Design Application and Research of Substation Comprehensive Automation System Based on Smart Grid

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Abstract. This paper analyses the needs of smart grids for smart substation automation systems, studies and proposes a new scheme for smart substation automation systems, which applies vertical integration of intervals to reduce the implementation of protection and monitoring functions, improve system reliability and ease of maintenance; Adopting network parallel redundancy protocol to improve the reliability and standardization of information transmission in the station; applying service-oriented monitoring function to improve the level of information sharing and coordination and interaction between substations and control centres. The key technology of the system is expounded, and its application prospect is prospected. Finally, the discussion and analysis of some problems that may exist when the system is popularized and applied.

Key words. Smart grid, substation automation system, reliability.

1. Introduction

In the traditional remote terminal unit (RTU) era, substations do not have a complete integrated automation system. The remote-control device is used as a remote server of the dispatch automation system to process and forward the four remote information required by the main station. At that time, the substation did not have independent automation. System, RTU only exists as the front-end equipment of the main station dispatching automation in the substation. With the gradual promotion of the needs of substation automation business and monitoring business, the comprehensive automation technology of substations is becoming more and more mature, and gradually forming an automation system that meets the needs of equipment monitoring and operation and maintenance in substations. After this, the main station and substation automation system began to develop in a direction of independence from each other, and the communication between the substation and the main station still retained the traditional four-way method, forming a relatively independent development situation of the main plant station.

The integration of the main plant and station proposed in this article is based on the second idea. On the basis of the closer information exchange between the substation and the main station, the complementary or coordinated interaction between the main station and the plant station is realized from the perspective of data interaction and application functions. By adopting an open basic platform and
a service-based communication protocol, the on-demand access of the master station to the plant data is
realized in terms of data interaction, and the on-demand provided services, subscription push services,
and request-response services are realized in terms of functions. Support, strengthen the master station's
ability to perceive the operating status of each plant station, meet the current business needs and adapt
to the future development direction of grid automation technology [1].

2. Smart grid substation integrated automation system
The structure diagram of the integrated automatic substation system is shown in Figure 1. The
characteristics of the integrated automation station are: first, the integrated automation station has 4
remote functions—remote signalling, telemetry, remote adjustment, and remote control. Second, the
integrated automation station has a 2-layer architecture—master station layer and bay layer. The main
station layer can be divided into engineer station, local monitoring main station, remote control main
station, etc.; the partition layer mainly refers to various protection, measurement and control devices,
automatic devices, measurement units, etc. The equipment on the partition layer can be centralized and
distributed installed on the local switchgear; because there is no unified modeling, there are various
specifications in the system, which makes the system design and maintenance very troublesome. Third,
the communication network layer generally uses the fieldbus type: 422, 485, CAN, nonworks, etc., and
a small number use Ethernet communication. Fourth, the communication medium generally uses twisted
group with shielded cable, which has a low communication rate and low efficiency. Fifth, the spacer layer
and the primary device are connected by a cable. Because the collection unit and the execution unit are
scattered inside each spacer unit, a large number of repeated cable connections between the spacer layer
and the primary device are caused [2].

![Figure 1. System diagram of integrated automation substation](image)

2.1. Overall framework
The substation integrated automation system implements various network management functions such
as device configuration management, end-to-end business management, topology management, alarm
management, performance management, and security management through an intuitive and user-
friendly interface. The substation integrated automation system completes the configuration and
maintenance of various types of managed equipment through the southbound interface, while providing
a northbound interface upward to meet the connection requirements of the upper-level services of the
power system. The overall framework of the substation integrated automation system is shown in Figure
2. The switch network can be divided into multiple business networks from the bottom by the substation
integrated automation system in advance, the configuration information of different business networks
is isolated from each other, and the communication data and communication quality do not interfere
with each other. At the same time, a dedicated network management network dedicated to network
management data transmission (called the zeroth network) is divided. The corresponding switch port in
the zeroth network needs to be free of bandwidth available for the zeroth network.
2. Main functional modules

The intelligent network centralized management and control platform includes business management, topology management, configuration management, security management, fault management, performance management, system management, maintenance management, and statistical management. The main functional modules are shown in Figure 3. Topology management is based on the key technology of automatic physical topology mapping, which realizes the automatic discovery of fibre links between network elements and devices, that is, the automatic discovery of topology, segments, and protection rings, simplifying network construction operations. Provide hierarchical domain, subnet, and network element structures to achieve effective navigation and management of the network. Support multi-view functions such as main topology view, business view, clock view, etc., to meet users' information control needs. Business management realizes the automatic discovery and end-to-end business management of GOOSE, SV and MMS services. The business multi-level path view can visually display the logical relationship of end-to-end business at different levels, so that users can manage the business more clearly and conveniently. The service can be flexibly constructed according to the user's choice, including automatic optimal path selection, automatic label calculation, and service protection implementation, etc., making the complex process of creating a service simple, reliable, and efficient. It supports the reverse calculation of the actual device data to reconstruct the user's business, thereby making it easier to reconstruct and restore the network [3].
2.3. Service-oriented monitoring function
The service-oriented monitoring function uniformly designs a standardized bottom platform, changes the single interaction method of the previous dispatching and substation system, designs various interactive services, and uses a service-oriented wide-area service bus to realize vertical service flexible call and information. The interconnection provides support for the coordination of various distributed applications of dispatching and substation systems, and improves the standardization, integration and interaction of dispatching and substations. On the basis of this architecture, the application functions of the current smart substation are analysed and summarized, and the service-oriented substation application functions are designed and developed according to the principle of distributed integration, and the distributed integrated application of wide-area collaboration between dispatch and substation is realized. The system architecture has good dynamic scalability, not only capable of supporting existing applications, but also easily supporting new business functions and adapting to new demands for future development.

The bottom layer of the system adopts the platform technology of the smart grid dispatching control system, and establishes a unified platform for unified standards and dispatching and unified technology in the substation, including communication bus, historical database, real-time database, file-based data storage and management, unified data access interface, system Management, authority management, model management, man-machine interface, security protection and other modules. The unified platform has standard, open, reliable, and safe technical characteristics and good adaptability, and provides support and services to various applications on the upper layer of the monitoring system.

3. Key technical analysis

3.1. General Service Agreement of Power System
The communication protocol is the basis of the interaction between the main plant and the station. It carries all the information transmission between the substation automation system and the dispatching master station automation system. It can be said that the communication protocol directly determines...
the coupling degree and interaction level between the two ends of the communication. For the dispatching master station and intelligent substation, to realize the interconnection between the two, the following conditions need to be met.

1) The interaction of data between the main plant stations presents the characteristics of networking, and supports data access across grids and across domains. 2) The interactive features of the functions between the main plant stations conform to the service-oriented architecture (SOA) and can provide object-oriented services. 3) According to the principle of “available and accessible on demand”, both the plant station and the master station can be used as service nodes in the power grid [4].

The general service agreement of the power system is not only a protocol compatible with the communication protocol between the existing main plant stations, but also a set of communication system of the main plant stations based on the service architecture. The universal service protocol directly maps the communication service and its message structure to the TCP/IP or Ethernet protocol stack, absorbs and expands the real-time characteristics of protocols such as IEC 60870-5-10 and DL 476, and establishes object-oriented technology based The real-time data transmission mechanism, while ensuring the real-time and reliability of the real-time monitoring and control data of the power grid, draws on the self-descriptive features of IEC 618050, adds the functions of custom communication services and custom message structures, and adopts a binary protocol structure and data unit , Service mechanism and service primitives, to achieve static and dynamic service data exchange between various levels of power grid dispatch control centre, various power plants and substations. In the IEC61850 standard, the substation system is divided into three layers: station control layer, bay layer, process layer; 2-layer network: MMS (communication network between station control layer and bay layer), GOOSE, SV (both belong to Process layer network, GOOSE network is used to transmit event messages, SV network is used to transmit sample value messages). The IEC61850 standard provides detailed descriptions of the logical device, logical node model, data structure, data model, and communication message frame format of each layer. The rate of Ethernet is related to the sampling rate and can be calculated according to the following formula:

\[ SR \times TL \times nMU \leq DR \]  

Among them, DR is the Ethernet rate, SR is the sampling rate, TL is the frame length, and nMU is the number of merging units. If the sampling rate is 196 points/cycle and the APDU contains only one ASDU, the frame length is 984 bits (including a 96-bit frame gap). Considering the system redundancy, the rate can be selected as 100 Mbps. The calculation is as follows:

\[ (196 \times 50) \times 984bit \times 1 = 9.6432Mbps \geq 100Mbps \]

3.2. Service-based remote interaction technology of the main sub-station

Different from the traditional telecontrol communication protocol, which only considers the transmission efficiency, the service-based remote interaction technology of the main and sub-stations also needs to consider the scalability and security of the communication, not only to meet the current problem of information sharing and application collaboration between the main and sub-stations, but also to meet the future new Demand. Because the main station adopts a dual-network cascade architecture and the sub-station adopts a dual-network non-cascade architecture, the wide area service bus needs to meet the transmission control protocol (TCP) communication mechanism of both architectures at the same time to achieve high efficiency, reliability and reliability between dispatching and substations. Secure TCP communication. The mechanism uses multicast-based link state monitoring and TCP communication methods, including multicast message monitoring, intelligent network card selection, real-time state judgment, and unknown node filtering [5].

In addition, security is also an important aspect of the remote interaction between the main and substations, especially whether the safety of remote operation and operation and maintenance can be guaranteed has become a key issue to support unattended substations. On the basis of traditional vertical encryption authentication, it is necessary to further study the integrated deep security authentication strategy of the main and sub-stations, and establish secondary security protection mechanisms such as
digital signatures and authorization authentication between the main and sub-stations to ensure the remote interaction security of the main and sub-stations [6].

4. **Take the F6 circuit breaker status monitoring system as an example for system function detection**

The information model and communication service of IEC 61850 is the basis for ensuring interoperability between condition monitoring IDs. The following uses the SF6 circuit breaker condition monitoring system as an example to analyse its modelling method and communication process in detail. According to the characteristics of the SF6 circuit breaker, the actual monitoring methods mainly used include partial discharge, SF6 gas, mechanical characteristics and working state monitoring of energy storage motors. In response to the above monitoring quantities, logical nodes such as partial discharge monitoring (SPDC), gas dielectric insulation monitoring (SIMG), circuit breaker monitoring (SCBR), and operating agency monitoring (SOPM), as well as their data and data attributes, can basically reflect the circuit breaker. The running status is shown in Table 1.

**Table 1. Logical node of SF6 circuit breaker monitoring**

| Node type                                   | Monitoring quantity | CDC type | description                  |
|---------------------------------------------|---------------------|----------|------------------------------|
| Partial discharge detection logic node      | Patch Type          | ENS      | Partial discharge type       |
|                                            | PlsNum              | INS      | Number of pulses             |
|                                            | AcPaDsch            | MV       | PD level                     |
|                                            | ApPaDsch            | MV       | Apparent PD discharge        |
|                                            | NQS                 | MV       | Average discharge current    |
|                                            | UhfPaDsch           | MV       | Partial discharge UHF level  |
| Gas dielectric insulation monitoring logic  | Pres                | MV       | Insulation gas pressure      |
| node (SIMG)                                 | Den                 | MV       | Insulation gas density       |
|                                            | TP                  | MV       | Insulating gas temperature   |
| Circuit breaker monitoring logic node       | OpTmOpn             | MV       | Minute operation time        |
| (SCBR)                                     | OpTmCls             | MV       | Operating time               |
|                                            | ColA                | MV       | Coil current                 |
|                                            | En                  | MV       | Energy storage               |
| Operating mechanism monitoring logic node   | MotTM               | MV       | Motor running time           |
| (SOPM)                                     | MotA                | MV       | Motor current                |

Table 1 gives the measurement data (type MV). In practical applications, at least one of AcPaDsch, ApPaDsch, NQS and UhfPaDsch should be used. In the existing standard, the SPDC lacks the partial discharge type and the number of pulses. It adopts the newly added enumerated state (ENS) type and integer state type (INS) of IEC61850 version 2 to extend the SPDC to the new data objects PaDschtpe and PlsNum [7].

5. **Conclusion**

The design, configuration, operation and maintenance of intelligent substations are very different from conventional substations. Intelligent substations pay more attention to unified modelling and unified configuration, which puts higher requirements on substation auxiliary software. In this article, intelligent substations the detailed analysis of the various links of use and its current situation, and the corresponding technical requirements are put forward. On the basis of not only embodying the technical characteristics of the intelligent substation but also shielding the complex technical details of the bottom layer, an implementation plan for the use of the intelligent integrated substation integrated system...
software is proposed, and the requirements, functions and modes are elaborated. The program is operable and has a strong promotion value.

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