CONSTRUCTION AND OPERATION OF DISTRIBUTION AUTOMATION SYSTEM BASED ON GIS

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ABSTRACT

The experience on construction and operation of current Distribution Automation (DA) is summarised in this paper. A pilot project of DA based on Geographic Information System (GIS) is conducted and some effective measures for improving the system are discussed considering the problems in practice. Due to the large quantity of distribution devices and frequent changes, a system interface to achieve graphics – models integration could be utilized to solve the data maintenance problem for DA and ensure its applicability. An integrated data maintenance procedure for GIS and DA is proposed to increase the data accuracy and timeliness. Research on the operation and maintenance technologies, functional improvement, as well as advanced application software development for DA system (DAS) are conducted, and a customizable DAS is built to satisfy different needs of distribution application. The results are successfully applied to a large city distribution networks, which illuminates its high theoretical and practical engineering value.

1 INTRODUCTION

The operating status and load distribution of distribution networks could be known in a DAS by monitoring the remote devices and analyzing the system information available. Therefore, it is possible to discover, forecast, diagnose, isolate, and handle the system faults, contingencies timely, and then quick restoration and large- blackout prevention is achieved. This greatly increases the security and reliability of the distribution networks. DA, as a very important part of smart grid, is worth researching [1-6].

The supply security and reliability for most power users is the core issue for a regional supply corporation. With DAS constructed, it is beneficial for increasing the level of distribution management and power supply reliability. On the other hands, real-time system monitoring is available with developed DA technologies, and then it is possible to decrease the duration and affected areas for network faults, as well as to increase the supply reliability. The deeper DA is studied the higher level it could bring the management, maintenance and overhaul for distribution systems to [7-9].

According to China Southern Grid (CSG)'s requirements, Guangzhou Power Supply Co. (GPSC) has started the construction of DA since July 2007. After 3-year operation, the DA system has been developed to a certain scale. The host station was completed at the end of 2008. DA terminal devices are installed from November 2008. By now, 2475 switch board rooms and 14820 circuit breakers have been enhanced with automation functionality. The currents of 7745 distribution transforms are monitored. Remote metering, remote signaling and even remote controlling could be implemented in different areas via optic-fiber or carrier communication or public communication nets.

According to the plan, the construction of GPSC DA would fully complete in 2013, and a coverage of 100% over Guangzhou with DAS classified as Type A, B and C. At that time, there would be 10184 remote control items, 332.7 thousands of telemetries and 221.8 thousands of remote signals.

2 DA CONSTRUCTION

2.1 Overall idea

It is necessary to consider the compatibility, openness, security, advancement and practicality in the construction of DA, so as to avoid large-scale reconstruction or even starting all over. The cost of DA operation could be fully evaluated to increase the cost-effectiveness.

Reconstruction on host system and remote terminals could be the focus of the construction of DA. With economical and convenient communication to obtain data from distribution measurement system, load controlling system and dispatching system, real-time status of the whole distribution networks could be obtained in DAS. At the same time, all operation management systems could be creatively integrated into DA and GIS could also be introduced.

'Uniformed platform – decentralized structure' could be adopted in DAS. A host station is setup where all remote terminal data are gathered. Relevant information is collected from metrology automation, load control, EMS/SCADA, and then exchanged, processed and analyzed to provide dynamic data service for other systems. Different district power supply bureaus could access the host system by optical fiber to acquire data needed for daily monitoring and operating tasks. Automation and information system are upgraded with IEC61970, IEC61968 standards applied to all system interfaces.

2.2 Architecture of DAS in GPSC

The architecture of DAS in GPSC is based on an integrated platform with 2 layers. Some systems, such as GIS, dispatching automation, client calling service, demand-side management, metrology automation and production control, as well as the quasi-real-time database, have already been set up in GPSC. On the basis of DA host station system as well as the quasi-real-time data platform, an unified distribution network data acquisition and production management platform, which conforming with IEC61968 and IEC61970 standards, is built for information sharing among different related automation or management systems with safety protective measures being taken in data exchange. At the same time, different system may focus on its own application and management. Therefore, coordination among these systems and unified maintenance are necessary. The relationship of DAS and other automation systems are shown in Fig 1.

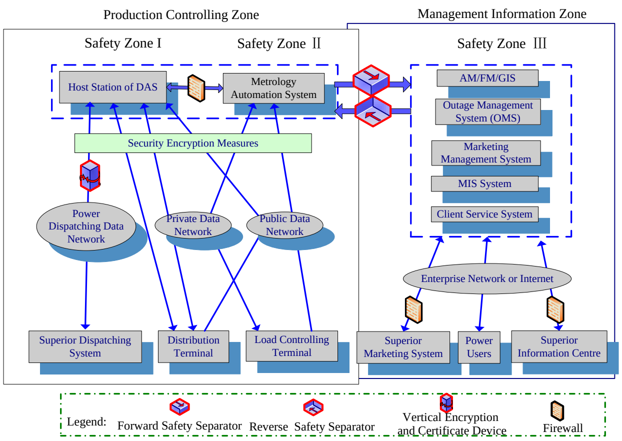

Fig. 1 Relation of DAS and other automation systems

With centralized data acquisition, higher requirements are necessary for the host station. The DAS in GPSC is one of the largest in China with large number of distribution switchgears. The scale of the distribution networks in GPSC is enlarging, so does the monitoring scope of DAS, which requires the DAS could be expanded sustainably in long-term and with the ability to access large amounts of distribution network terminal. The acquired real-time data in the host station system would be up to more than 700,000, which leads to higher stability and data processing requirements for the DA host station system platform.

2.3 Main problems in DA construction and operation

(1) Data maintenance for DAS

There are many devices in an extra-large distribution networks. Therefore, new or upgraded devices are frequently introduced into the DAS, which leads to a burden in data maintenance for DAS. How to guarantee the construction and maintenance of DAS to adapt to the rapid development and changes in distribution networks might be the biggest problems encountered.

The upgrade of the power distribution networks could be very frequent, and the procedure to introduce automation terminals in a project, for example, construction of a new substation, into DAS is very complicated. It may include the check and adjustment for the access scheme, network graphics drawing in host station, and data import and maintenance in DAS. In addition, the time limit for a project is often very urgent and many departments and scheme modification may be involved in the project. So, it is really a challenge to access the automation terminals in DAS. How to finish the access of DA devices quickly and ensure the accuracy of images and data is a key issue in construction and operation of DA.

(2) Advanced applications

The parameters of every power devices and their topologic relation are also available in DAS, which makes the real-time monitoring of the operating states of power distribution equipment possible. How to, on the basis of the existing SCADA of distribution networks, fully develop the advanced applications of DAS to satisfy the requirements in distribution operation and management is a very important work in the further development of DAS.

3 INTEGRATED DATA MAINTENANCE FOR DAS

3.1 Integrated data maintenance technologies for DAS

In order to reduce the workload in system maintenance and to keep the consistency, some principles for system maintenance are established in GPSC, for instance, at the beginning of design for the DA host system, the principle with a single interface for image and data maintenance, i.e. the shared data could be only modified in one automation system, is determined. All the information is integrated based on IEC61970, IEC61968 CIM standards and SVG graphic criterion, which assures the consistency, timeliness and accuracy for the data of distribution networks. Then, data share in different automation systems is possible.

All the images of network model come from the GIS system and dispatching automation system. Based on CIM/XML and SVG criterion requirement, the export of images and models could be done in DAS. Quasi-real-time data platform is used as the center of images, models and data, and all relevant data could be connected to eliminate information islands. According to the requirements for equipment models in DA, the models of equipment at or under 10kV, which would be integrated with the models of GIS as the whole distribution network model, is split from the main power grid models on the quasi-real-time data platform, and some relevant norms are design to eliminate the naming inconsistency of the equipment on the border between main grid and distribution networks. Based on SVG standard, single line diagrams (SLD) exported from GIS, together with the models of main grid from EMS, are merged on the quasi-real-time data platform. So, images and models could be shared among different automation systems. Besides, an incremental refreshing mechanism is designed for upgrading and keeping data consistency.

3.2 Data maintenance procedures of DAS

(1) Data quality control of DA

In the construction of DA and its integrated data maintenances, it is necessary to ensure the data accuracy. DA brings higher requirements for the accuracy of all automation systems, particularly the nomination, affiliation and topology relation of devices in GIS. Due to some difference between GIS and DA in models, image and application, some new requirements might be proposed to solve the data quality problem as the GIS is the source of images and models for distribution devices.

By establishing 'GIS input criterion', GPSC developed some checking routines for topology relationship, device nomination to ensure data accuracy. When some errors exist in device name and its affiliation, GIS is not allowed to publish image and model. The service would be restored after deleting old devices or modifying related device properties.

(2) Timeliness control of data maintenance

It is necessary to ensure the timeliness in data communication when integrated data maintenance method is adapted for different systems. Both technical and management measures could be taken to ensure to transmit the graphics and models of data in time.

In the construction or device upgrading of distribution network, in order to ensure that the DA could obtain the relevant information before field test, it is regulated that GIS should publish images and models during the joint trail procedure instead of installation completed. Accordingly, a debug state of SVG images is added for publishing images and models for field test, and after installation, updating SVG images are provided to ensure the timeliness and the accuracy of distribution data. A real-time incremental transmitting mechanism is also adapted for publishing models, thus the timeliness of splitting, integrating and importing of the models is provided.

3.3 Data maintenance for DAS in GPSC

The GIS, DA and quasi-real-time data platform have been integrated and analyzed since April 2009 in GPSC. With some test on GIS, the data quality problem, such as unreasonable syntax and inconsistency in type description, as well as the image problem, such as system pixel staggering and character overlap, are solved. Then some data exchange specifications are established.

By enacting 'criterion for data exchange between GIS and DA', data input criterion and digital communication procedures of GIS are specified, which, with CIM/XML standard and SVG image solutions, makes the integrated data maintenance for DA system be possible. By now, the DA has imported over 3000 SLD from GIS over 11 districts in Guangzhou.

4. CUSTOMIZABLE AUTOMATION SYSTEM BASED ON A UNIFIED DATA PLATFORM

4.1 Customizable vital power supply system

To satisfy the high reliability requirement of some particular power users in certain scenario, it is needed to provide higher quality monitoring for distribution devices. Thus, new requirements arise. Using integrated device model and topology, as well as the operating and device information from EMS, DMS, GIS, and field automation grid, main distribution topology is joined together to form a unified grid data platform. On this platform, new functions are developed to achieve source track and risk evaluation over the networks. For particular needs, data quality could be improved by optimizing the display and DA functions according to the requirements. Customers could select their interested content and functions to customize the DA system.

Some high requirements for power supply are raised in the 16th Asian Games. A monitoring system based on DA system for the Games is built in GPSC. The network modeling conforms to the IEC61970 CIM/CIS international standard, so application interconnection is available. CORBA intermediates are selected to encapsulate operating system and hardware platform, which provides good environment for distributed operation and interface development. Combining with the highly reliability of power supply for the Asian Games, power assets in both transmission and distribution networks are effectively integrated and some management functions are enhanced, which provides power supply with technically support during the Games.

The relative information and data from transmission and distribution automation systems are merged in the Asian Games monitoring system, which provides a global real-time monitoring for power supply devices ranged from 500kV to 10kV, and even 380V. During the 16th Asian Games, the risk level varied as the requirements for reliable power supply in different scenario. This provided operators of vital power supply with timely and correct information to backtrack the power source with full topology of distribution networks. The supply path could also be displayed with the Asian Games gyms as centers, which greatly help the operation manager to send out dispatching commands.

4.2 Distributed energy access

Following the concept of low-carbon economy, the demand of distributed energy access has been increasing as well. According to the features and capacity of different distributed energy, a flexible way of accessing is acquired. Both network and distributed energy management departments need to monitor the network states neighbor to the access point, though different contents are focused. Therefore, the interior automation systems of EMS, DMS should be joined and flexibly tailored on a uniform data platform, according to their own demands.

In order to enhance the level of access for DGs, it is necessary to launch research on distribution load forecasting and distributed generation access. Combining with the requirements of network access of distributed generation, customer energy storage, mobile energy storage, real-time load connection and VAR/voltage control could be achieved by strengthening the functions of DAS.

4.3 Rapid restoration system

Rapid restoration technology is used to reduce the duration of outage and improve the reliability of power supply. A collaborative rapid restoration mechanism built on the basis of uniform power grid model, asset models and GIS could achieve rapid diagnosis, isolation and restoration.

Through a uniform topology model, the backtracking route of power supply is built up from 380V to 500kV, which could identify quickly the position of faults.

By programmatic dispatch, wide-area spare power automatic switching, remote relay protection, smart black-start auxiliary decision techniques, power supply could be restored as soon as possible through quick operating-mode switch and fault isolation. Network security constraints after faults are also calculated automatically to provide full auxiliary restoration decision functionality.

Based on the real-time data and topologic analysis, risk and fault could be identified and some real-time simulation could be done. With these results, some measures for risk control could be established, and then risk forecast and controlling decision are available.

5 CONCLUSION

In this paper, the current DA construction and operation experience is summarized, and the idea of DA construction basing on GIS is proposed. Combining the real problems encountered during the practical construction and operation, some effective solutions were proposed as followed:

(1) According to the features of distribution devices, which are large quantity, frequent change, system interfaces for integrated image-model maintenance and auto-incremental publishing are used to solve DA data maintenance problem to ensure applicability.

(2) Integrated data maintenance procedures for GIS and DAS are built to improve maintenance accuracy and timeliness.

(3) Taking advantage of uniform network device model and topology, a network data platform is built to flexibly customize the automation system according to deferent demands so as to implement the distributed energy access and satisfied the requirements in power supply insurance and rapid restoration system.

(4) The practice of Guangzhou DAS, Asian Games monitoring system and the research of DG access in this paper are successful and contain high theoretical and engineering value.

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