Research of the Smart Substations Scheme Based on Centralized Protection and Control Unit

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Abstract: The smart substation plays an important role in the smart grid. This paper expounds the ideas of centralized protection and control unit (CPC) in smart substation, and analyzes the situation in the engineering applications.

1. Introduction

Smart grid is the core and support of energy transition, and smart substation plays a vital role in the construction and development of smart grid.

For a long time, the primary and secondary integration of smart substations and the integration of secondary equipment have been a topic attracted much attention. This paper will not repeat the mature integrated systems and integration schemes. Starting from the technological development trend, we will discuss the solution of centralized protection and control unit within substation and explore the realization of its functions.

2. The architecture and functions of centralized protection and control unit within the whole substation.

2.1. The overall architecture of the centralized protection and control unit

2.1.1. Concept of centralized protection and control unit in substation

The switch of the process level and the secondary equipment of the bay level are integrated into a host by the integrated hardware platform of multi-core, multi-CPU and high-performance FPGA, with secondary functions defined by software. And the device of protection, measurement and control, security and stability control devices, and network transmission equipment in substation are fully optimized and integrated in a centralized way, thereby greatly improving the ability to share data in the substation, avoiding repeated collection of information, enhancing the reliability of the efficiency of information interaction and transmission, and reducing secondary equipment and on-site optical and cable connection. At the same time, later software upgrades and platform function expansion can be used to meet the diversified requirements for advanced application of smart substation.
2.1.2. **Overall architecture of centralized protection and control unit in substation**

The centralized protection and control unit is generally divided into three layers: data collection, data communication, and business application, as shown in the figure below.

![Fig1: Secondary system architecture of centralized protection and control unit(CPC)](image)

Data collection layer: primary equipment information such as current, voltage, switch position, switch relay alarm, and power supply alarm signal.

Data communication layer: Based on 10 Gigabit data exchange technology, it transmits GOOSE and SV messages between each bay to realize data exchange equipment between process level and bay level.

Business application layer: the protection, measurement and control, metering and other secondary equipment functions of the substation are presented in the form of software, and software algorithm is used to realize the corresponding secondary system functions.

2.2. **Hardware design of centralized protection and control unit**

Taking into account the reliability of the device and the independent management of each bay-level functional equipment, the centralized protection and control unit of the substation adopts the design of independent function board. Each function board is equipped with an independent CPU, which can independently complete the calculation and processing of a single business function or a single bay of multiple business functions. The hardware design is shown in Figure 2. C1～C10 are function boards, H1 and H2 are central control boards, and J1 and J2 interfaces are process layer interfaces. The J1 interface of the function board is connected to the merging unit of the bay to collect the SV information (current, voltage) of the bay; the intelligent terminal of the J2 interface bay collects and sends the GOOSE information of the bay (switch position, control command, status information, block information and alarm, etc.).

![Fig.2 The data transmission architecture of CPC](image)
The H1 and H2 central control boards respectively provide two high-speed data exchange channels, and the data channels of the two central control boards are hot standby for each other, which improves the reliability of platform data transmission.

2.3. Function board design of centralized protection and control unit

Each functional board is equipped with an independent CPU. As shown in Figure 3, the functional board collects SV and GOOSE information from the merging unit and smart terminal. On the one hand, it uses its own CPU to calculate and process data, support interval protection, interval measurement and control, and interval Software functions such as metering; on the other hand, the SV and GOOSE in the bay are forwarded and output for the business use of other function boards, such as bus protection, main transformer protection, fault recording, etc.

For important secondary functions across bays, plug-in boards can be independently configured, such as busbar protection, busbar measurement and control, main transformer protection, etc. The independently configured business function boards can adopt the same hardware architecture as the function boards.

![Fig.3 The diagram of function board of CPC](image)

2.4. Analysis of the realization of the secondary function of centralized protection and control unit

2.4.1. Realization of line bay

For a line bay as shown in Figure 4, a merging unit is configured for current and voltage transformers, and smart terminals are configured for circuit breakers, isolation switches, and ground switches. The function board is connected to the interface of the merging unit and the intelligent terminal to realize the data exchange of GOOSE and SV. The business functions of line protection, measurement and metering are integrated on the line bay. The line protection exits the GOOSE signal, and the point-to-point direct access to the bay intelligent terminal to ensure the protection of quick mobility.

![Fig.4 The protection and control function diagram of line bay](image)
2.4.2. Realization of main transformer interval function
Considering the operation reliability of the main transformer protection, the main transformer function board is configured with two plug-in boards. The main protection, measurement and metering are integrated on one function board, and the backup protection on each side is separately integrated on the second function board, as shown in the figure 5 shown.

The main protection, measurement and metering are integrated on a functional board. The sampling, control and interlocking of the corresponding electrical quantities are realized in the function board, and the main protection action signal is directly sent to the intelligent terminal of the main transformer point-to-point.

The backup protection on each side of the main transformer is separately integrated on the second function board. When a conventional transformer is used, the current and voltage collected by the backup protection function board is recommended to use a different transformer secondary winding from the main protection. It is recommended that the current and voltage collected by the backup protection function board and the main protection use different SV channels when the electric transformer is used.

The two service boards of the main transformer exchange information through the data exchange channel in the CPC.

2.4.3. The realization of bus interval function
The bus protection adopts independent business board to realize, as shown in Figure 12.

The busbar function board mainly realizes the busbar protection function. The plug-in board collects the current SV and GOOSE information of each bay from the other bay function boards of the CPC. At the same time, it collects bus merging unit, bus intelligent terminal, segment merging unit and segment intelligent terminal through external interface. SV and GOOSE information, and then develop
the bus differential protection function. At the same time, it forwards GOOSE information such as bus voltage SV, bus isolation switch and bus protection action to other function boards.

When using conventional transformers, bus protection and line protection collect current information from different secondary windings, and use independent SV channels to ensure that there is no dead zone in the protection.

The busbar protection function board can also be regarded as the busbar and public measurement and control function board. By collecting the SV and GOOSE information of the other interval function boards of the platform, the SV and GOOSE information of the busbar and the segment interval, the busbar and public measurement and control are realized in the function board.

The busbar protection trip signal uses the internal data channel of the platform, and is directly connected to the local intelligent terminal through the interval function board.

3.3 Analysis of the effectiveness of centralized protection and control unit

The expected results are as follows:

1. The primary and secondary equipment uses prefabricated optical cable connection, and it can be functioned as soon as it is plug in, which greatly reduces the on-site optical and cable wiring and installation and debugging time.

2. Repeated collection of information are avoided, and the reliability of information interaction and transmission efficiency is enhanced.

3. The process layer network is integrated within the CPC, and the internal data channel of the platform is used for data exchange, which simplifies the data transmission environment and improves the efficiency of data transmission.

4. The secondary equipment is greatly reduced, and the maintenance of the substation is simpler.

5. Functional upgrades and transformations can be carried out through software to meet the requirements of substation expansion and secondary upgrade transformation.

3. Conclusion

The core of the intelligent substation adopts the object-oriented modeling method of IEC 61850, which emphasizes data sharing, interchangeability and interoperability between devices. After more than ten years of development in traditional smart substations, there are still problems in the actual application process such as complex network structure, multiple intermediate data transmission links, and inability to share data.

This paper proposes centralized protection and control unit in the substation, and discusses the feasibility of its realization on the technical level. Since the scheme will merge the secondary protection and automation equipment from the physical level, it will have a profound impact on the existing operation, management and maintenance related management systems. At the same time, it is limited by the production process. Therefore, there is still a long way to go to make this scheme popular. However, this is still a development direction of smart substations. Hopefully, it can provide some ideas and reference for the smart manufacturing and equipment upgrade of smart substation in the future.

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