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A Study of Key Technology and Implementation Structures for Smart Substation

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Smart Substation, System Architecture, Intelligent.

1 INTRODUCTION

Many countries and regions, especially the United States and Europe, are interested in the smart grid as a new way of electric development in the new century. In the United States, the research of smart grid mainly is from the degradation of the electric power system reliability because of under-investment in the infrastructure combined with growing demand and security threats from terrorist attacks and operation failures. In Europe, the driving force has been the integration of renewable energy sources to a distribution network that was not designed for this purpose. According to China's actual conditions, China has proposed the development of smart grid, which has the four basic characteristics of the information, digitization, automation and interaction. In China, the target is to build the powerful electric grid with ultra-high voltage transmission corridor and increase the integration of renewable energy sources^[1-2].

Substation is an important supporting node connecting transmission and distribution grids, and is basic operation data collection source and command execution unit for grid. Existing digital substation does not verify equipment stability and reliability in the process level, lacking relative evaluation system and means etc, which produces negative effect on the efficiency of production operation for substation and goes against further improvement of the grid security level. Along with the development of smart grid construction, smart substation is the inevitable stage for the substation automation.

Smart substation has the following function characteristics: primary equipment intelligence, intelligent primary equipment network; basic data completion, information exchange standardization; operation control automation, information showing visualization; analysis and decision online optimization, equipment maintenance state; protection control collaborative, equipment installation on-site; systems design unionization, systems highly integrated. The key technical characteristics of smart substation are analyzed from smart primary equipment, information integration platform, smart advanced application and new smart substation protection and control technology respectively.

2 SMART SUBSTATION ARCHITECTURE

2.1 Smart Substation Concept

Smart substation is the technology fronts for the substation, which does not have united definition in the world. China points out the definition of smart substation^[5]: The advanced, reliable, integration, low carbon and environmental primary equipments are applied. Basic requirements including the total information digitization, communication platform network, information sharing and standardization are found in the smart substation. Basic functions such as information collection,

measurement, control, protection, measurement and monitoring are automatically completed. And according to need, advanced application such as real-time automatic control, on-line analysis and decision, and cooperative interaction are applied. The concept of the smart substation is shown below in the figure 1.

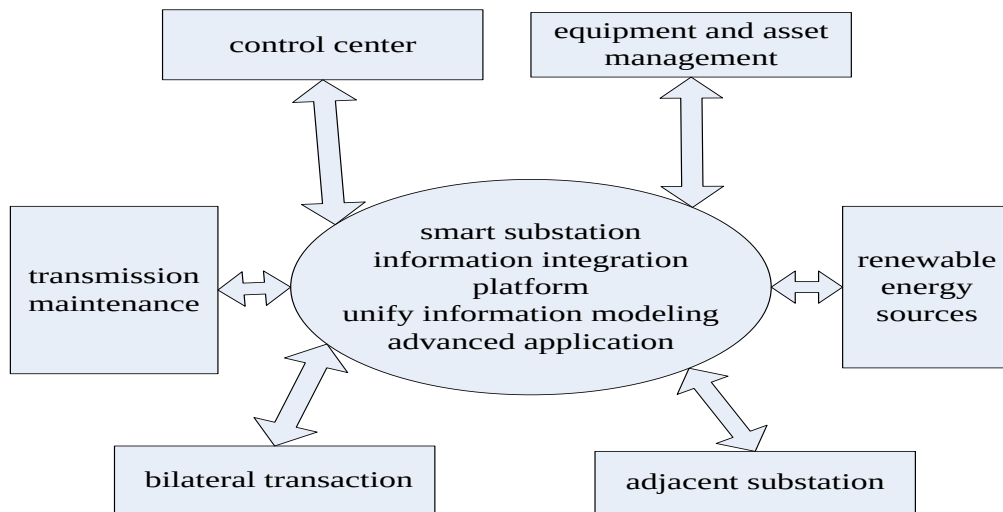


Fig. 1: The smart substation concept figure

In the basis of the existing digital substation, smart substation further solves the key technical problems of the substation inside, substation and adjacent substation, substation and control center, in the figure 1. Seamless communication between smart substation and control center is realized; Bilateral Transaction between Smart substation and major users such as steel; Information interaction between smart substation and its adjacent substation is realized.

2.2 smart substation system architecture

Relying on the digital substation architecture, smart substation architecture has process level, bay level and station level. There are transformers, circuit breakers, CT/PT etc primary equipment and their own intelligent components as well as independent intelligent electronic devices in the process level. Bay level mainly includes secondary equipment such as relay protection device, system measurement device, and monitor equipment etc, which communicate with all sorts of distant input/output, sensors and controls equipments. Station level includes monitoring control system, substation domain control, communication system etc, which realize many functions such as: the entire station equipment monitoring; supervisory control and data acquisition, SCADA, protection information management and other related functions.

3 KEY TECHNOLOGY CHARACTERISTICS of SMART SUBSTATION

3.1 Intelligent primary equipment

Intelligent primary equipments not only have the function of transmission and distribution power but also have measurement, control, protection and other functions. Intelligent primary equipment includes host and intelligent components these two parts. Host is the high-voltage primary equipment. Intelligent component are composed of many intelligent electronic devices (IEDS), which are responsible for measurement, control, monitoring, accounting and protection functions of smart substation. An intelligent component may complete all function independently or multiple complete all function together. Intelligent component can be placed outside the host, also can be embedded in the host. Intelligent primary equipment is a technical extension between primary and secondary equipment, which will gradually integration and structural function in the future. Intelligent primary equipment mainly includes intelligent switch, intelligent transformer, controlled reactor and electronic transformer etc. Electronic transformer is a new type of power transformer, which has no iron core. The insulation structure of electronic transformer is simple, reliable, small volume, light weight, excellent linearity and no saturation phenomenon. At the same time output signal of electronic transformer can be directly connected with the interface of microcomputer-based measurement and protection device. Currently, optical electronic current transformer (OCT) is applied successfully.

Advantages of OCT include wide bandwidth (1A-63kA) , insulating ability, high accuracy of measurement (0.2S) , protection relays, wide range of frequency, small volume, light weight, cover small area, environmental protection, energy saving, using face extensive, easy installation and maintenance, simultaneously measuring AC and DC and other significant advantages. The application of the OCT has brought the fundamental change about measurement, protection and measurement. New features of the measuring: digital output way replaced analogue output way; Optical device isolate primary equipment and secondary equipment. New features of the protection: OCT could quickly obtain real images of current from primary equipment; no saturation; the speed of protection is quick, etc. New features of the accounting: no relationship between precision and load; Electromagnetic interference do not affect on accuracy; also good precision under the condition of the high current; adopting rational algorithm whose errors can be neglected etc.

3.2 Information integration platform

Because all sorts of new system integration and data integration, various advanced application needs, smart substation designs a powerful information integration platform. The information integration platform supports a variety of data access, storage and highly efficient retrieval, making data model standardization by adopting unified modeling thoughts and methods. In the basis of integrated and consistent basic data, smart substation establish unity date platform, which provides standardization and panoramic information access for various intelligent application, greatly improving the sharing and interoperability of system information by managing various data of heterogeneous system.

Source-side maintenance is an important function feature of the information integration platform, also is an important concept for smart substation, namely data from the source realizes standardization, unified configuration, unified debugging maintain and increase work efficiency, reduce duplication of work; Substation offers a panoramic view of the data information, various standardization models, charts, and graphics for control center; graphics adopt IEC 61970-based SVG exchange format; graphics and model associating with each other automatically; finally seamless communication is realized between smart substation and control center.

Model graphics and information exchange etc have not achieve sharing, automation, and interaction between current digital substation and control center. Model and graphics configured in the substation need to be artificially edited and imported again in the control center, which is repeated maintenance, wasting money and time, at the same time artificially editing inevitably produces human error, increases the dangerous of the grid and reduces the grid security. When control center requires real-time data from substation, the information island are created because of inconsistent model between substation and control center.

The information integration platform provides the optimized, standards, and convenient configuration tool. In the configuration tool, interface, importing model file and exporting model and SVG file, is designed, which could check primary equipment model and ensure the legitimacy of the model. Primary equipment model is obtained by editing icon on the interface, which is easily associated with the secondary equipment model. After configuration, it can output new SCD file and create SVG single line diagram. The configuration operations include two modes, i.e. device objects and function types. For example, it can add power transformer, bay, conducting equipment, terminal and connectivity node as objects, and can also delete objects by a single mouse clicking with all related objects. When exporting file, the configuration tool executes syntactic and semantic validations. It will prompt warnings and modification proposals once rule violations found. The information integration platform generates CIM model meeting the control center requirements through shared modeling between digital substation and control centre. Finally CIM model and graphics associated with each other automatically are imported into the control center.

Source-side maintenance greatly reduces maintenance quantity and human errors, at the same time improves the work efficiency, achieves shared information and eliminates information island etc.

3.3 Intelligent advanced application

In order to timely process accidents, monitor the state of equipment in the substation, reduce the burden of control center, smart substation develops related advanced application based on information integrated platform. Advanced application is one of the main differences between smart substation and

existing substation. According to the technology development and management requires, advanced application function also vary, several typical applications of which are as follows:

1. Visible state of equipment: intelligent power transformer, breaker, etc primary equipment status information, in the smart substation, can be displayed and sent to superior system, which provides basic data for control centers to realize lifecycle of equipment optimizing management based on state detection.
2. Intelligent alarm: smart substation, according to the importance of substation events, reasonably arranges alarm information, shielding meaningless information. A lot of the alarm information is layered and classified in the term of the pre-set the alarm information category, priority and reasoning rules, which could avoid spreading fault due to the delay discrimination.
3. The comprehensive analysis and decision of fault information: In the condition of the power system accidents or fault, system, according to various kinds of obtained information, automatically provides an analysis report of accidents and gives accident treatment plan for attendants, which is convenient to quickly determine the cause of the accident and can directly provide relevant data for manual analysis information.
4. Sustaining economic operation and optimizing control: According to the real-time operation of substation, smart substation gives economical operation and optimization control strategy by using the mathematical model as well as algorithm, the method of voltage regulation and reactive cast cut, which mainly services for control center, such as voltage reactive-power control limits value may be issued by the control center.
5. Renewable energy sources access and management: it can predict the output power of renewable energy sources and isolated grid has control function of the emergency when large grid is disconnected.
6. Video monitoring should linkage monitoring system: Real-time image information of operated objects is presented when equipments are operated or accidents are treated, which further guarantees reliable implementation of the whole process, reduce staff labor intensity, and is also the development direction of nobody on-duty substation operation mode.

In practical applications, every advanced application should be as an agent. These agents could coordinate with each other and interact with large grid, adjacent substation and control center.

3.4 New protection and control technology of smart substation

New protection and control technology of smart substation not only includes the content of protection, but also includes the content of information and networked, at the same time adopts double network, network protocol. The new protection technology, which satisfies four characters: reliability, selectivity, agility, quickly, makes special treatment for operation flow of sending and receiving data, which can effectively prevent tripping command of loss, delay etc. New protection and control technology of smart substation basically has the following characteristics:

1. The function of protection and control systems for smart substation is an integration, which exerts the whole performance by primary equipment, secondary equipment and protection units coordinate with each others. Intelligent terminals action time should be no more than 7ms. IEC 61850-9-2 send interval less than 10 microseconds.
2. Protection technology for smart substation should be double principles whose two processes of layer network are completely independent. Double configuration SV or GOOSE network are not allowed to connect with each other by Ethernet switch, however, SV or GOOSE from different voltage level could connect with each other by Ethernet switch.
3. Protection technology for smart substation follows the principle of direct sampling and direct tripping. Direct sampling is that intelligent electronic equipment directly transmits sample value by the way of point-to-point instead of Ethernet switches. Direct tripping is that intelligent electronic equipment directly transmits the tripping signal by the way of point-to-point instead of Ethernet switches. Communication between the protection equipment and intelligent terminal is adopted the way of GOOSE peer-to-peer.

4 CONCLUSION

Smart substation is the developmental trend of electric power system in the next 10 ~ 20 years. At present, smart substation is in the stage of demonstration, reconstruction. Electronic transformer, protection networking and information integration platform have been applied in the practical engineering. Protection based on the electronic transformer, various advanced application and intelligent primary equipment are being researched or pilot operation. The construction for smart substation is gradually implemented.

Smart substation has the following function characteristics: information exchange standardization; operation control automation; analysis and decision online optimization, protection control collaborative, equipment installation on-site etc, which is essential different from existing substation. Along with the rapid development of smart grid, more and more smart substations are experimented, demonstrated and extended, which will make the whole designing of substation simple, the cost of building decreased, interaction between inside and outside substation convenient, information exchange standard, maintenance easy etc. Finally, smart substation will gradually develop to be mature.

REFERENCES

- [1] Lu Yong, Gan De Qiang, John N.Jiang. Issues of Smart Grid and Distributed Generation Development in the Unites States. Automation of Electric Power Systems, 2010, 34(9):12-16.
- [2] Chen Shu yong, Song Shu fang, Li Lan xin etc. Survey on smart grid technology [J].Power System Technology, 2009, 33(8):1-7.
- [3] Tang Yi, Manisa Pipattanasomporn, Shao Sheng-nan etc. Comparative Study on Smart Grid Related R&D in China, the United States and the European Union[J].Power System Technology, 2009, 33(15):7-15.
- [4] Chang Kang, Xue Feng, Yang Wei dong. Review on the Basic Characteristics and Its Technical Progress of Smart Grid in China [J]. Automation of Electric Power Systems, 2009, 33(17):10-15.
- [5] IEC/TC57, IEC 61850 Communication Networks and Systems in Substations [J], 2004.
- [6] Li Yong Liang, Li Gang. An Introduction to 2nd Edition of IEC 61850 and Prospects of Its Application in Smart Grid[J]. Power System Technology, 2010, 34(4):11-16.
- [7] Technical guide for smart substation[S], State Grid Corporation of China, 2009
- [8] Technical Specifications of Protection for Smart Substation [S], State Grid Corporation of China, 2010.
- [9] Gao Xiang, Zhang Pei chao.Main Features and Key Technologies of Digital Substation [J]. Power System Technology, 2006, 30(23):67-71.
- [10] Ding Jie, Huang Xiao feng, XU Shi ming etc.Characteristic and Frame of Digital Substation Technology. Jiangsu Electrical Engineering, 2007, 26(addition):29-31.
- [11] Wang Yong, Mei Sheng Wei, He Guang Yu. The Characteristics and Realization of Digitization of Primary Equipment in Substations [J]. Automation of Electric Power Systems, 2010, 34(13):94-99.