Planning and Design of Secondary Monitoring System

X Y Tong¹, K Li¹, K M Sun¹, H Wu², X Wang¹ and G H Zhang¹

¹State Grid Shandong Electric Power Research Institute, Jinan, China
²State Grid Jinan Power Supply Company

Abstract. The current safe and stable operation of the power grid is highly dependent on secondary systems such as protection, security control, decommissioning / load shedding, automation, and communications. Compared with the means of primary grid monitoring, analysis, and control technology (EMS), the construction of secondary system monitoring, analysis, and control technical means (SMS) is lagging behind and cannot fully meet the needs of the secondary system itself and the safe and stable operation of the power grid, which has become a short board that restricts the development of power grid regulation and control business. The secondary system bears the important responsibility of monitoring, protecting and controlling the primary equipment. Once an important secondary system such as the three lines of defense of the power system and the dispatch automation master station are abnormal, it will pose a serious threat to the safe and stable operation of the power system and may lead to an increase in the scope of the failure or even a large-scale power outage. The construction background, ideas, goals, and overall architecture of the secondary monitoring system are described, and the system functions and typical scenarios are displayed to provide a reference for related research and construction work.

1. Introduction

In recent years, with the continuous expansion of the scale of the power grid, mixed operation of UHV AC and DC, large-scale centralized access of new energy, the characteristics of the power grid have changed from regional mode to global mode, the power grid has gradually developed into an interconnected whole, and the ability to optimize the allocation of power grid resources has significantly improved, the characteristics of power grid integration are even more prominent. How to ensure the safe and high-quality operation of a large power grid is the most fundamental issue for power grid regulation operation and management [1].

At this stage, with the rapid development of electric power dispatching communication networks and computer information technology, the gradual establishment of the safety protection system for electric power secondary systems, the accelerated implementation of smart substations, the degree of power grid regulation operation and management rely on secondary equipment and systems (protection, security control, automation, network security, communication) is continuous improving. The secondary system bears the important responsibility of monitoring, protecting and controlling the primary equipment. Once an important secondary system such as the three lines of defense of the power system and the dispatch automation master station are abnormal, it will pose a serious threat to the safe and stable operation of the power system and may lead to an increase in the scope of the
failure or even a large-scale power outage [2]. As the first line of defense of the power system, the relay protection status and performance are critical to the safe and stable operation of large power grids [3]. The “2 · 4” blackout in the Brazilian power grid was due to an abnormality in the failure protection that was not detected and eliminated in time, which caused the operator to expand the accident after operation and eventually caused the northeast Brazil power grid to collapse. In China, two sets of main protection of the line have been lost due to abnormal communication power. Due to the timely and correct disposal, the occurrence of power grid accidents has been avoided. There has been a failure of the switch of the dispatch automation master station system, which caused the master station real-time monitoring (SCADA) and control (AGC / AVC) functions to withdraw from operation in a short time, which affected the adjustment of regional operation modes and automatic adjustment of frequency and voltage. With the continuous increase of the number of secondary system equipment, the operation mode is intricate and complicated, any abnormality of the secondary system equipment may cause a chain reaction of the primary equipment. The existing secondary system operation monitoring method [4] cannot meet the needs of integrated operation of large power grids, nor can it support the long-term safe and stable operation of the large power grid, which is mainly manifested in the following aspects: The secondary system monitoring, analysis, and control technology lacks a unified architecture, incomplete information collection, insufficient integrated analysis functions, and lack of mining of a large amount of historical operating data. It cannot fully meet the needs of real-time operation monitoring, analysis, and early warning of the secondary system, nor can it meet the needs of the life cycle assessment and management of the secondary system.

In response to the above problems, the research and construction of the secondary monitoring system [5] (SMS) is carried out, explaining the secondary monitoring system from three aspects of the construction goals (construction ideas, construction effects), the overall architecture (main station architecture, station end architecture, system deployment method), system functions and typical scenarios. With a view to providing references for related research and construction.

2. Construction ideas and goals

Construction of a secondary monitoring system based on the integrated modeling and comprehensive collection of operation information of secondary equipment such as protection, security control, decommissioning / load reduction, automation, communication, and network security. Realize secondary system real-time monitoring, comprehensive alarm, online analysis, remote control and evaluation management, support grid dispatch operation and secondary system on duty monitoring, improve secondary system management efficiency, and provide reliable guarantee for the safe and stable operation of large power grids.

The functions of the secondary monitoring system include the functions of being able to serve the dispatcher and secondary watchkeepers directly or after being perfected in business applications such as protection, security control, automation, communication, and network security, as well as integrated monitoring, alarm, analysis, and early warning application functions based on the unified monitoring of the secondary system [6] model, jointly supporting grid dispatch operation and secondary system on-duty monitoring. Schematic diagram of construction ideas of SMS is shown in figure 1.
The secondary monitoring system aims to strengthen the collection of information such as the operating status, strategy, and setting values of the secondary system, and improve the sensing ability of the secondary system [7]. To realize the integrated monitoring, analysis, and early warning functions of the secondary system. To dig deeper into the value of the data and improve secondary system operation management level.

As is shown in figure 2, the construction of the secondary monitoring system does not change the existing business processes, and the operation status of secondary equipment such as protection, security control, automation, and communication is still performed by the substation operators, power plant operators on duty, and the dispatch secondary professional on duty in real time and reports to the dispatcher in time when there is an abnormality. By constructing a secondary monitoring system, the important information of the secondary system can be pushed to the dispatcher in real time.

**Figure 1.** Schematic diagram of construction ideas of SMS

**Figure 2.** Construction renderings of SMS

Construction effect of secondary monitoring system:
2.1. Fast perception
The existing business process uses a manual reporting mechanism. Substation centralized monitoring
watchkeepers, power plant watchkeepers, secondary system (communication, automation, network
security) watchkeepers or subordinate dispatchers find abnormalities and report them by phone after
analysis and judgment, which is poor timeliness. The secondary monitoring system is
comprehensively analyzed and judged by the program, and is pushed in real time to the dispatchers
and secondary duty personnel to improve the efficiency of power grid dispatching operation and
disposal.

2.2. Comprehensive information collection and correlation analysis
Existing systems have incomplete collection of information about the operating status, strategies, and
settings of secondary equipment. The secondary monitoring system achieves comprehensive collection
and correlation analysis of the above-mentioned various types of information, and the staff on duty can
quickly locate the cause of the fault and command processing.

2.3. Risk early warning
Existing business processes mainly deal with the rapid disposal after a fault occurs [8]. The scan and
analysis of the weak links of the secondary system under normal operation of the power grid have not
been implemented, and risk early warning and pre-control cannot be achieved.

3. Overall architecture

3.1. Master station architecture
The master station part of the secondary monitoring system brings together the protection, automation,
security control, and communication professional data information of the dispatch automation system,
the dispatch data network management system, the network security management platform, the
dispatch and control cloud [9], the communication TMS system, and the station-side platform system.
Receive the master station automation operation information, protection equipment key information,
security control / decommissioning / load reduction equipment key information, substation automation
operation information, etc. Perform model data, operation data, and real-time data interaction with the
dispatch and control cloud horizontally. Receive communication channel status from communication
TMS system, and Collect down-site operation information of station end, secondary system
configuration information, etc. The master station architecture is shown in figure 3.
3.2. Station-side architecture

The station-side architecture is shown in figure 4. The operating status, strategies, and settings of various secondary equipment in the station are connected to the telecontrol device through the station control layer network and sent to the master station. The communication between the secondary equipment and the telecontrol device is recommended to use the IEC61850 protocol [10], and the communication between the telecontrol device and the master station is recommended to use protocols such as 104 and GSP.

![Figure 3. Master station architecture diagram](image)

![Figure 4. Station-side architecture diagram](image)
Protection sends key information such as action events, device status and monitoring data, device pressure plate and function pressure plate, and settings. Security control sends key information such as action events, device status and monitoring data, device pressure plate and function pressure plate, settings, and strategies. Decommissioning / load reduction upload and send action events, device status and monitoring data, device pressure plate and function pressure plate, settings and other key information. Automation sends key information such as device status and monitoring data, equipment communication status, network status, server, workstation, network equipment, security protection equipment, database, etc. Cyber security sends important cyber security incidents.

3.3. System deployment method
The secondary monitoring system (SMS) is deployed at four levels: national, branch, provincial, and local. Horizontally synchronize the unified secondary model from the dispatch and control cloud, obtain real-time data from business systems and stations, and perform synchronous operation data to the dispatch and control cloud, functions such as demonstration, analysis and training simulation are carried out on the cloud. Vertically realize real-time sharing of secondary equipment information between control centers, as is shown in figure 5.

Figure 5. System deployment diagram
4. System functions and typical scenarios

4.1. Main functions

![Secondary monitoring system (SMS)](image)

**Figure 6.** Schematic diagram of main functions

As shown in figure 6, the SMS master station completes the unified modeling, collection, monitoring, and alarming of the secondary equipment, realizes the global comprehensive analysis of the secondary system, and can support remote control of the secondary equipment. The SMS master station data is synchronized to the dispatch and control cloud for panoramic display, analysis, mining and evaluation of the data. The station end complete the data collection of various secondary equipment, and provide remote maintenance and access means.

4.2. Typical scenarios

Fully consider the secondary system risk points, and combine the actual work needs of dispatchers and monitors to classify from the four aspects of real-time monitoring, comprehensive alarm, risk early warning, and remote control and propose typical scenarios for secondary monitoring systems.

4.2.1. Typical scenario 1. Dispatcher-oriented secondary system panoramic monitoring (real-time monitoring).

Through visualization technology, the important abnormal operating status of the secondary system is superimposed on the primary grid diagram of the power grid to achieve panoramic monitoring of the integration of primary and secondary equipment, quickly locate faults and impact ranges, and provide integrated real-time monitoring of the entire process. When a secondary system failure seriously affects the operation of the power grid, the secondary monitoring system actively pushes the corresponding fault information, and the specific faulty equipment can be retrieved through the hierarchical screen.

4.2.2. Typical scenario 2. Master station under network attack (integrated alarm).

The dispatch control system suffered a network attack, and the breakers of multiple plants and stations were maliciously displaced. Through comprehensive analysis of information such as...
protection action information, security control device action information, SCADA remote control commands, station monitoring system operation instructions, and network security management platform alarms, the cause of the event was that a front-end unit of the dispatch control system was hijacked. The comprehensive research and judgment results are pushed to the dispatcher and the secondary monitor, and it is recommended to isolate and check the abnormal front-end machine and take measures to disable the issuing of commands of other front-end processors. Figure 7 is a multi-system comprehensive research and judgment diagram for a master station subjected to a network attack.

![Diagram](image)

**Figure 7. Comprehensive research and judgement system**

4.2.3. Typical scenario 3. Secondary system weak point scanning (risk warning).

Automatically scan the weak points of the secondary system, and manually set the expected fault set of the key secondary equipment. Based on the current operation mode of the power grid and the primary and secondary equipment associations, locate the weak points of the secondary system operation, and implement the secondary system operation risk assessment and early warning. Table 1 shows the risk scan items of the secondary system weakness.

**Table 1. Weakness point scan item of secondary system.**

| Secondary system classification | Weakness point risk scan items |
|---------------------------------|--------------------------------|
| Protection                      | Protection device lockout, abnormal operation status of the protection device, overhaul of the protection device, abnormal protection channel, etc. |
| Security control                | Locking of security control device, abnormal operation status of security control device, overhaul of security control device, abnormality of security control channel, etc. |
| Automation and cyber security   | Critical application server running abnormally, database server running abnormally, abnormality of collection channel, abnormality of vertical encryption |
4.2.4. Typical scenario 4. Remote operation and maintenance of the secondary system (remote control).

As is shown in figure 8, a secondary equipment remote operation and maintenance control center is deployed in the secondary monitoring system (SMS), through the dispatch data network and the telecontrol device of the substation, the remote operation and maintenance of the protection, security control, automation, network security, and communication equipment in the substation can be realized to improve the operation and maintenance efficiency. The protection and security control professional relies on remote operation and maintenance functions to carry out works such as switching the setting area and version verification. The automation and network security professional performs businesses such as remote device point table maintenance, key configuration modification, restart of telecontrol device, configuration modification, and device restart. The communication professional conducts businesses of equipment configuration and arrangement check.

5. Conclusion
During the “Thirteenth Five-Year Plan” period, as multiple UHV DC projects across the region were successively put into operation, the nationwide interconnected power grid pattern was gradually formed, the ability to optimize the allocation of power grid resources was significantly improved, the characteristics of power grid integration became more prominent, and higher requirements for the support capability of integrated control of large power grids, and more reliable and intelligent power secondary system support is urgently needed. Therefore, strengthening the operation management of the secondary power system, strengthening the secondary system's own state perception, information interaction, analysis and early warning, and coordinated disposal have become essential links to ensure the security of the power grid.
The research and construction of the secondary monitoring system (SMS) is carried out, elaborating the secondary monitoring system from the aspects of construction goals, construction ideas, construction effects, overall architecture, system deployment methods, system functions, and typical scenarios. With the construction of the secondary monitoring system, it is possible to achieve unified model, data sharing, architecture optimization, and application integration of the various professional dispatching and operation support systems of the secondary power system. It is possible to break the horizontal and vertical barriers between the original secondary systems, realize the centralized operation analysis of the entire business and the entire process of the secondary system, and combine with the primary system to provide support for joint early warning and decision-making of primary and secondary equipment failures, so as to escort the safe operation of large power grids. At present, the overall design of the secondary monitoring system has been completed. It is planned to pilot in 2020, establish related technologies and rules, make full use of the software and hardware resources of the existing system, and build a secondary monitoring system, initially achieve the goals of supporting power grid dispatch operation and secondary system monitoring.

References
[1] Bao Y H, Xu T. S and Zhou H 2019 An online pre-decision method for safe and stable emergency regulation Electric Power (8): 12.
[2] Ren X H 2018 Research and application of on-line monitoring and intelligent Diagnosis of operation status of power grid dispatch automation system Power System Protection and Control 46 (11): 156-161.
[3] Zhao L L, Li X M and Ni M 2014 Research review and prospect on hidden faults of relay protection and safety and stability control system Automation of Electric Power Systems 38 (22): 128-135.
[4] Tian F, Dong C H and Li Y L 2011 Research and development of power system operation and safety monitoring simulation system Proceedings of the CSEE 31 (28): 80-86.
[5] Wu M Y 2014 Design and implementation of information monitoring system for power system dispatching secondary system University of Electronic Science and Technology of China.
[6] Jin X C, Sun W and Liang Y 2011 Design and implementation of intranet security monitoring platform for secondary power system Automation of Electric Power Systems 35 (16): 99-104.
[7] Zhou F, Zhou H and Diao Y L 2020 Development ideas of key technologies on intelligent perception of ubiquitous power internet of things Proceedings of the CSEE 40 (01): 70-82+375.
[8] Wu Z M, Liu D and Zhou H 2009 Risk based preventive control decision analysis of power system security early warning Electric Power Automation Equipment 29 (09): 105-109.
[9] Xu H Q 2017 Architecture of dispatching and control cloud and its application prospect Power System technology 41(10): 3104-3111.
[10] Chen D H, Xu L and Zhao X C 2019 Development and analysis of kernel IEC standard for automation and protection of Intelligent Substation Automation of Electric Power Systems 43 (21): 229-239.