A NEW ARCHITECTURE OF CENTRALIZED PROTECTION SUITING FUTURE DEVELOPMENT TREND OF DISTRIBUTION NETWORK

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ABSTRACT

With the deepening of China's urbanization and the trend of multi-source distribution network is more and more obvious, traditional local protection cannot solve the new emerging fault recognition problems. Urban land tension makes the construction and reconstruction of substation particularly difficult, furthermore, long recovery time of secondary equipment becomes the bottleneck restriction of power system restoration after catastrophe. This paper proposes an integration secondary equipment based new architecture of distribution network named Protection Intelligent Center. The center takes over most functions of the former substation protection and automation. On one hand, the center can optimize protection principle. On the other hand, the center also alleviate the pressure of substation area in the city by concentrating the substation's secondary equipment and simplify the rebuilding process after the disaster of regional grid. Then explain the function concept, overall architecture, configuration and rapid disaster recovery of Protection Intelligent Center. This architecture provides a reference for the construction of urban intelligent power distribution substation.

INTRODUCTION

With the vigorous development of the national economy, China's urbanization level has been deepened. With distributed generation, energy storage device, and electric vehicle connected into the power systems, multi-source trend of distribution network is increasingly obvious [1]. Existing local protection cannot solve the new emerging fault recognition problems [2-3]. At the same time urban land tension makes the construction and reconstruction of substation particularly difficult, urban compact substation and the underground substation not only cost more but also bring much inconvenience to operation and maintenance of equipment [4], furthermore, long recovery time of secondary equipment becomes the bottleneck restriction of power system restoration after a disaster. Consequently, breakthrough to new protection architecture meeting the needs of distribution substation such as area miniaturization, high reliability, flexible multi-source distribution network protection and adapting to the informatization and intelligentization trend of the grid is in urgent need.

In recent ten years, the rapid development of information technology makes the interaction between wide-area information possible, the bottleneck restriction of substation protection and control technology is gradually disappearing, which provides an opportunity to solve the problem mentioned above. Application of high performance microprocessor, high speed communication network and theoretical research of the integrated protection [5], thus making modular design and function integration of protection and control equipment possible. Paper [6] proposed a centralized protection facing to the whole substation. Paper [7] proposed a centralized backup protection within substation. Due to the application of IEC61850, sharing and interaction of information between and within substation have been realized, therefore, using the information of other equipment or substation to promote the performance of protection will become possible [8]. Paper [9] introduced an integrated intelligent protection unit based on transient protection, integration protection and wide-area protection.

As intelligentialize is the inevitable tendency of the development of relay protection., based on concept of segregation of primary equipment and secondary equipment, a new architecture named Protection Intelligent Center is proposed in the paper. Based on the integrated two-way high-speed communication network, Protection Intelligent Center divides protection function accomplished by multiple local protection from its substation primary system, and centrally deploys the protection function in a remote integration protection center, and integrates wide-area protection based on panoramic information. With this method, the center can not only make the optimal protection scheme based on the panoramic and local information, but also reduce the area of substation in the city by cancelling the master control room and concentrating the substation's secondary equipment. By adopting all-in-one Secondary Device which integrated local measurement and simple protection function; also the paper propose a fast recovery strategy needless of secondary system setting and debugging after grid catastrophe. The architecture can effectively enhance the robustness and flexibility of regional multi-source distribution network.

BASIC CONCEPT OF PROTECTION INTELLIGENT CENTER

Protection Intelligent Center is a new architecture protection system based on integrated two-way high-speed communication network with the latest sensor and measuring technology, equipment technology, and modern decision making system. Designed and constructed under the principle of "integration, intelligence, modular", conforming to the technical specification of the smart grid operating system, Protection Intelligent Center can put forward complete protection and control strategy to ensure safe and reliable operation of power grid.

Protection Intelligent Center has the following functions:

- With the backup of local protection by Protection Intelligent Center, local protection will upgrade to double protection including the center remote protection and the original double protection will become triple configuration, which can reduce the possibility of total substation electricity losing and improve reliability of protection system. At the same time center backup will contribute to system reconstruction by providing flexible remote protection service after grid catastrophe.
- By centralization of several local protection and integration of panoramic information, Protection Intelligent Center can realize higher performance of main protection and backup protection.

As shown in Figure.1, deployed with backup server, data server, application server, operate and maintain work station, center layer is located in a third-party location with high anti-disaster ability. Local layer adopts distributed and centralized structure, an all-in-one Secondary Device handles the protection and control function of several bays, by configuring multiple all-in-one Secondary Devices, realizing the coverage of protection and control function of all bays within the substation

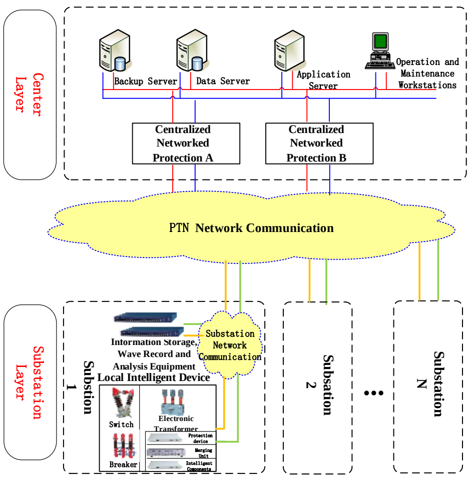

Figure 1. The framework of protection intelligent center

THE STRUCTURE AND FUNCTION OF THE CENTER LAYER

The structure of the center layer

The center layer is divided into two modules: centralized network protection equipment, operation maintenance monitoring and management system. Network protection equipment is constituted by the backup server, data server and application server, they together complete the backup of the local protection and better performance protection. The operation maintenance monitoring and management system configures operation and maintenance monitoring server and workstation to complete the functions of operation monitoring, system configuration, equipment maintenance, offline analysis of centralized network protection system.

The function of the center layer

Protection of remote multiple configuration.

The backup server of center layer stores the mirror image of the local protection. Remote protection of the central layer whose software-hardware system and functions are the same with the local protection of the corresponding substation can be established. According to the local doubling protection and characteristics of different primary equipment, the multiple protection criterion containing the voting and coordination mechanism for each primary equipment is set up. When the local protection is in good condition, considering the reliability of the remote protection, Protection Intelligent Center can export backup protection, namely the priority is lower than that of the local doubling protection; when one of local main protection exits for repairmen, Protection Intelligent Center and another protection equipment will constitute a remote doubling protection. With the safety and reliability of the communication platform guaranteed, the decision weights of remote protection can equal to that of local criteria, namely three sets of protection can make decision equally when taking the protection tripping strategy of voting mechanism. When all the local protection is lost, local functions will be transferred to the center, center layer takes over all substation protection completely.

Wide area main/backup protection.

For the lines whose protection setting is difficult because of multi-source, multi-branch and multi-level cooperation, wide area differential protection is adopted to improve the speed, sensitivity and selectivity in order to remove fault components within the region quickly. While backup protection system is based on real-time voltage information, current information, circuit breaker status information of the regional power grid and action information of main protection etc, wide area backup protection based on the longitudinal direction information and the longitudinal distance information can be adopted to discriminate fault element (bus, transmission lines, transformers, etc.) within the regional network. When the main protection or breaker fails, wide area backup protection isolates fault according to the optimal tripping strategy. At the same time, transplanting the last line of the traditional local protection such as the zero sequence four segment current protection to the Protection Intelligent Center as backup protection, which ensures that the faults of regional power grid can be removed.

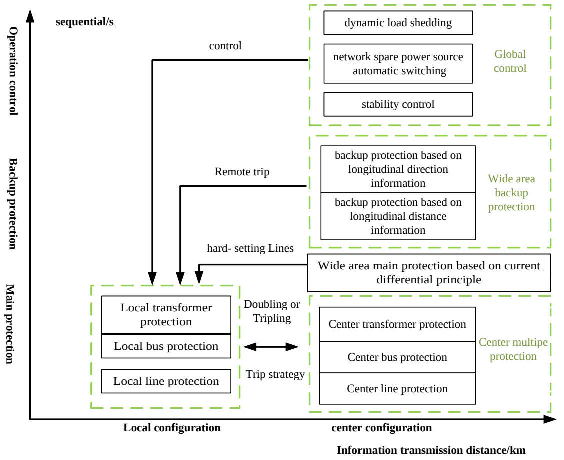

Figure2. Wide area-local protection cooperation diagram

Regional control function.

The Protection Intelligent Center will integrate the functions of dynamic load shedding, equipment automatic input and stability control, and realize the coordination and cooperation mechanism of protections based on information sharing.

Fast disaster recovery of the secondary system

When the power grid recovers from the disaster, the main power grid can be reconstructed quickly through mobile primary equipment, but the recovery and reconstruction steps of the secondary system are cumbersome in the past, which is a bottleneck restricting the speed of power grid restoration. After using the integration center, on the premise that the Protection Intelligent Center is preserved intact, the reconstruction of the primary and secondary system can be completed by reconstructing 1 optical cable to every reconstructed substation. If using the emergency communication method based on wireless sensor ad hoc networks, fast reconstruction of communication channel without any detour path can be completed, which an exempt from complex setting and debugging of the secondary system. The design of the secondary protection system proposed in this paper is not only conducive to the disaster reconstruction, but also reduce the cost of the secondary equipment installation and maintenance.

In the process of power system restoration, the topology structure may be changed. Therefore some protection setting values need to be readjusted. In this regard, the wide area differential protection can replace the traditional current protection to avoid the complex setting and debugging of the secondary system.

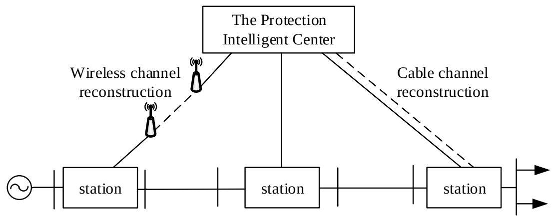

Figure 3. Rapid recovery of the secondary system diagram

THE STRUCTURE AND FUNCTION OF LOCAL LAYER

The structure of local layer

Local layer is composed of primary and secondary devices in substation. Primary devices includes electronic transformers, circuit breakers, knife switches and so on. Secondary devices such as merging unit, protecting device, intelligent component are integrated as secondary all-in-one devices. Simultaneously, an integrated equipment gathering the function of record, storage and analysis of the three state data is deployed in substation.
The internal structure of the All-in-one Secondary Device is shown in Figure.4. SAV sampling module can collect real-time data, mainly including voltage, current and breaker status. Also, and preprocess the collected data. Besides, All-in-one Secondary Device can share information with communicating module. General-purposed computing module can read the necessary electrical information within Ethernet to identify faults and send tripping signal to tripping module.

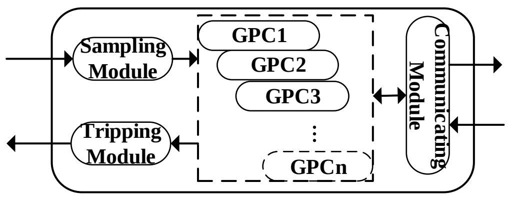

Figure 4. Inner Structure of All-in-one Secondary Device

The function of local layer

A distribution centralized structure composed of multiple All-in-one Secondary Devices is adopted in the local layer. The All-in-one Secondary Devices can realize real-time process and comprehensive utilize of massive concurrent data orderly, and communicate with other All-in-one Secondary Devices through LAN and WAN. Single device can collect voltage and current measurement in the primary side as well as switch signals, such as the position nodes of breakers. It can realize the fast protection by its own processor by the method of local measuring and local tripping. Meanwhile, a plurality of all-in-one devices can constitute united group collaboration, and provide comprehensive information for a cross bay protection such as transformer differential protection, bus differential protection and so on.

The cooperation of All-in-one Secondary Devices

Bus differential protection for example, taking the bus section operation into account, the distribution centralized structure as shown in Figure.5. All-in-one Secondary Device 1 takes the charge of transformer low voltage side, device 2takes the charge of the outlet line L1 and L2, device 3 takes the charge of the outlet line L3 and L4.

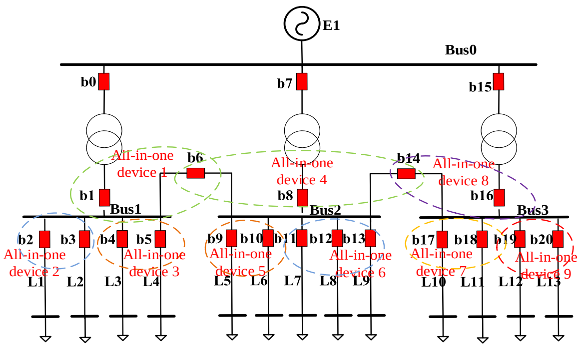

Figure 5. The distribution centralized structure

Typically, the All-in-one Secondary Device that charges the bus inlet line and the bus tie is set to be the main device (device 1 in Figure.5). The All-in-one Secondary Device that charges the bus outlet line is set to be the slave device(device 2 and device 3 in Figure.5). The protection of bus 1 need to be covered by the cooperation of All-in-one device 1, 2 and 3. The specific implementation process is shown in Figure.6.

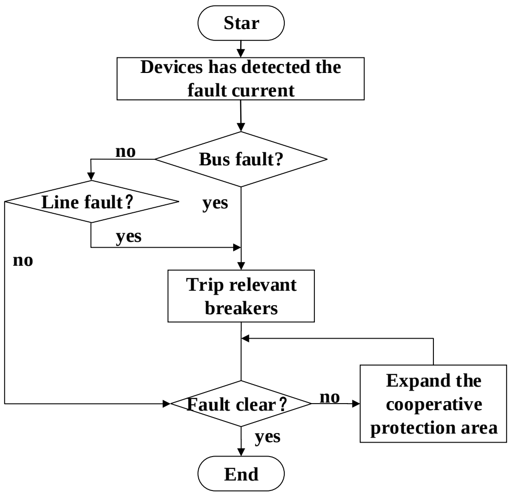

Figure.6. The cooperative process of All-in-one Secondary Devices

The main devices not only participate the cooperation with other devices, but also interact with the superior centralized wide area. The voltage and current electrical measurement of primary devices, the position node of circuit breakers and knife switches are upload as a remote backup.

THE STRUCTURE AND FUNCTION OF COMMUNICATION NETWORK

Network between local layer

The communication between local layer and center layer can be implemented by PTN (Package Transport Network) network or SDH (Synchronous Digital Hierarchy) network. For the area with SDH network laid, an extra PTN network is needed to improve the reliability. For the area without SDH network, two PTN network can be installed directly. With two independent communication network installed, the fast reliable transmission of information between center layer and local layer can be realized. Information of local layer is uploaded to center layer by exclusive access equipment as shown in Figure 7.

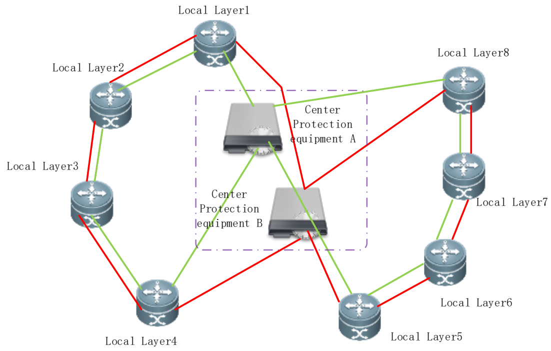

Figure.7. The network structure of Protection Intelligent Center.

Network within local layer

In each substation of certain protection area, two mutually independent communication network is installed, by which the equipment of local layer provide two-way data to connect with external network, realizing the bidirectional data transmission between local layer and far-end center.

Each network has to support cross transmission of two-way data to guarantee anti failure ability of every single point from local layer to center layer.

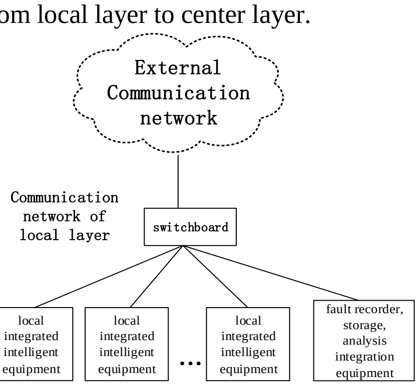

Figure. 8. The network structure of local layer

Time synchronization

Applications such as longitudinal differential protection, the entire network synchronization phasor dynamic monitoring, etc., are on the foundation of tine synchronization, therefore, from the perspective of entire network, taking 1588 time synchronization into consideration is a must. Based on IEEE1588 time synchronization mode, time synchronization of entire network can be realized as the two mode in Figure.9.

- Mode 1:time synchronization between local layers can be realized by GPS(Global Positioning System), as Figure.9(a). Absolute time serial data and the second pulse signal from GPS receiver installed in each local layer are input to the GC within the local layer, which means clock synchronization of each layer GC is guaranteed with the help of GPS.
- Mode 2: time synchronization between local layers can be realized by IEEE 1588, as Figure.9(b). BC(boundary clock) of every local station has to synchronize with the IEEE 1588 of primary station, which needs the support of entire network communication.

Mode 1 realizes time synchronization by GPS, while synchronizing by IEEE1588 within local layer. Compared to the existing GPS time synchronization, this mode is needless of hard connection, though the mode not only increase hardware investment of IEEE1588 but also increase the time synchronization error. Mode 2 realizes time synchronization by IEEE1588 between and within the local layers economizing the investment of GPS receiver. In terms of the whole network, GPS only offers an absolute reference time, the whole network can be synchronized while the satellite communication network suffered damage or interference, however the whole network time is different from the standard time. The drawback of mode 2 is the increasing investment of hardware supporting for IEEE1588, and with the network expanding, the node increasing, more rigorous testing is needed for the accuracy of time synchronization. In terms of digital substation implementation, mode 1 will become the preferred because of its simplicity and feasibility. Future application of mode 2 depends on the need of time synchronization precision requirement and the wide area communication network supporting IEEE1588.

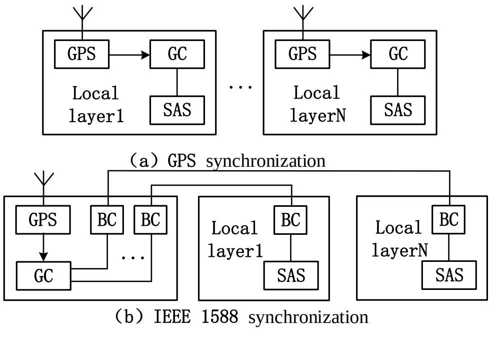

Figure.9. time synchronization of IEEE 1588

CONCLUSION

This paper proposes the concept of Protection Intelligent Center, interpret its overall structure, function of the two layers and the cooperation between them. After analyzing the structure of communication network and its synchronous scheme, the paper proposes a network communication scheme that can be applied to new generation of intelligent substation. The Protection Intelligent Center realize the optimization of protection principle, miniaturization of substation and fast recovery after catastrophe, enhancing the security and flexibility of operation as well as system robustness, at the same time promoting the development of information sharing and function integration.

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