control Center has integrated the power transmission and transformation equipment status online monitoring system into the monitoring system, to ensure that detailed operating condition information of the power transformation equipment (including oil-containing equipment) can be provided by the system, specific monitoring content and parameters are shown in Table 2.

**Table 2. Online monitoring content of transformation equipment.**

| Online monitoring device | Monitoring parameters                                      | Detection defect                        |
|--------------------------|-----------------------------------------------------------|----------------------------------------|
| Dissolved gas in oil     | 7 characteristic gas content + relative / absolute gas production rate | Internal overheating / discharge / iron core multipoint grounding / damp |
| moisture in oil          | Micro-water                                               | Damp / overheat                         |
| partial discharge        | Local discharge and discharge spectrum                   | Partial discharge                       |
| Iron core grounding current | Iron core current value                                     | Iron core multipoint grounding          |
| Top oil temperature      | Top oil temperature                                       | Overheat                                |

The system also provides the assistant decision for the monitors. Monitors can judge the light gas alarm signal is false or real signal of oil equipment fault through the real-time data change of the non-electric quantity and the operating condition information of equipment under the normal state. At the
same time, in order to ensure the availability of the system, we put forward the management index for the use of the system, the specific indicators are as follows:

\[
\text{Annual availability} = \frac{\text{Total operating time} - \text{Cumulative fault time}}{\text{Total operating time}} \times 100\%
\]  

(4)

- The annual availability of data processing and storage applications is not less than 99.9%.
- The annual availability of alarm processing function is not less than 99.9%.
- The annual availability of fault diagnosis and other advanced application functions are not less than 99.5%.

### 4.4. Improving the stability of auxiliary video monitoring system

To solve the problem of the auxiliary video monitoring system running unstable and signal disappearing easily, we add UPS power supply into the system and improve the reliability of it. The above solutions ensure that the monitors can monitor the real-time picture of the substation during the fault, and provide effective help for accident treatment.

To strengthen the operation and management of the auxiliary video monitoring system, improve the reliability of equipment operation, Liaoning Electric Dispatching and Control Center cooperate with Easion Technologies Inc. to develop the real-time feedback system of substation server operating condition based on the production assistant integrated monitoring platform, the real-time monitoring of video terminal is realized.

### 5. Conclusion

The lesson learned from "12.14" accident in Xujia substation, has a great significance on the working ability promotion of power grid equipment monitoring. Power grid equipment monitoring should not only rely on the alarm information of the monitoring system, but also rely on auxiliary monitoring platforms such as the online monitoring system of power transmission and transformation and the auxiliary video monitoring system. In the monitoring process of power grid equipment operation, frequent information should be paid much attention to, the common misinformation should be vigilant and not subjective, and a variety of technical means should be relied on for objective analysis and judgment. At the same time, we must constantly improve the function of existing monitoring platforms, and apply advanced artificial intelligence technology to the power grid equipment monitoring business, so as to improve the monitoring efficiency of monitors, reduce labor costs, and ensure the safety of power grid equipment monitoring.

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