Research on Main-auxiliary Combination Technology of New Generation Smart Substation

Shanglin Yang\textsuperscript{1*}, Xudong Liang\textsuperscript{1}, Hongxiang Pan\textsuperscript{1} and Bin Zhou\textsuperscript{1}

\textsuperscript{1} NARI Research Institute, NARI Group, Nanjing, Jiangsu, 211106, China
Email: yangshanglin@sgepri.sgcc.com.cn

Abstract. Combined with the development status of smart substation secondary systems, this paper introduces and analyzes the future development direction of substation secondary system intelligence. Based on the evolution of the main and auxiliary control function and structure of substation, the main and auxiliary combination control structure and control process are described. At the same time, from the perspective of the main auxiliary integrated control architecture of the next generation smart substation, this paper summarizes the different types and methods of main auxiliary linkage, as well as the improvement effect of main auxiliary combination on substation intelligence.

1. Introduction

With the application of the IEC61850 standard and electronic transformer in the early 21st century, the substation has realized the standardization of information sharing and sampling digitization, and the substation has begun to develop excessively to the intelligent stage [1]. With the development of current substation technology, it has the functions of primary equipment intelligence, equipment condition monitoring, and advanced application analysis. With the application of these technologies, substation technology has entered the primary stage of intelligence.

The preliminary smart substation has the ability of situational awareness of some key equipment and information, and can automatically respond to some specific accidents or events. At present, the linkage of video monitoring systems and smart substation monitoring systems has been widely used in smart substations; Fire linkage has also been applied in substation fire prevention.

With the improvement of digital level, facing a large amount of data in substation, the current weak smart substation has a low utilization rate of the whole station information and high data independence between different businesses. The interrelated business is limited by the segmentation and processing capacity of the system. At the same time, the processing capacity of the existing system is close to the limit, and it is difficult for ordinary substations to directly bear the pressure of new energy access.

Given such shortcomings, the new generation of smart substations should improve the business integration level of the system platform. By enhancing the intelligent processing ability of the system, the substation will have higher autonomy and stronger autonomy, and improve the access ability of new energy. To solve the problems of substation business isolation and limited interactive linkage, it is necessary to further study the main-auxiliary combination technology.
2. Evolution of Overall Structure of Substation Main and Auxiliary Control System

2.1. Safety Zoning and Function of Substation

According to the characteristics of the power secondary system, it is divided into production control area and information management area [2]. Production control is divided into the control area (safety area I) and the non-control area (safety area II). As shown in figure 1, information management is divided into production management area (Safety Area III) and management information area (Safety Area IV). Different safety protection requirements are determined for different safety zones, among which safety zone I have the highest safety level, followed by safety zone II, and the rest are analogized.

![Figure 1. Safety zone and communication structure of Substation.](image)

- Zone I, real-time zone/control plant area.
  The traditional typical business system of the control area at the plant and station end includes a powerful data acquisition and monitoring system, substation automation system, etc., and its main users are operators.
- Zone II, non-real-time zone/non-controlled plant area.
  The traditional typical business system in the non-control area includes electric energy remote terminal, fault recording device, etc. Security, fire protection, and other non-electric systems are also arranged in this area.
- Zone III & IV, information management area.
  Information management area refers to the collection of power enterprise management business systems outside the production control region.

2.2. Main and Auxiliary Control Structure and Combination Control Methods of Smart Substation

According to the principle of safety zoning of secondary equipment, the smart substation arranges the auxiliary equipment and its monitoring system in zone II, which is uniformly controlled by the auxiliary equipment monitoring system [3].

The basic structure of the auxiliary equipment monitoring system is shown in the figure 2. It is mainly composed of auxiliary equipment monitoring host, workstation, operation inspection network shutdown, patrol robot host, video monitoring host, intelligent analysis unit, local module, etc. [4] the system is connected to online monitoring, patrol robot, video monitoring, fire protection, safety prevention, environmental monitoring, SF6 monitoring, lighting control Intelligent locking control and other subsystems.

In the figure, the auxiliary equipment monitoring host realizes the functions of area II auxiliary equipment data access, operation monitoring, operation control, intelligent linkage, authority management, system configuration, storage management, etc. The software architecture of the smart substation auxiliary equipment monitoring system adopts standardized and modular design packaging [5], so the software architecture has good portability and scalability and can be applied to substation applications of different scales.
3. Main Auxiliary Integrated Monitoring System and Its Combination Methods

With the development of the substation monitoring system and the improvement of the intelligent level of primary equipment and auxiliary control equipment, the power grid began to explore a new generation of substation secondary system architecture to adapt to the improvement of intelligence.

As shown in figure 3, the first mock exam is designed according to the unified model and the basic requirements of the unified platform. Through the deep integration of main and auxiliary equipment information in function and interface, the system can realize the functions of operation monitoring, operation and control, intelligent application, main station support service.

The integrated application host realizes the general functions of substation auxiliary equipment, online monitoring of secondary equipment, network security monitoring, centralized collection, storage and processing of metering data, main and auxiliary linkage, software version control, equipment management, and has special functions such as SCD visual configuration maintenance and network security monitoring. At the same time, it provides relevant business support for service network shutdown and intelligent online patrol host.

Compared with the traditional auxiliary control host, the integrated application host can interact with the equipment data of the convergence layer and the sensing layer in zone II. At the same time, it should have the ability to interact with the equipment data of the station control layer such as the monitoring host in zone I, the service network shutdown in zone II, and the online intelligent patrol host in zone IV. The data flow is shown in figure 4.
Figure 4. Data flow of main-auxiliary combination in the system.

4. Main-auxiliary Combination Strategy
In the smart substation, the data interaction direction between the main control area and the auxiliary control area is shown in the figure 5. The integrated application hosts follow the standardized interaction process and information interaction format to realize the configuration of zone I monitoring host and the reception of linkage information, and to return the linkage results of zone II auxiliary equipment. Similarly, the patrol host in Zone IV receives the configuration file and linkage information of the integrated application host and returns the linkage result of the video camera.

Figure 5. Data interaction direction between the main control area and the auxiliary control area.

a) The monitoring host configures the equipment resource information configuration file. After the data link is established, the equipment resource information configuration file will be automatically sent to the integrated application host. If video linkage is required, the integrated application host will continue to send the file to the online intelligent patrol host.

b) After the data link is established, when the monitoring host has remote control operation or alarm information, it immediately sends relevant information to the integrated application host. The integrated application host determines whether to send the information to the online intelligent patrol host according to the linkage information configuration file transmission frame format type identification received in step a).

c) After the linkage operation of the integrated application host and the online intelligent patrol host is completed, the linkage result information files are generated respectively as needed. The
integrated application host should immediately send the result information file to the monitoring host and complete the confirmation of the linkage result; The online intelligent patrol host should immediately send the result information file to the reverse isolation device. The integrated application host periodically detects the result information file on the reverse isolation device and forwards it to the monitoring host, and completes the confirmation of the linkage result after monitoring the file.

Based on the establishment of the above information link, the main-auxiliary combination can be divided into the following types:

4.1. Linkage between Main Equipment and Video Information
For example, the video linkage function triggered by remote control of monitoring host and alarm information inspection. This kind of linkage is triggered by specific operation events or alarm events. The monitoring host sends the resource information configuration and linkage information to the zone II integrated application host according to the operation type and specific content of the trigger event. After processing, the video linkage request is sent to the relevant host in zone IV. Such linkage can complete the following functions:

- Linkage display of main equipment operation.
  According to the operation command, it supports corresponding video preview, video recording, and other functions.
- Linkage display of main equipment operation status.
  The status change information such as equipment switching, protection action, switch and knife switch displacement of the main equipment monitoring system shall be linked to display the corresponding real-time video.
- Linkage display of abnormal alarm of main equipment monitoring system.
  Abnormal alarm signals such as grounding short circuits and sudden accidents of main equipment shall be linked to the corresponding video preset position.

4.2. Linkage between Main Equipment and Auxiliary Equipment
In such linkage, the remote control equipment of the monitoring host triggers the auxiliary equipment in the corresponding substation area to enter the working state. The actions of some equipment have an impact on the substation environment and need to be handled by auxiliary equipment, such as GIS equipment operation linkage exhaust fan startup. For other operations, it is necessary to activate the monitoring of some areas of the substation, such as a one-touch sequence control operation to turn on the lighting of relevant areas.

4.3. Linkage between Auxiliary Equipment
Based on the large business scope of the auxiliary control area, the auxiliary equipment is generally divided into multiple subsystems. The linkage between auxiliary equipment is triggered by some specific auxiliary equipment signals in zone II, which is directly processed by the integrated application host to carry out linkage control on the associated auxiliary equipment and send alarm linkage signals to the monitoring host at the same time. If necessary, send video linkage requests to relevant hosts in zone IV. Such linkage generally includes:

- Security equipment alarm linkage:
  Turn on the lighting of the alarm defense area and send the alarm linkage signal.
- Fire fighting equipment alarm linkage:
  Support the emergency door opening of access control in fire alarm-related areas; Start the on-site lighting in linkage and start the on-site audible and visual alarm; Support the on/off linkage of on-site fans; Send alarm linkage signal.
- Linkage of environmental monitoring out of limit alarm:
  Outdoor micrometeorological (typhoon, rainstorm, etc.) data out of limit alarm; Send alarm linkage signal (support the startup of on-site fans, water pumps, dehumidifiers, air conditioners, and other equipment).
• SF6 monitoring concentration out of limit linkage:
  SF6 concentration out of limit alarm, supporting the start of exhaust fan; Send alarm linkage signal
  (support remote control operation of main equipment and accident and abnormal alarm signals).

4.4. Video Reverse Linkage
With the development of pattern recognition technology and the wide application of video surveillance,
a large number of video signals in substations can also be effectively analyzed and applied. The online
patrol host can effectively identify personnel activities, personnel identity, dangerous goods, and other
information in the station through video signals [6], and send alarm linkage signals to the
comprehensive application host according to the identification results. For example, if the video
identifies that someone has entered a dangerous area, it will link with the audible and visual alarm
system in the relevant area.

4.5. Application Information Linkage
Including condition evaluation and fault diagnosis [7], one or more data identification and analysis
software will run on the integrated application host. The results obtained by this analysis software not
only have mathematical significance but also can become a key prompt signal and trigger the linkage
of auxiliary equipment. For example, if the power data analysis software finds that the power
information of certain equipment is abnormal in the maintenance state, it shall send an alarm linkage
signal and linkage the audible and visual alarm system of relevant equipment at the same time.
Similarly, some information management systems should also be able to trigger video linkage. For
example, if the authority management system detects multiple authority verification failures, it shall
link the video signal to identify the operators in the monitoring room.

5. Conclusion
As one of the construction cores of smart substations, main auxiliary combination technology is an
important means to ensure smart substation operation and maintenance, save manpower, and improve
operational efficiency and reliability. This paper combs the information flow between security zones
of smart substations, the architecture of main and auxiliary combination systems, and the types of
linkage strategy, and analyzes the technical implementation methods and linkage function of
intelligent linkage between station end information systems. At present, the linkage technology is still
in the early stage of development, and the main and auxiliary linkage is an independent function
driven by specific needs. The establishment of a complex and standardized linkage system will
promote the autonomy of substations and the construction of power Internet of things.

References
[1] Yang W C, Wang Y X, Hong L Q 2018 Improvement and development of intelligent
substation secondary system Scientific and Technological Innovation and Application
(31): 138-139.
[2] Huang L, He S, Jin X H 2018 Overview of safety protection system of substation
monitoring system Electrical Switch 56(03): 1-4.
[3] Pan H, Li H, Yan Y B, Mao Q W, Li G, Ying C Y 2020 New technology analysis of
secondary and auxiliary control system of Smart Substation Hunan Electric Power
40(04): 68-73.
[4] Yan Y B, Li G, Li H, Mao Q W, Pan H, Ying C Y 2020 Analysis on intelligent
combination technology of intelligent substation monitoring system Hunan Electric
Power 40(03): 77-81.
[5] Lu S, Fan P, He H W, Yong M C 2020 Implementation of main and auxiliary control
linkage control method based on UDP protocol Electronic Technology and Software
Engineering (21): 30-32.
[6] He S Y, He Q Y, Zheng D, Hang M Q, Li Q, Wang J L 2018 Research on substation 
intelligent application system based on video image technology Journal of Testing Technology 32(01): 65-70.

[7] Zhang J, Wang L, Zhang Q W, Li P, Fu Z Y 2016 Substation equipment health assessment 
and multi system collaborative diagnosis method based on information fusion. Proceedings of 2016 smart grid development seminar of China Electric Power Research Institute Beijing: 3.