RESEARCH AND PRACTICE ON TECHNOLOGIES OF SMART DISTRIBUTION NETWORKS

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ABSTRACT

The utilization efficiency of energy and the security of energy-supply system could be improved by digital networks and artificial intelligence (AI) control technology. With smart distribution Networks, the information technology is fully used to rebuild the energy system, and the intelligence and reliability of the system is increased. According to the practice of the regional distribution networks, some key technologies of information-support system of smart distribution networks, including the smart dispatching based on the real-time and global information, the distribution management system (DMS) based on Geographic Information System GIS, the data platform based on the real-time database and data-mining of distribution networks is analyzed and discussed in the paper. The status quo of research and practice of smart distribute grid in Guangzhou is introduced.

INTRODUCTION

With the development of the modern power grid, the increasing uncertainties and risks threaten the security of the power system. On the other hand, the emergency of energy, green resources and sustainable development are focused by countries around the world. Smart grid based on distribution data transformation, computing and controlling is one of the approaches to solve such issues, and it could satisfy the higher and higher requirements of power quality and reliability from the power users [1-7].

As so far, Europe and America have done a lot of research on smart grid [8-16]. EPRI provided ideas of Complex Interactive Networks / Systems Initiative (CIN/SI) in 1998 and 'IntelliGrid' in 2000, which are the rudiment of the smart grid. Department of Energy (DOE) distributed the reports of "Grid 2030" and "National Transmission Technology Route Map", which depict the vision and technical strategy of the future power grid in 2004 and 2005, as well as starting the projects of "GridWise" and "MGI". Then DOE published the report of "The Smart Grid" in 2008. In the economic revival plan of President Obama, smart grid, listed with high importance, would be designed to ultimately exploit the value and efficiency of American grid and increase the reliability and security level. This plan would benefit American enterprises from technology in the electrical information field. In March 2008, Bohr, a city in the west, became the first "city of smart grid" across US [17].

In order to tackle the problem of electric infrastructure aging, electricity market construction and access of renewable generation across Europe, Europe Electrical Smart Grid Forum is founded [18], hoping to switch the conventional power grid to an interactive service grid for users and operators, so as to increase the transmission efficiency, security and reliability, and clear the obstacle for accessing large-scale renewable energy. In 2006, the perspective of smart grid is proposed, and Strategy Research Agenda (SRA) to guide European Union (EU) and its member countries to launch relevant projects of smart grid [10,14] is established. A "Green Paper" on Energy Efficient Efficiency, in which smart grid technology is referred to as the key and direction to ensure power quality in EU, is issued by EU council. Currently, UK, France, Sweden, and Italy, etc. are all accelerating their applications of smart grid technologies.

In China, a National Project 937, "research on enhancing reliability of large-scale inter-connection power grid", to provide a systematic platform of research and development for novel smart grid operation and control [19-21] is undertaken by China electric power research institute, and an all-in-one platform, called SG186, is constructed by National State Grid Corporation of China (SGCC), which involving the provinces of Shandong, Zhejiang, Jiangsu, and Shanghai, etc.

BASIC TERMINOLOGY

A. Smart Grid

Generally speaking, smart grid contains a dynamic pricing smart metering system, an intelligent dispatching system with priority to clean energy, and an intelligent technology system, which optimizing the balance between generation and demands. Based on an open information model, and the application of distributed intelligent devices, broadband communication technology, and automatic control system, global system monitoring is available. Therefore, all nodes across the power grid could be seamlessly integrated. The global information could be collected from the Internet, and then being filtered, and analyzed for decision making, and energy management optimization.

Based on robust grid architecture and an information-exchange platform, product and operation information could be integrated, which would enhance dynamic analysis, diagnosis, and the optimization of business flow thus provide operators or administrators with a complete operation status diagram. Auxiliary decision support is offered at the same time to achieve more accurate, detailed, timelier and better power grid operation and management. Control could also be conducted at different levels in a smart grid, which is helpful to flat the system infrastructure and modularize the system function, which would optimize the system efficiency and service quality.

Smart Grid could improve not only the security and reliability, but also the long-life performance of the power grid, which then intent to operate a grid with cost-competitive technologies and sustainable development through using efficient, environmentally-friendly power sources. Compared with conventional power grid management, smart grid actively monitors users' demands, and then provides efficient power supply, which beneficial to maintain supply security and operating efficiency, and thus better service to power users.

B. Smart Distribution Network

Smart distribution network, which is closer to a regional power supply company, is a significant part of smart grid. It ensures a vast number of end-users' securities and reliability of power supply. Therefore, it is very valuable to study in smart distribution networks and then elevating the management level and reliability of distribution operation.

Self-healing and self-adaption are very necessary for smart distribution networks. Through on-line monitoring and system information analysis of remote devices, real-time operational status of the networks could be obtained, and then reasonable load distribution for power demands. Besides, the system malfunction and hidden danger could be detected and then isolated more quickly in case of contingency. With some corrective actions being taken, the security and stability of the networks could be predetermined, and hence reducing the possibility of outage significantly.

It is possible to complement resource optimization in smart distribution networks by means of some technologies, such as real-time pricing and smart metering, which could greatly support the competition in electricity markets and enhance demand-side management.

In smart distribution networks, it is necessary to keep favourable compatibility and standard interface to allow accessing large-scale renewable energy resources and interacting with users easily, thus the high power quality and supply reliability service is available.

C. Information Supporting System.

A robust grid and an intelligent information supporting system are two complementary parts in smart grid. The grid itself is the foundation while the information supporting system is the means to realize smart operation. The building of smart grid is a comprehensive task, which involving in all the procedure of power system, generation, transmission, distribution and utilization. To construct smart distribution networks, some consideration should be taken carefully in every phases of network planning, design and construction, operation and maintenance, technical reformation, and equipment retirement. The data stream contains acquisition, communication, presentation, integration and application. In brief, smart distribution networks could be considered as a highly integrated system of electricity flow, information flow, and business flow.

RESEARCH OF THE KEY TECHNIQUE FOR INFORMATION SUPPORTING SYSTEM

A. System Feature

The key of smart grid is to establish an open system for information share. To construct such an information platform, the features of flat structure, multi-level and functional modularization, and flexible configuration could be stressed, as well as the relevancy and integration of information and business. Robustness, flexibility, anti-attacking and self-defence are also essential characteristic of the platform. With reformation of existing information network and development of new system, a smart information sharing platform could be built, and all available resources could be efficiently used and various research and application of new technologies could be possible.

For years, distribution automation and information technology have been widely studied, which could be the foundation of future smart distribution networks. However, it is necessary for some expansion as wide-area, topological and real-time information supporting and advanced technology for data collection, integration, as well as sharing. As for data acquisition, real-time data could be obtained from the existing system, for instance, the EMS system, or a new-built system. Besides, data of maintenance and data from other channels, such as the marketing management system, could also be collected. As for data integration, data related to power dispatch and production management could be focused on.

B. Key Technologies

i) Smart dispatch

Smart dispatching automation is an important extension for an existing dispatching control centre. Intellectualized operation, including fast simulation and modelling (FSM), intelligent warning, operating optimization, preventive control, accident management and restoration, dynamic network visualization, and real-time decision-making, could finally result in the informatization, digitization, automation and interaction of distribution management. The ability to acquire wide-area, global information is the premise for a smart dispatching system. However, it is also inevitable to develop some advanced relative technologies and a comprehensive and distributed data structure for information exchange and analysis. Engineers could conduct precise and accurate power delivering plans only with fully information sharing.

ii) Distribution automation (DA) based on GIS

Developing and building a distribution automation system (DAS) based on GIS could enhance the real-time monitoring and control for devices in distribution networks. Therefore, the duration and the range of outage could be reduced so as to enhance the supply reliability.

During DA construction, Compatibility, openness, security and practicability have to be guaranteed to avoid large-scale reformation or even starting all over. On the other hand, maintenance cost assessment is necessary for balancing the cost in construction and management.

iii) Data platform based on real-time database

To achieve data exchange between various systems and departments, it is necessary to build a standardized integrated data platform for data consistence and completeness. Thereby all sorts of application could share the accordant data integration, display and search. The platform based on IEC 61970/61968 /61850 standard and SVG graphic standard could offer real-time and duly data services by uniform models and graphics. Moreover, it is also essential to take some net security requirements, such as the physical isolation devices for different management information areas separation and mirror-image technology for data synchronization, into account in the platform construction.

iv) Data mining

Various types of load exist in power systems and each may have its own profile. In order to accurately understand the feature of the load, load classification in distribution networks should be done to acquire real-time load data for regularity analysis. This information could assist power producing, marketing and planning.

On the integrated platform, standard interface and high-speed database are utilized to gather data, models and graphics from SCADA system, and a standardized system for load characteristic analysis accumulates data of various load tendency types, and then data-mining technology is utilized to perceive load regularity. Once the statistics and load profile are created, professional supporting services are available to promote network security and economy.

APPLICATION OF THE INFORMATION SUPPORTING SYSTEM

A. Intelligent dispatching technology

Guangzhou Power Supply Co. (GPSC) started to construct a dispatch & centralized control integrated automation system in 2005. This system, currently one of the largest scale and most complex functions in China, comprises of 6 subsystems: SCADA, PAS, AVC, DTS, protection information and network topology analysis. Following SCADA/PAS/DTS integration, source tracing and graphic status management could be implemented. Furthermore, some other new application, such as remote Spare Power Automatic Switching, low frequency load shedding, auto-reclosing and anti-mis-operation, are also designed based on the whole topology.

On the basis of operational centralized automation, GPSC also organizes some other studies, such as "research on operation in the electro-magnetic loop mode" and "spare power automatic switching strategy and its remote control", in which the former studies the feasibility of loop power flow operation and security assessment, while the latter achieves the remote control of substation relay protection. The achievements increase the utilization rate of automatic devices, release the operational potential, and reduce the possibility of breakdown and outage.

In consideration of spare power automatic switching, the steady-state security assessment changes from "N-1" failure analysis to "N-1+M". Short term and even ultra-short-term load forecasting is used for dispatchers to determine the system security. Combining the real-time operational state, the security level of the power grid could be assessed, and security margins, accident potentials and warnings are presented to operators.

B. Automation system based on GIS

DAS in GPSC is constructed from July 2007. Meanwhile, the host station system has already been built with which more than 2000 terminals are connected. After obtaining data from measurements, control and operation systems and 10kV devices, the ongoing DAS, based on GIS, would access the real-time condition of the distribution networks. Now, the system runs in a stable, reliable, economical, advantageous, and open way.

The so-called "uniform platform and distributed applications" structure is adopted in GPSC's DAS. Remote terminal data would be sent to the host station for data collected, exchanged, handled or analyzed. Departments other than dispatch centre could access the host station via optical fibre to implement distribution monitoring, operational management and other daily routines.

All automation systems and information systems could be updated or extended under the standard of IEC61970 and IEC61968 to implement system interconnection. By doing this, the whole system could be maintained uniformly and every application could make use of them.

C. Data platform

Cooperating with Oriental Electronic Co., GPSC started building quasi-real-time data platform. Basing on PI real-time database, models of the whole power grid could be built, in which the power devices, including marketing, distribution and transmission ones from 380V to 500kV, are the core. The models and some of the operational information are saved according to the IEC 61970 standard. Through this platform, modelling, data, and graphic services are available in operation centre or even throughout the network.

Quasi-real-time data platform is built under standards of IEC61970/61968/61850, adopting all-in-one design to integrate models, images, real or non-real time data, and to provide a data exchange and share platform for every application among different systems, which is helpful for data management, display and mining. The interfaces of the platform are accordant with the IEC61970/CIS standard so as to integrate different application systems. Layer structure is utilized in this platform so that data is comprehensively processed for follow-up advanced applications such as inquiry and analysis, generation reporting and data mining.

With the load data, complete network model would help to check planned operational pattern during particular time period, by which the overload, scheduled outage conflicts and influences, risks on weakest link could be analyzed, and intelligent assistant for daily operation is available. By intelligent check, the reliability and security are greatly improved while repetitive outage and workload for staff are reduced.

D. Load analysis and management

The PI high-speed database is utilized on the GPSC's quasi-real-time data platform with standard interface, so, data, models and images could be collected from SCADA, automatic measurement, distribution automation and marketing distribution integration systems to construct the topology from 500kV to 380V with unified models created, and hence improve the load analysis and assessment. Based on dynamic load classification, global multi-dimension and multi-target categorical statistics are achieved while analysis for various load regularity is done and supporting services are available in generation, marketing, planning to promote security and economy.

With the load pattern analysis system, real-time acquisition and management of various load data across Guangzhou region is achieved, and control of different kinds of loads could be possible. The personalized services and overall power quality for different kinds of loads then are available. All in all, the efficiency of power consume could be increased, and losses reduction, economical operation and security would be achieved with this system.

According to different features of different types of loads, foreseeable and pertinent marketing strategy and method could be applied to formulate electricity pricing decision and shift peak-load more scientifically and reasonably. Strategies for system integration and optimization as well as the market leverage could be considered, so as to assure the healthy and well-organized development of power systems with distributed renewable energy.

CONCLUSION

Smart Grid, which bases on distributed data communication, computation and control, introduces some completely original concept to current power systems, and could optimize the power grid benefits as it improves the power utilization efficiency as well as the security of power supply.

For regional power supply companies, it is necessary to carefully tailor the smart grid. The research could focus on power generation and operation, especially on the power supply reliability. The development could be prioritized, starting with market, security, power quality and environment in some mature business sectors. It is very important to integrate the operational information and production management information, and intelligent smart distribution grids could be very promising.

Based on the practical situation of regional distribution system, some of the key techniques of smart grid information supporting system, such as smart operation technology based on real-time global information, distribution automation system based on GIS, power grid integrated data platform based on real-time database and distribution data mining, are discussed, and experience in GPSC is summarized as practical development for these key techniques, which maybe a good example for future reference.

REFERENCES

[1] Shuyong Chen, Shufang Song, Lanxin Li, Jie Shen, 2009, "Survey on Smart Grid Technology", Power system Technology, vol 8, 1-7 (in Chinese).

[2] Chongqing Kang, Qixin Chan, Qing Xia, 2009, "Prospects of low-carbon electricity", Power system Technology, vol 2, 1-7 (in Chinese).

[3] Kai Xie, Yongqi Liu, Xhixhong Zhu, et al, 2008, "The vision of future smart grid", Electric power, vol 6, 19-22 (in Chinese).

[4] Yixin Yu. Wenpeng Luan, 2009, "Smart grid", Power system and Clean Energy, vol 1, 7-11 (in Chinese).

[5] Yixin Yu, 2006, "Intelli-D-Grid for the 21st century", Southern Power System Technology Research. vol 6, 14-16 (in Chinese).

[6] Jianmin Chen, Jian Zhou, Lin Can, 2008, "Substation secondary technology damand analysis for intelligent grid vision", East China Elecric Power. vol 11, 37-38 (in Chinese).

[7] Mingjun Wang, 2007, "Self-healing grid and distributed energy resource", Power System Technology, vol 6, 1-7 (in Chinese).

[8] EPR1, 2004, "Technical and system requirements of advanced distribution automation", Palo Alto, CA, USA:EPRI.

[9] EPR1, 2006, "Profiling and mapping of intelligent grid R&D programs", Palo Alto, CA and EDF R&D, Clamart, France: EPRI.

[10] European Commission, 2008, "European technology platform smart grid: vision and strategy for Europe's electricity networks of the future", http://ec.europa.eu/research/energy/pdf

[11] VON DOLLEN D. 2005, "IntelliGrid: enabling the power delivery system of the future", Proceedings of 9th International Symposium on power-Line Communications, Vancourer, Canada.

[12] The National Energy Technology Laboratory, 2007, "A systems view of the modern grid", Pittsburgh, PA, USA: NETL.

[13] The National Energy Technology Laboratory. The Modern Grid Initiative. Pittsburgh, PA, USA : NETL , 2007.

[14] French Electricity Coporation, 2009, "The Trial Smart Grid to Increase the Efficient of Electricity from Wind Farm", http://www.chinapower.com.cn /newsarticle/1082 (in Chinese).

[15] Ming Lin. Guangyu He, Chen Shen. et al, 2006, "Brief introduction to the IECSA project", Automation of Electric Power Systems, vol 13, 99-1041-7 (in Chinese).

[16] Shijie Xiao, 2009, "Consideration of Technology for Constructing Chinese Smart Grid", Automation of Electric Power Systems, vol 9, 1-4 (in Chinese).

[17] Huafeng He, 2009, "Intelligent Revolution of Power Grid", http://blog.caijing.com.cn /topic_article-5-331.shtml (in Chinese).

[18] Minghuan Jiang, 2009, "Profiles of Smart Grid and Smart Energy Resource", http://www.china5e.com /subject/subjectshow.aspx?subjectid-97&classv-&pageid-1(in Chinese).

[19] Lin Wenbo. Zhang Boming. Wu Wenchuan, et al, 2008, "An On-line Early Warning and Preventive Control System for Static Voltage Stability", Power System Technology, vol 17, 6-11 (in Chinese).

[20] Research Reports International. Understanding the smart grid, RRI 00026 [R]. 2007.

[21] The National Energy Technology Laboratory, 2007, "Modern grid benefits. Pittsburgh", PA, USA: NETL