Research on the Architecture and Key Technology of Data Two-way Interactive Distribution Automation System

Yinghua Song$^{1,2,*}$, Gang Wang$^3$

$^1$NARI Group Corporation (State Grid Electric Power Research Institute), Nanjing, 211106, China
$^2$NARI Technology Co., Ltd, Nanjing, 211106, China
$^3$State Grid Liaoning Electric Power Supply Co., Ltd, Shenyang, 110004, China

$^*$Corresponding author’s e-mail: ssyyhh786@163.com

Abstract. On the basis of analyzing and summarizing the current situation of the construction and use of distribution automation systems at home and abroad, according to the requirements of the use of distribution automation systems, a data two-way interactive distribution automation system architecture design is proposed. In response to the requirements for multi-source data collection in the distribution network, a distribution automation system architecture with partitioned collection and bidirectional data flow is proposed to improve the perception of distribution network equipment. Propose the self-recognition technology of power distribution system and terminal based on IEC61968 and IEC61850 model mapping to realize the fast access of power distribution terminal. Propose a grid integration modeling and global decision analysis method based on model splicing technology to realize multi-dimensional data fusion and analysis applications.

1. Introduction
Since the construction of smart grids has gradually accelerated in 2009, the construction of distribution automation systems has been carried out in nearly 160 cities in China, and the main domestic urban agglomerations have been basically covered. The distribution automation systems are all in operation monitoring, fault handling, and information interaction. It has achieved good construction results and played an important role in the operation and dispatch of the distribution network [1,2,3].

2. Situation Analysis
The power distribution automation system still has the following shortcomings in terms of technology:

(1) Insufficient flexibility of system architecture [4,5]

Internationally, the distribution automation systems of companies such as ABB and Siemens generally include FES, SCADA, DMS and other parts. The FES part is responsible for terminal data channel management and data access, and the SCADA part is responsible for the operation, monitoring and control of the distribution network. The DMS part is responsible for the realization of fault handling, operation analysis and operation optimization of the distribution network.

(2) The efficiency of power distribution terminal access and debugging is low [6,7]

The important characteristics of the distribution network are complex lines and a large amount of equipment. For a distribution network with more than 400 10kV lines, after the construction of the distribution automation system, the number of power distribution terminals that need to be connected...
is more than 1,600. The 104 protocol transmission between the electric terminal and the automatic 
system only solves the problem of data transmission, the meaning of the data is unclear, the necessary 
association relationship between the data is lacking, the terminal equipment lacks the self-description 
function, and the terminal access debugging efficiency is low.

(3) The extended application software has insufficient practicability and cannot adapt to the 
integrated analysis application of multi-application data[8,9,10]

The distribution automation system covers all aspects of distribution network production, operation 
and service. The integration and sharing of data and information in each link, and then the realization 
of integrated analysis and decision-making, is an important trend in the development of current power 
distribution applications. The existing power distribution automation system does not support the 
unified modeling of multiple application data, nor does it support the modeling of new equipment such 
as distributed power sources and electric vehicles. The application software does not support the 
integration of multi-source data forms, state estimation, network reconstruction, etc. Insufficient 
practicality of extended application software.

3. Overall design

3.1. Design Principles

The design of the data two-way interactive distribution automation system follows the following 
design principles:

(1) Provide a broad range of support for distribution network modeling

Combined with the development trend at home and abroad, the design of the data two-way 
interactive distribution automation system fully considers the scale of the distribution network and the 
needs of business system integration. According to the law of distribution network operation, the 
distribution network system requires main distribution and configuration integration, that is, the 
distribution network system has a construction covering the entire network (500kV, 220kV and above 
main network, 110kV, 35kV and 10kV distribution network, and 380V low-voltage users). It also 
supports modeling of distributed power sources, micro-grids, energy storage, and electric vehicle 
charging and swapping stations.

The scale of the system fully considers the planning level of the city's substations, distribution lines, 
distribution transformers, and urban population, meets the development needs of at least 5 years, fully 
considers the needs of static graphics and dynamic real-time data modeling, and supports big data 
processing.

(2) Support cross-regional multi-source data collection interactive mode, and build a generalized 
distribution network automation system architecture

The data two-way interactive power distribution automation system consists of two major 
subsystems deployed in the production control area and the information management area. The 
production control area collects the wired communication terminal. The information management area 
collects the wireless communication terminal, and the two subsystems exchange data in two directions. 
The data two-way interactive power distribution automation system support platform can support the 
district application mode, and the support platform supports the C/S and B/S hybrid architecture.

(3) Comprehensively optimize and enhance the analysis and application functions of the 
distribution network

In view of the technological development trend of multi-application data information integration, 
the distribution network analysis application software should fully consider the actual situation of the 
distribution network application data is not strong, and comprehensively use the real-time data 
collected by measurement, quasi-real-time data and manual data to match the distribution network. 
The network data is supplemented and comprehensively analyzed to realize the effective analysis of 
the data of the operation status of the distribution network, and realize the integrated modeling and 
global decision analysis of the distribution network.
3.2. Architecture design

Following the above design principles, the data two-way interactive power distribution automation system DMS-3220 realizes the architecture system of "one supporting platform, multiple application subsystems". Functionally, the system is divided into three major subsystems: distribution network data collection, operation monitoring, and analysis application. Among them, the distribution network operation monitoring and distribution network analysis application subsystems belong to real-time applications. They are deployed in the safety zone I and can be used for III. District applications provide service support. Distribution network data collection is deployed in District I and District III to meet the requirements of multi-source data partition collection, and two-way data interaction can be realized between the two regions.

(1) One supporting platform

Following the principles of standard form, development, scalability, advancement, security, etc., build a standard support platform to provide general technical support for the development, operation and management of various applications of the system, and provide unified exchange services, model management, Data management, graphics management, and standardized information interfaces meet the needs of various real-time, quasi-real-time and production management services of distribution network dispatching, establish a complete and rigorous distribution network model, and support distribution network data collection, operation monitoring and analysis applications.

(2) Three application subsystems

Based on a unified support platform, it meets the requirements of dispatching operation control and production business respectively. Data collection is the basis for the perception of power distribution terminals, which realizes data collection and interaction of different types of terminals in multiple regions, and provides data support for distribution network analysis applications. Operation monitoring applications are the basis of the real-time dispatching business of the distribution network, and use information to realize the real-time monitoring of the power grid, fault judgment and processing and other applications. Analytical applications complete the effective analysis of the operating status of the distribution network, use the operating data of the distribution network and the result data provided by other application software to analyze and evaluate the operation of the distribution network, and realize the optimized operation of the distribution network.
4. Key technology

4.1. Multi-application integrated architecture design

The data two-way interactive power distribution automation system provides technical support for the flexible combination of multiple application modes including the integration of main distribution, integration of distribution and grabbing, and integration of prefecture and county from the three levels of support platform, data processing, and distribution network application. The design of multi-application integrated system is shown in the figure below.

![Multi-application integrated architecture design](image)

At the support platform level, it focuses on providing unified service and system management and power grid modeling support, realizing real-time database partitioning, master-distribution integrated responsibility area and authority management, and supporting multi-application clustered system management. Dynamically set the real-time library partition range according to the regional setting, and support the synchronization and switching management of master and backup.

At the data processing level, the focus is on the performance and efficiency of multi-application integrated systems. Distribution automation system partition data acquisition is realized through distributed front-end, and distributed SCADA calculation realizes data processing and grid analysis calculations downloaded to the real-time database partitioned power grid.

At the distribution network application level, it mainly realizes the integration of application and display, and realizes the integrated graphical monitoring application of the grid based on the integration of the operation and distribution and the whole grid analysis.

4.2. Plug and play of power distribution terminal based on IEC 61850 and IEC61968 model mapping technology

IEC61850 provides a unified standard for substation automation, and provides a foundation for realizing interoperability between different intelligent devices. The DMS-3220 system applies the technology and methods of IEC61850 to distribution network automation, and combines the widely used IEC 60870-5-104 standard to solve the communication problems between power distribution terminals and automation systems. Finally, the plug and play of the power distribution terminal is realized, which improves the efficiency of on-site construction and maintenance of the power distribution terminal.
The power distribution terminal transmits the equipment self-description information and related information such as the service capabilities of the power distribution terminal to the automation system, and the system can select/subscribe to the services it needs from the service items supported by the terminal. According to the distribution network model information of the system, the automatic mapping function from the IEC61850 model sent by the distribution terminal to the IEC61968 model of the distribution automation system is realized, and the system configuration file of the terminal is generated and sent to the distribution terminal. The power distribution terminal generates the configuration information of the terminal itself according to the received system configuration file, realizes the automatic identification of the power distribution terminal equipment.

4.3. Multi-application data integration whole-grid modeling and analysis
The data two-way interactive distribution automation system supports integrated modeling and model import of high, medium and low voltage distribution networks. Contains high-voltage diagram (110kV/35kV station information, including 10kV outlet switch and load), 10kV feeder part (from 10kV outlet switch to distribution transformer), and low-voltage part (from 10kV distribution transformer to low-voltage user). The modeling principle is shown in the figure below.

4.3.1. Modeling of high-voltage distribution network
Mainly refers to the equipment and lines in the 10kV and above substations. The modeling completely adopts the existing dispatching automation system modeling method and follows the IEC61970 standard for modeling. The plant is used as the modeling container, and the high-voltage distribution network and the medium-voltage distribution network are demarcated. Outgoing switch at 10kV.

4.3.2. Medium voltage distribution network modeling
Mainly refers to the 10kV/20kV/6kV feeder part, which is modeled according to the IEC 61968 standard. The boundary between the medium-voltage distribution network and the high-voltage
distribution network is the 10kV/20kV/6kV outlet switch of the substation, and the boundary with the low-voltage distribution network is the 10kV/20kV/6kV distribution transformer. The medium voltage distribution network model is used to manage the distribution network feeder and station model outside the substation. The equipment container in the distribution network includes two types: feeder and switch station.

4.3.3. Low-voltage distribution network modeling
The voltage level is the 380/220V part, and the boundary between this part and the medium voltage distribution network is the distribution transformer. The main application requirements for low-voltage distribution networks are low-voltage monitoring, fault research and judgment, etc., and accurate low-voltage analysis and calculations are not required. Therefore, low-voltage modeling can usually ignore low-voltage lines, and the key considerations are the distribution transformer and low-voltage switch, the low-voltage switch and the low-voltage branch phase, the hierarchical relationship between the low-voltage branch box and the meter box, and the meter box and the user.

5. Applications
Following the above design, the data two-way interactive power distribution automation system DMS-3220 was developed. The system has been demonstrated and applied in many domestic engineering sites. The pilot project deployed 2 database servers and disk arrays to support the storage of all data. Deployed a DSCADA cluster composed of 4 DSCADA servers for parallel computing and processing. Network real-time data, 4 front-end servers are deployed to receive measurement data sent by all power distribution terminals. Four distributed collection servers were deployed, located in Zone I and Zone III, to collect real-time data from the power distribution terminal.

The main functions include data collection, distribution network operation control and distribution network analysis and statistics, including network analysis, operation mode management, risk early warning and auxiliary decision-making, and safety and error prevention.

6. Conclusions
Based on the analysis of the current situation of domestic and foreign distribution automation system construction and application, this paper proposes the data two-way interactive distribution automation system technical architecture, and focuses on the rapid access of power distribution terminals and grid integration based on IEC 61850 and IEC61968 standards. A number of key technologies such as modeling and global decision analysis, and based on the design, developed the DMS-3220 distribution automation system. The system has been piloted in domestic engineering sites, which fully proves that the technical ideas are feasible and correct.

Acknowledgments
NARI Group Technology Project (524608210002)“Application development of distribution operation and power supply service based on SaaS layer of Internet of things cloud platform”

References
[1] GUO Jiancheng, QIAN Jing, CHEN Guang, ZHANG Wei, DU Peng, CUI Lizhong, SHANG Xuewei. Technical Scheme of Smart Distribution Grid Dispatching and Control Systems [J]. Automation of Electric Power Systems, 2015, 39(1): 226-231.
[2] Yin Zili, Qian Jing, Chen Yuxing, Huang Wenying, Guan Shenliang, Ren Xiaohui. (2016) Dispatching/Distribution Integration Technology Scheme Based on D5000 Platform[J]. Automation of Electric Power Systems. 40(18):162-168
[3] WANG Haoming, TANG Chong, et al. Dynamic Reliability Assessment of Distribution Network Based on Equipment State Evaluation Model[J]. Proceedings of the CSU-EPSA, 2017,27(7):68-74.
[4] WANG Liang. Discussion on application practice of distribution automation. Power system protection and control. 2016, 44(20):12-16.
[5] Lü Yan, DENG Chunjian, ZOU Kun. Design of Portable Antenna Device Control Equipment[J]. Laboratory Research and Exploration. 2017, 36(4):119-122.
[6] LIU Junhong, DENG Zhaoyun, LI Zeke, LI Huanming. Automatic information verification technology of smart substation based plug and play. Power system protection and control, 2018, 46(2):137-143.
[7] LIANG Wumin, ZHOU Shuibin, PAN Jing, WANG Weijie, ZHENG Hao, MAO Lina. A plug and play sensor design method of high voltage equipment. Electrical Measurement & Instrumentation. 2018, 55(6):133-135.
[8] Han Yinfeng, Wang Dong, Kang Xiaoping, Zhang Qihua. (2018)Research on Engineering Issues of Large-scale Application in Automatic Feeder Automation[J]. Distribution & Utilization. 35(3):58-63
[9] Shen Bingbing, Zhang Zizhong, Zhang Weiwei. (2015)Framework Construction Strategy of Power System Interoperability Based on IEC 61968 Standards[J]. Southern Power System Technology. 9(11):13-17
[10] ZHANG Tao, TIAN Bin, ZONG Zhigang, YU Yuan, et al. Planning and Typical Engineering Application of Distribution Automation. Electric Power. 2017, 50(9):44-51.