Research and Implementation of The Fault Information System FOR Relay Protection Based on Cloud Computing Technology

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Abstract. With the continuous development of smart grid technology, it is of great engineering application value and urgent practical demand to collect and manage more intelligently the operation and fault information of relay protection in 110kV and below substation. With the introduction of "cloud computing" technology, a cloud platform of fault information with good expansibility, high stability, loose coupling, strong reusability and convenient maintenance could be built up, which is the core of the system construction. In order to make full use of the existing data network channels and network resources in 110kV substation, a fault information system of relay protection, with its sub-station modeling and communication management, is presented based on "cloud computing" technology to realize a more efficient and convenient relay protection exchange between 110kV substation and the dispatching control center.

Keywords: Fault information system, cloud computing technology, relay protection; smart grid, communication management.

1. Introduction
With the continuous development of operation and maintenance on smart grid, the real-time monitoring and fault information management technology of relay protection has made great progress. The traditional relay protection fault information sub-station system of 220kV and above substations is installed in substations. When a fault occurs, the system should obtain the SOE event information and recording files from relay protection devices in time, carry out relevant pretreatment (including information filtering and classified storage) in the substation, and transform fault data in an unified date specification to fault information master-station which is in dispatching control center. The classification and integration of information from installations of different type and from different manufacturer also costs much time and money.

The data standardization, daily maintenance and management of relay protection devices in 110kV and below substations is greatly different from 220kV and above substations. In order to centralized processed and analyzed the information from different devices conveniently, the key point of system structure design is to cut the cost of construction and maintenance and improve the practicability and reliability, while not reduce the stability and security.

The fault information system should follow these principles: do not affect the normal operation of existing equipment, do not affect the process of the original system and do not change the device
interface and network resources of the original system. The practice has proved that the fault information system based on cloud computing technology can follow all the principles above.

2. Cloud computing technology
Cloud Computing is developed from Parallel Computing, Distributed Computing and Grid Computing. It is also a mixed evolution of Virtualization, Utility Computing, IaaS, PaaS, SaaS, and other concepts. The fault information system based on "cloud computing" technology has the following technical characteristics:

1) Variable size.
"Cloud computing" can use a server in a super-large scale, or a small scale based on real-time needs.

2) Virtualization.
Users of cloud computing can obtain application services in anywhere through a variety of terminals. The requested resources come from the "cloud" rather than accessing a fixed physical server. With network services, users can achieve a variety of data computing and analysis, even supercomputing.

3) High reliability.
"Cloud" will store multi-copies while its computer nodes are identical and interchangeable. Thus cloud computing is more reliable than local computing.

4) Generality.
Cloud computing is not for a specific application, but a great variety of applications. It also supports multiple applications running at the same time.

5) High scalability.
The scale of "Cloud" can be dynamically regulated to accommodate the scale of applications and users.

6) Extremely cheap.
First, cheap nodes will be mainly chose because of the multi-copies strategy. Second, users will not have to afford the increasingly high cost of data center management. Last but not least, resource utilization will be improved, which leads to a deduction of the average cost.

3. System overview
The fault information system is an information processing system that is composed of computer hardware and software, network devices, information resources and a series of business rules. The system is generally built on a physically independent hardware environment. The system can access those equipment in the substation through its own or external interfaces. The networking architecture of the system is simple as it is managed through the local engineer station in the substation. With the development of networked and unmanned operation and maintenance technique, it comes up a great challenge to realize a centralized data interaction, operation and maintenance of regional sub-stations in complex network environment.

In a traditional relay protection information sub-station system, on-site debugging and equipment maintenance are usually adopted to ensure the stability of system integration and data transmission. Thus, any change of an accessed equipment would bring field maintenance of the sub-station system. Based on physical equipment, those distributed systems can collect information from the corresponding substation equipment, instead of from the regional power grid, which leads to lower scalability.

Based on cloud computing technology, the fault information system for relay protection will easily realize the cloudily data process in substation, both in technique and application. And the system on the Cloud is easy to maintain. The challenges are, business system modeling calls for more normative definition, computational resources need to be allocated appropriately and monitored in time, the system should be accessed seamlessly by the master-station, and centralized data processing gives a higher request to the security and stability.

As a result, to build a fault information system for relay protection, based on cloud computing technology, is fraught with many technical challenges. This paper focus on how to make sure that the
new cloud platform would adapt different device interfaces, networking protocol and interactive mode, while realizing centralized data collection and dissemination on the basis of network security.

4. The structure of the fault information system based on cloud computing

4.1. Basic Principles
The fault information system, based on cloud computing technology, can run multiple application instances on the same physical host computer. Every application instance of sub-station is independent of each other.

In the centralized fault information sub-station system, the data interception service and data interaction of every instance are realized on the virtual system platform.

When build virtual networks, the physical host computer can create many different IP addresses in one network segment on the demand of the relevant sub-station instance.

The actual data interaction between a sub-station instance and the relay protection equipment is effected through the same physical network.

Each sub-station instance can only access its own virtual network. Many different sub-station instances share one physical host computer.

In the centralized fault information sub-station system, sub-station is defined as the owner of the virtual network. Each sub-station instance can be assigned one or more virtual networks, then standard IEC61850/GW103 service is provided through the virtual network. Although the sub-station instance is limited in its own virtual network, servers of virtual network can communicate with each other. Therefore, different sub-station instances cannot use the same IP address.

4.2. Implementation Method
In dispatching control center, the centralized fault information sub-station system and network address isolation and mapping system are deployed. In substations, network address isolation and mapping equipment is deployed. In accordance with the original communication specifications, the centralized fault information sub-station system could communicate with relay protections in substations, through network address isolation and mapping system, to access the operation and fault information.

The typical topology of the system is as follow:

![Fig.1 The typical topology of the system](image)

The centralized relay protection sub-station system on the dispatching side consists of four sub-systems, which are virtualized operation management sub-system, relay protection information
processing sub-system, network isolation and mapping sub-system, and data publishing sub-system. All the hardware is deployed in the dispatching computer room, so as to meet stability and reliability requirements of data collecting and processing. According to the different quantity of substations and functional requirements, the configuration of this system can be regulated.

The centralized relay protection sub-station system is deployed in AREA II of the dispatching data network. As the connection of AREA II and AREA III, it demands high stability and security. In order to improve the reliability, the system uses two-path redundant configuration and can be hot-standby in different places. As a communicate hug between sub-stations and relay protection, this system also takes the responsibility of data delivery. The large database in the system takes the task of front-loading communication, data storage, computing analysis and data backup.

Both baes on the specification GW103 or IEC-61850, this system could communicate with the relay protection master-station system seamlessly. Through the existing network, the system could access to the master-station system on the original communication protocol and support all original function, while satisfying the safety requirements.

As network transmission channels between the centralized relay protection sub-station system and relay protection in substation, the network address isolation and mapping system on the dispatching side could exchange network or serial data with the network address isolation and mapping equipment on the substation side. The function of network address isolation and mapping system is as follows: encrypting transmission of the network data, network address mapping, and isolation virtual network data transfer channels.

4.3. Comparison with the traditional fault information system

The traditional fault information system is different from the fault information system based on cloud computing. The comparison is as follows.

| Item               | The fault information system                                                                 |
|--------------------|---------------------------------------------------------------------------------------------|
|                    | **Plan A: traditional**                                                                      | **Plan B: based on cloud computing**                                                          | **Analysis**                                                                 |
| Data flow          | The fault information goes from the relay protection in substation to the fault information  | The fault information goes from the relay protection in substation to the centralized fault    | Since more data is transferred from the substation to the dispatching control center, plan B requires more network bandwidth than plan A. |
|                    | sub-station equipment in substation, and then to the fault information master-station system | information sub-station system via the network address mapping system, and then to the fault |                                                                                  |
| Information        | Information is preprocessed and forwarded by fault information sub-station equipment          | Information is sent to the dispatching control center, then processed and filtered by the     | In the dispatching control center, more comprehensive data can be accessed by plan B than plan A. Thus, more advanced applications can be developed. |
| processing         |                                              | centralized fault information sub-station system                                             |                                                                                  |
| Network security   | In state grid, the security of the fault information system is checked by the substation     | The security and confidentiality of data communication is guaranteed by the network isolation  | Both schemes can realize the security protection of communication.                  |
|                    | network security monitoring platform. The security and confidentiality level of relay         | mapping system through encrypted transmission strategy.                                      |                                                                                  |
|                    | protection external communication is high.                                                  |                                                                                             |                                                                                  |

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Tab.2 Project Implementation

| Site       | Plan A: the traditional fault information system | Plan B: the fault information system based on cloud computing | analysis |
|------------|-------------------------------------------------|------------------------------------------------------------|----------|
| Substation | 1. config communication point table and debug the sub-station equipment.  
2. check data in the relay protection.  
3. config communication point table for master-station.  
4. communication debug with the master-station system. | 1. config network address mapping equipment.  
2. communication debug with the dispatching side. | Plan A: all the work, such as config and debug, needs to be completed in substation. Plan B: network config needs to be completed in substation, and other work can be done in the dispatching side. Workload in substation is greatly reduced. |
| Dispatching center | Communication debug with the sub-station equipment | 1. Communication debug with the relay protection in the substation.  
2. finish sub-station modeling and config communication point table.  
3. check data in the relay protection in substation.  
4. config communication point table for master-station system. | |

Tab.3 Daily maintenance

| Site       | Plan A: the traditional fault information system | Plan B: the fault information system based on cloud computing | analysis |
|------------|-------------------------------------------------|------------------------------------------------------------|----------|
| Substation | Under the premise of the data network maintenance interface is opened, some maintenance work can be done in the dispatching side, but others must to be done in substation. | Under the normal condition of the network address mapping system, all maintenance works can be done in the dispatching side. | Plan A: a part of problem can be solved in the dispatching side. Plan B: all problem can be solved in the dispatching side. |
| Dispatching center | 1. maintenance the fault information system.  
2. maintenance the network channel. | 1. maintenance the fault information system,  
2. maintenance the network address mapping system. | The maintenance workload is no difference for the fault information system and the network between plan A and plan B. |
Tab.4 Software/hardware configuration

| Site          | Plan A: the traditional fault information system | Plan B: the fault information system based on cloud computing | analysis                                                                 |
|---------------|------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------------------------|
| Substation    | 1. the fault information sub-station equipment  | The network address isolation and mapping equipment          | Compared with Plan A, the hardware cost of plan B in the substation is greatly reduced. |
|               | 2. the fault information management software   |                                                             |                                                                          |
|               | 3. cabinets                                   |                                                             |                                                                          |
| Dispatching center | 1. The fault information master-station system | 1. the centralized relay protection sub-station system       |                                                                          |
|               | 2. servers                                    | 2. servers                                                  |                                                                          |

5. Application
With the development of the smart grid, The Fault Information System FOR Relay Protection Based on Cloud Computing Technology is researched and developed by STATE GRID XUANCHENG ELECTRIC POWER SUPPLY COMPANY. This system strengthens the daily management of relay protection in substation and improves the information support ability for maintenance work.

Based on cloud computing, the system is designed as a relay protection management and fault monitoring platform of 110kV power grid. As it is centralized modeling, monitoring, operation and maintenance, this system could synthesize all the information related to relay protection. With the shared real-time information, the operation and management of relay protection in the 110kV power grid is improved dramatically. When an accident occurs, it provides quick decision support for dispatchers.

Fig.2 The centralized sub-station system

5.1. System configuration
- Hardware configuration is as follows:
  a) Dispatching data network in AREA II: one server for master-station, one Forward Isolating Device, one reverse isolating device, two servers for the centralized sub-station, two network switches.
  b) Dispatching data network in AREA III: one server for data publishing.
- Software configuration is as follows:
  a) Master/Sub-station Communication Module: Sub-station communication protocol, Command service program, Data warehousing program, Wave file intelligent filter program, which are all run on Linux.
  b) Master-station Data Processing Module: IEC61850 model file import tool, equipment configuration tool, screen rendering tool, screen display tool, which are run on Windows.
  c) AREA II/III Data Synchronization Module, which is run on Linux.
  d) Web Service Module.
e) Report Management Module.
f) Sub-Station Data Processing Module.
g) Network Address Isolation and Mapping System: Network address communication mapping management module, serial address communication mapping management module, external data access security authentication and isolation module, device parameter configuration and management.

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**Fig.3** Sub-station communication modeling flow chart

**Fig.4** Sub-station configuration
5.2. Construction period
It takes six months to build this system. In XUANCHENG City, all the 43 110kV substations are integrated in the system to achieve centralized modeling, monitoring, operation and maintenance.

5.3. System operation status
The operation and maintenance mode of this system is master-station with centralized management. One year after constructed, all the 43 110kV substations in this city is accessed to the system already. The access ratio of the relay protection in substation is 92%. The accuracy of sampling and catching rate of faults are high to 100%. Baes on Cloud computing technique, data is stored and intelligently processed on this centralized management platform. There is no need to go to and from the substations frequently, so efficiency improved.

6. Conclusion
In this paper, a technical program of fault information system for relay protection is presented based on Cloud computing technology. There are several advantages of this technical program: the original operational mode is preserved; the date collection is integrated and external interfaces are uniform; programs with different standards are compatible with this system; the development of a new sub-system does not affect the operation of original system; it is highly scalable, easy to operate and maintain, and low cost in construction and maintenance.

It is predictable that this system will be constantly improved with the developing Cloud computing and smart grid technology.

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