Research on Power System Automation Communication Technology for Smart Grid

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Abstract: The development of distribution network automation is the inevitable result of electricity market and economic construction. Nowadays, both enterprises and households have put forward higher requirements for the power quality of power grid companies. This forces power companies to ensure continuous power to users, and in the event of a power outage, the normal delivery of power should be restored in the shortest possible time. Therefore, this paper designs a distribution network automation communication system, which provide the functions of data collection, data processing, remote control, distribution network analysis application, etc. It can ensure the reliability of power supply, shorten the time of power failure, and effectively improve the operation management level.

1. Introduction

The structure and components of power system are extremely complex. However, the power system has brought about some very serious problems while benefiting human society. The amount of energy consumed by the power system is too large, and the amount of these non-renewable energy sources is limited. In the long run, energy will be exhausted. The interconnection of regional power grids is unstoppable, but how to solve the safe and reliable operation of large power grids still needs to be studied. Therefore, we need to increase the interaction with users, and constantly improve the automation level of the distribution side.

It is in this context that the smart grid came into being. The construction of smart grid is an inevitable trend of the development of the times and will bring great significance to the society. Firstly, the smart grid can guarantee energy security to a higher degree; secondly, smart grids consume much less energy than traditional grids and are more adaptable to weather conditions; finally, the smart grid is also an important measure to implement the energy sustainable development strategy.

Smart grid consists of intelligent transmission grid and smart distribution network. As far as the situation is concerned, the main reason for the blackout is the failure of the distribution system. Power quality is closely related to the performance of distribution network, and distribution network damage will directly lead to serious faults in power system. As far as China's power system is concerned, the level of the distribution network is far behind the transmission grid, both in terms of automation, intelligence, and self-healing and optimization capabilities of the network. Therefore, automation on the distribution network will bring huge changes to the power system, with realistic economic and social benefits.

2. Overall design of distribution network automation communication system

Distribution network automation is based on primary grid and equipment, with distribution network automation system as the core, comprehensive utilization of multiple communication methods to achieve monitoring and control of distribution system, and through the integration of information with...
related application systems, to achieve the scientific management of the distribution system. Distribution automation system can realize the automation system of medium and low voltage distribution network operation monitoring. It is generally composed of distribution automation main station, distribution automation terminal and related communication systems, and the distribution automation substation can be configured according to actual conditions as well. The design, construction and transformation of the distribution network automation system should be combined with the regional distribution network scale and application requirements, and be compatible with the distribution network operation and management system, so as to meet the safety and economic quality operation requirements of distribution network, improve the power supply quality and operation management level of distribution network.

2.1. System architecture
As mentioned above, the distribution network automation system mainly includes main station, terminal and related communication equipment. The overall architecture of distribution network automation system is shown in Figure 1.

Figure 1. Overall architecture of distribution network automation system

(1) Main station composition and configuration
The main station should be a distributed structure, constituting of hardware devices and supporting software such as servers, workstations, network devices, security devices, clock synchronization devices, etc. the main station critical equipment and software application services should be redundantly configured
The system hardware should use hardware devices such as general-purpose computers that conform to international standards, and use rack type installation. The key equipment should be equipped with dual independent power supply to meet the requirements of stable performance, convenient maintenance and flexible expansion.

1) Server: mainly includes SCADA server, history server, data collection server, WEB server, etc. It has the function of running application services to complete data collection, data storage, calculation analysis, service provision and other functions.
2) Workstation: mainly includes calibration workstations, maintenance workstations, report workstations, etc. It is responsible for running the user interface program and completing the human-computer interaction function of the system.

3) Network equipment: mainly includes backbone switches, data acquisition switches, WEB switches, distribution switches, routers, etc. It is responsible for the communication connection between the various computer devices in the system.

4) Safety equipment: secondary system safety protection equipment such as power special isolation device, vertical encryption authentication gateway, hardware firewall, intrusion detection system, and secure remote dialing product should meet the requirements of equipment selection specifications.

5) Clock synchronizer: provides uniform standard time for each node of the system with a redundantly configured Global Positioning System (GPS) or Beidou system clock set. The clock device should have B code time decoding and network timing function.

6) Application software: application software realizes distribution SCADA, feeder automation, distribution network analysis application, distribution network operation simulation, WEB release, data interaction, etc. All application software must be implemented on a unified underlying platform with a unified human-machine interface.

(2) Substation composition and configuration

Distribution substations are usually placed in substations or large switching stations, divided into communication substation and monitoring substation. Communication substation is only responsible for data collection and forwarding of the connected distribution terminal; while the monitoring substation not only is responsible for data collection and forwarding of the connected distribution terminal, but also has the functions of local monitoring and regional fault handling.

(3) Distribution terminal station composition and configuration

Distribution terminals can be divided into station terminal (DTU), feeder terminal (FTU), distribution transformer monitoring terminal (TTU) and other terminals according to their functional configuration and installation location.

Station terminal (DTU) should be selected for switching stations, ring cabinets and distribution stations; feeder terminal (FTU) should be selected for column switches; and distribution transformer monitoring terminal (TTU) should be selected for distribution transformers.

2.2. Communication requirements

The communication requirements of distribution automation system is shown in Table 1.

Table 1. Communication requirements of distribution automation system

| Data type       | Single terminal data flow | Real-time requirements | Reliability requirements | Safety requirements                      |
|-----------------|---------------------------|------------------------|--------------------------|-----------------------------------------|
| Telecommunication| ≥ 128 bit/s               | Delivery delay < 100ms | 100%                     | Allow public network transmission      |
| Telemetry       | ≥ 1024 bit/s              | Delivery delay < 100ms | 100%                     | Allow public network transmission      |
| Telecontrol     | ≥ 128 bit/s               | Delivery delay < 100ms | 100%                     | Control commands require secure channel guarantee |

Distribution network communication should adopt hierarchical structure of backbone layer and access layer according to the scale of distribution network. The communication hierarchy of distribution network is shown in Figure 2.
3. Design of distribution network main station

The system structure, interface, communication protocol, information and data exchange of communication master station should follow relevant standards and norms to realize information and data sharing. Redundancy configuration is necessary for key equipment and application services such as system server and switch. Switching between primary and standby nodes and application services or any single failure does not affect the normal operation of the system. The main station system supports heterogeneous hybrid platforms, provides standard interfaces and services, and supports the development and unified management of user and third-party application software.

3.1. Power distribution SCADA

1. Data collection

It receives and processes analog, state quantities, electrical energy and various SOEs in different formats. It can summon the collected data according to the set period and perform data summon refresh on the specified area. It can automatically collect or manually recall the historical data saved by the power distribution terminal according to the set cycle timing.

2. Data processing

SCADA handles the status of different formats, correctly determines the accidental remote signal displacement and the normal operation of the remote signal displacement, and has the function of automatic signal filtering. In addition, it handles all types of simulations and provides functions such as validity checking, data filtering, zero drift processing, engineering unit conversion, limit checking, and data quality labeling.

3. Remote control

It implements single point control, condition control and sequence control of the device, and the control process is designed to meet the requirements of the scheduling regulations and has multiple security measures. It can automatically perform sequence control based on user requests, predefined,
application requests, can be executed step by step or automatically, and can manually intervene in the execution process. The control process should be recorded, including the operator's name, control object, control content, control time, workstation used by the operator, control results, and so on.

(4) Partition monitoring

The monitoring system has complete information layering, partitioning and shunting functions. Access information can be divided into different responsibility areas according to the region, substation and line. Responsibility area should be defined offline and online through man-machine interface

(5) Accident recall

In order to facilitate the traceability of the accident process, the system provides the whole process of holographic accident recall retrieval and inversion of accident recall interface. Multiple event triggering function is designed, and the trigger conditions can be customized. Event recall data is saved in full data section, and the model, graph, and data are consistent during inversion.

(6) Man-machine interaction design

The man-machine interface of the system provides a convenient, intuitive and fast method of operation. It has the characteristics of multi-window display, menu-driven, simple operation and accurate display of information. The system provides flexible and convenient mapping mode, so it can quickly call the corresponding screen through the alarm bar in the alarm window. It supports the display of geographic wiring map and can identify the power supply range or stop sound range of the whole network or area on the map. In order to facilitate rapid retrieval, query pages support filtering and querying by region, line, device and selected time period.

3.2. Distribution network analysis application

(1) Network topology analysis

Topology data can be automatically generated during drawing and topology connection error detection is provided. The system supports network topology and dynamic coloring. It can visually distinguish colors, power failures, faults, charging, heavy load, overload, etc., and power outage range, fault range, and power supply range. In addition, it can realize dynamic power analysis and display. For different power distribution networks, different colors are used to distinguish power supply paths.

(2) State estimation

State estimation is to detect, identify and troubleshoot bad data, and display in a list. Based on the real-time information provided by SCADA and the analysis results of network topology and other related data, the system could give the bus voltage, bus load and line current in the distribution network in real time.

(3) Power flow calculation

In a given mode of operation, the system performs set operations, changes the mode of operation, and analyzes the power flow distribution of the system. The setting operation can simulate the opening and closing of the circuit breaker, the line retreat, etc. on the primary wiring diagram. It also supports power flow calculations for regional power flow calculations and distribution line decoupling operations.

(4) Network reconstruction

The system can meet the optimization and adjustment of the distribution network in the normal operation mode, and can also meet the network reconstruction under the new construction, reconstruction and expansion of the distribution network and the fault conditions. The purpose is to reduce the line loss of the distribution network and optimize the system economy by optimizing the operation mode of the distribution network. When the distribution network fails, the system adjusts the network operation mode to restore the power supply in the non-faulty area and improve the reliability of the power supply.

3.3. Distribution network intelligence application

(1) Distributed power access and application
Intelligent application has the function of monitoring and managing the access, operation and exit of distributed power supply and micro grid, and provide corresponding optimal control strategy to ensure the safe and economic operation of power grid.

(2) Fast simulation of distribution network
According to the collected real-time data, the system carries out comprehensive data analysis technology, actively analyzes the operation status of the distribution network, quickly finds the weak links in the operation of the distribution network, and accurately captures the monitoring points.

(3) Intelligent early warning
Through real-time measurement of distribution network information, combined with climate, environment and natural factors, the system can predict the trend of distribution network operation, and evaluate the safe operation level of distribution network, and thus put forward corresponding security early warning and preventive control strategy.

(4) Self-healing control of distribution network
In the area of feeder automation, according to the operation status of distribution network, the corresponding control can be implemented through certain control strategies, which can make the distribution network transfer from the current operation status to better operation status.

4. Design of distribution network substation
(1) Distribution network
The communication substation communicates with the power distribution terminal, the power distribution main station and other intelligent devices, forwards the collected information and its operating status to the power distribution main station, and forwards the control information of the power distribution main station to the power distribution terminal. It can perform communication channel monitoring and channel failure alarms, support local and remote maintenance, including parameter setting, operating condition display, system diagnosis, and self-recovery function. In terms of interface, the communication substation has RS232/RS422/RS485 interface and Ethernet interface. The number and type of interfaces can be configured, and it has independent RS232 or Ethernet maintenance interface.

(2) Monitoring substation
In addition to all the functions of the communication substation, the monitoring substation should meet the following requirements:
1) With analog acquisition, status acquisition, receiving and executing remote and reset commands;
2) Can detect and identify regional transient faults and permanent faults, identify faults such as phase-to-phase shunt circuit and single-phase grounding, and have the function of identifying multiple faults; fault types and related information are reported to the master station actively;
3) Record and upload the load data of the feeder power failure time, with the functions of event sequence recording, historical data storage, and historical data supplementary uploading;
4) Can view real-time data, query and export historical data, with remote control, manual setting, and communication message monitoring function;
5) When the signal of the master station is received, the GPS or Beidou clock signal can also be used.

5. Conclusion
In order to build a business-oriented, service-oriented, integrated and modern power supply enterprise, and improve equipment level and operation management level of distribution network, based on existing automation technology, this paper designs a distribution network automation communication system, and presents its architecture, application functions, performance indicators, and system configuration of the distribution network automation system.

Practice shows that, the system is proved to be advanced and has good scalability, compatibility and maintainability. It can ensure the reliability of power supply, shorten the time of power failure, and effectively improve the operation management level. And research results of this paper have certain value for guiding the design, construction and transformation of distribution network automation system.
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