Analysis on the Comprehensive Applications of Relay Protection Fault and Relay Protection for Electrical Equipment

Piaopiao You

North China University of Water Resources and Electric Power, Zhengzhou, Henan, 450046, china.

ypphaoyf@163.com

Abstract

The increasing demand for the quality and safety of power grid construction in China has also improved the attention to relay protection. In relay protection, especially in the protection of medium and low voltage distribution network, the accurate localization of the fault positions is the prerequisite for improving the correct operating rate of the protection device. In this paper, first the common faults of relay protection are analyzed and the invisible faults are identified as the primary fault factors; then the principles of three types of existing methods on fault localization are briefly introduced, followed by comparison of advantages and disadvantages of different methods; finally the key investigations into the principles, system composition, performance and characteristics of relay protection on the comprehensive automation system are conducted, and its applications in relay protection fault localization and relay protection processing are studied. The results indicate that the comprehensive automation system of relay protection is not only capable of effectively carrying out fault analysis and fault processing, but can also significantly improve the reliability and economy of power system operations.

Keywords

Electrical equipment relay protection fault; relay protection; fault location; fault processing; comprehensive automation system

1. Introduction

The relay protection is gaining significant attention due to the increasing demand for the quality and safety of power grid construction in China. The relay protection device of power system reflects the faults or abnormal operating states on primary electrical components, acts on the circuit breaker and sends signals to cut off the power supply of faulty components or sends signals to the operator on duty in time, thereby greatly reducing the probability of fault occurrence. Various factors such as unreasonable design of relay protection, immature principle, errors on setting value calculation, existing defects on secondary equipment of (transformer) substation (Type I, Type II, and Type III defects) and poor maintenance cause faults on relay protection. Therefore, analyzing the types of faults and handling them decently will ensure normal operations on the relay protection devices and properly setting up the relay protection is the necessary pathway to improve the safety and reliability of the relay protection devices. Regarding to the types of faults, the invisible fault is the most primary fault. In the lines of power transmission and distribution, the faulty elements should be emphatically identified and handled.

The operation mode of neutral point non-effective grounding is used in most of the medium and low voltage distribution networks in China. The neutral point non-effective grounding system, also named as the small grounding current system, can be generally divided into: neutral point non- grounding system, neutral point grounding system via arc suppression coil, and neutral point grounding system via high impedance, where the systems have the characteristics of small current and high voltage. In these operation modes, the single-phase grounding faults have the highest incidence of faults. Therefore, locating this type of faults quickly and accurately is crucial for the safety, stability and economical running of the entire electric power system. Many scholars have conducted a great number of investigations towards the problem of fault localization for distribution networks. In this paper, based on the research on fault localization by various researchers, current methods on fault localization are concretely summarized and analyzed. Finally, the significance of investigating the techniques on fault location is specified and the development of methods on fault location is explored.

2. Common Types of Relay Protection Faults on Electrical Equipment and the Related Factors

2.1 Operation Faults

Operation fault is the most common and the most serious type of faults in the relay protection of electrical equipment. For example, the long term acting of high-order harmonic waves generated by nonlinear load on the electrical equipment may significantly increase the surface temperature, thereby resulting in protection failure. The secondary circuit on the voltage transformer is the weakest link of power network operations. Since the voltage transformer is the starting point of the measurement devices in relay protection, it is significantly associated with the initiation of protection device operations.

2.2 Equipment Malfunctions

Failure to meet the standard of power system operations due to the inherent defects (Type I, Type II, and Type III defects) of secondary equipment in (transformer) substation will increase the fault probability. Because of the inherent defects of secondary devices such that the devices haven’t met the operational stands of electronic systems, the probability of occurrence of faults will increase. The quality of various types of plug-in devices for the protection, measurement and control devices is the core of component quality. When the quality is not high enough, it will affect the performance of the entire relay protection device making the device unable to operate or falsely operate.

2.3 Invisible Faults

Invisible fault is a type of fault that does not affect the system during its normal running. When some parts of the system are changed, this type of fault will be triggered further, causing faults in a large area. According to the statistics from department of the domestic power management, the large-scale power outage or operation faults of the power electronic system are closely related to the invisible faults of relay protection. The working staff should pay high degree of attention to the operational management and maintenance procedure of the power transmission line and pay close attention to the operational status of the switch in order to help themselves cope better with the invisible faults.

3. Technology of Current Relay Protection and Fault Location

The electrical components of the power system are usually connected to each other by circuit breakers, each of which is equipped with a corresponding relay protection device that can issue a tripping pulse to the circuit breaker when a fault occurs to cut off the faulty part and keep the rest of the parts running normally. That is, the relay protection can shorten the range of accidents. The following text mainly introduces the protection of medium and low voltage distribution network under the condition of single-phase grounding fault, in operational mode of non-effective neutral point grounding.

The traditional three-section current protections, namely the instantaneous relay protection (section I protection), the time-restricted fast-breaking current protection (section II protection) and the definite time over-current protection (section III protection), can be used for fault location.

Section I protection is adjusted to avoid the maximum short-circuit current when the short circuit occurs at the terminal of the line and is expressed as:

$$I_{\mathrm{set1}}^{I} = K_{\mathrm{rel}}^{I} \cdot I_{k.\max} \tag{1}$$

Section II protection is adjusted to avoid the action current of the section I protection of each adjacent element ahead and is expressed as:

$$I_{set.1}^{II} = K_{rel}^{II} \cdot I_{set.2}^{I} \tag{2}$$

Section III protection is adjusted to avoid the maximum load current and is expressed as:

$$I_{\mathrm{set}}^{III} = \frac{K_{rel}^{III} K_{ss}}{K_{re}} \cdot I_{L.\max} \tag{3}$$

The three-section current protection is widely used in systems under 35KV due to its simplicity and reliability. However, when variation occurs in the connection mode and operation mode of a power electronic system, the setting value of the protection should also be adjusted. In the relay protection of important transmission lines, the fault of short-circuit among phases is generally easier to detect due to the over-current phenomenon and the three-section protection can take effect. However, the three-segment protection may fail to operate in case of fault of single-phase grounding that has the highest occurrence probability. The fault is vulnerable to develop into two or multiple points of failure and is characterized by weak fault current and unstable fault electrical arc. Hence, locating this type of fault is critically important and a difficult task. Therefore, it is necessary to install a protection device that is capable of accurately locating the single-phase grounding faults. Next, several types of methods to solve the fault localization are introduced.

Currently, fault localization methods can be summarized into three categories: the fault-localization technique, the signal injection method and the outdoor fault-point detection method. The main purpose of fault localization method is to measure the distance of the fault from the line terminal. The signal injection method realizes tracing by injecting specific signals towards the system after a fault occurs while the outdoor fault-point detection method determines the fault section according to the different fault information before and after the fault point.

3.1 Fault Location Method

Jia-Jun Liu *et al.* [1] applied the impedance analysis scheme on component current at fault location of the relay protection system. The impedance method assumes that the line is uniform and under different types of faults, the calculated impedance or reactance in the fault loop is proportional to the distance between the measurement point and the fault point. Thus, the distance from the measurement point to the fault point can be obtained by dividing the impedance or reactance at the measurement point by the unit line resistance or reactance. However, the line impedance parameters are not accurate enough in distance protection and the accuracy of fault location by the impedance method needs to be dealt with by certain means. Because the impedance method is greatly influenced by the parameters of line impedance, the line load and the parameters of power supply, this scheme is unable to remove the pseudo fault for distribution line with multiple branches and is only suitable for the lines with relatively simple structures.

Ping Chen *et al.* [2] investigated the modern fault location device using travelling waves and its operation device. The principle of travelling wave approach is to calculate the fault distance by measuring the round-trip time of the travelling wave generated by the fault between the fault point and the bus, or exploiting the time difference of the fault-travelling wave upon arriving at the two ends of the line. Based on the successful applications of the traveling-wave fault location technique on transmission lines, Feng Yan, Qi-Xun Yang and Zheng Qi *et al.* [3] conducted research on the traveling wave fault location for distribution networks and proposed the single-terminal measurement scheme through recognizing the single wave reflected from the point of fault and two coherent waves from discontinuous points, and obtaining the distance between the fault point and the monitoring terminal from the maximum correlation time of the two waves. Jing-Han He *et al.* [4] used the double-terminal travelling wave scheme to realize the fault location and solved the problem of discontinuity of variation in the wave velocity. The distribution networks have very complex structure, in which the positions of mixed lines joints, line parting, line branch and load are all discontinuities for wave impedance, where the refraction and the reflection cause the measured waveform of the wave travelling from one terminal of the line extremely complicated. Therefore, it is hard to accurately identify the reflected waves from the fault point, which makes fault distance measurement difficult. In the double-terminal traveling wave fault location method, only simple simulation validations of faults distance measurements are performed. However, at present, it is not widely used because the demands on keynote techniques are relatively high.

It should be pointed out that both the impedance method and the travelling wave method are suitable for the single-phase grounding faults and the inter-phase short-circuits faults.

3.2 Signal Injection Method

The fundamental principle of the signal injection method is to realize the tracking after the fault occurs by injecting a specific signal into the system. The major signal injection methods include the S-injection method, the signal-excision transfer function method and the port fault diagnosis method. The advantages and disadvantages of these methods and their range of applications are listed in Table 1.

Table 1. Analysis on Three Types of Signal Injection Methods

Method of Fault location monitoring	Basic Principles of Monitoring	Advantages	Disadvantages	Types of Applicable Faults
S-injection method	Single-phase grounding fault location and ranging are realized by monitoring the path and the characteristics of the alternating current signals injected to the fault line.	Suitable for a system which only installs two phase current transformers in the lines.	The intensity of the injected signal is restricted by the capacity of the PT. It takes long time to search for the fault, which possibly causes an automatic trip of the line.	Suitable for a system which only installs the two-phase current transformer on the line and the single-phase grounding short-circuit.
Signal-excision transfer function method	A square wave signal is applied to the first terminal of the line. Single phase grounding fault is localized according to the frequency, phase and waveform characteristics of the transfer function spectrum at each branch port.	For neutral-point ungrounded systems, ranging is not affected by variations of the load parameters.	Impossible to localize faults of inter-phase short-circuit with only line-mode component. Practicability is poor.	Single-phase grounding short-circuit.
Port fault diagnosis method	By exploiting the characteristics of fault voltage and current after single phase grounding, starting from the port equation, localization of the fault branch is realized by comparing the variations of the test signal before and after the fault of measurable port of the transmission network.	Small workload for fault diagnosis and measurement.	The fault location of the branch can only be attributed to the connection point between the branch and the mainline while incapable of determining the exact fault distance. Data communication is needed when information from both sides of the line are adopted. Practicability is low.	Suitable for the fault diagnosis of large network and single-phase grounding short circuit.

3.3 Outdoor Fault Point Detection Method

The principle of the outdoor fault detection method is to install a fault detector at main nodes of the distribution line. The detected information is aggregated and analyzed to obtain the fault section. This method can localize the inter-phase short-circuits and the single-phase grounding fault of the line. The localization of inter-phase short-circuit can be achieved by detecting the over-current appeared in the line. The single-phase grounding fault localization can be achieved by detecting the amplitude of zero sequence current or measuring the fifth harmonic wave of space electric field and magnetic field and analyzing the relationship of its amplitude and phase. For power distribution networks that have already realized power distribution automation, line FTU is normally utilized for line faults detection and the detection results are sent to the SCADA system through communication networks. The SCADA system can automatically locate the fault section according to some certain fault localization algorithms. Most of the mathematical models, such as the power distribution network positioning method based on genetic algorithm, can effectively achieve the purpose of positioning. While for the system in which automation has not been realized yet, the line fault indicator is generally utilized to realize the fault localization.

3.4 Existing Problems of the Fault-Localization Schemes

According to the analysis above, all the detection schemes except the signal injection method are dependent on the parameter variations of the power distribution network before and after the fault occurrence. Each fault localization method has its technical restriction and poor practicability. The main faults in power distribution line are related to small grounding current system. Because of the problem such as weak fault current, vulnerable to electromagnetic interference and harmonic wave pollution, the collected signals by all the fault localization devices will have some errors.

Since the principles and theory of the fault localization scheme are both flexible and the internet technology is well-developed, the solution to the technical issues can be expected soon. The travelling wave method has the advantage of not being affected by some simple external factors. Hence, it is significantly important to realize travelling waves ranging. A good solution to the crucial technical issues in practical application is the key to the successful application of the travelling wave method.

4. Fault and Comprehensive Practical Applications of Relay Protection

Computer protection devices, developed since the early 1990s, are now widely used. They work though measuring the electrical quantity of sudden changes before and after the protective element mutates. When the value of sudden change reaches a certain amount, the logic control unit generates a corresponding pulse or tripping signal to make the remote control element act, which improves the accuracy and rapidity of protection.

The security issue of a power system is the most important and relay protection can continuously monitor the running status of a power system. If there is an unmanned monitoring system, the relay protection can also perform automatic adjustments. Currently, relay protection is widely used in all levels of power systems, especially in the voltage class of above 110KV. In order to examine the action behavior of the microcomputer-based high voltage transmission line protection device in the actual short-circuit case, an artificial short-circuit experiment was performed by Electricity Bureau of Hebei Province between the Tou Dian substation and the Wang Feng substation that belong to Handan Power Supply Bureau on September 26, 1987. The test indicated that the microcomputer-based protection device behaved with reliable and rapid operations, strong anti-arc ability and relatively accurate positioning. The relay protection device is developing towards the integration of monitoring, measurement, data communication, control protection and adjustment. Technically, a perfect relay protection device must satisfy four requirements: reliability, selectivity, quickness and sensitivity.

According to the inherent characteristics of relay protection, the faults of microcomputer-based relay protection devices are usually caused by the following reasons: (1) Problem of value settings that occurs due to the artificial setting error or the internal electronic components of the device. (2) Power supply issue. The inherent fault occurring on the independent working power supply provided to the other plug-in units of the device or human-based wrong operations both will cause instable supply voltage and protection device failure. (3) The interference problems. The artificial interference and the new electrical devices will generate all kinds of electromagnetic interferences in the operational process. In addition to the weak anti-interference capacity of microcomputer protection devices themselves, erroneous operations will take place on some logic components. (4) Problem of the relay component and human-machine conversation component inside the device.

While the microcomputer-based protection can effectively deal with line faults, it is incapable of handling well its own faults. When a fault occurs on an important device or a component, the faulty equipment or the lines should be cut off in an extremely short period of time. The time to be as short as from a few tenths of seconds to a few hundredths of a second. In order to prevent the protective device "malfunctioning" and "refusing to function", it currently requires that for each transmission line with voltage of 220KV and above, two sets of rapid protection circuits with different working principles, completely independent operating loops and independent tripping mode should be installed. The relay protection requires more perfect function and more advanced control techniques. The jointly installed relay protection device and the comprehensive automation system in each device can ensure the safe and reliable operation of the power system.

The comprehensive automation system of relay protection comprises the dispatching center, the EMS system, the dispatching management system, the surveillance system, the microcomputer protection device and the filters [6]. The function of dispatch center is to obtain the structure and the parameters of the substation; the function of the EMS system is to obtain the transmission flow and running status of the equipment in real-time; the function of the scheduling management system is to send the corresponding scheduling commands to be executed on-site; the function of the surveillance system is to validate the execution result; the function of the microcomputer protection device is to examine whether a protection device is in abnormal or fault status; the filter provides the information of substation faults. Therefore, the comprehensive automation system of relay protection is an integrated system that visualizes the faults for convenient human analysis and efficient control of the entire network.

4.1 Principle and composition of the comprehensive automation system for relay protection

The principle of comprehensive automation of relay protection varies slightly with variations of the object of protection. It mainly includes the data acquisition system, the signal processing system and the switch measurement input / output system.

A general relay protection device is composed of three parts: the measuring/comparing component, the logic judgment component and the executing/output component. The comprehensive automation system of relay protection is depicted in Fig. 1.

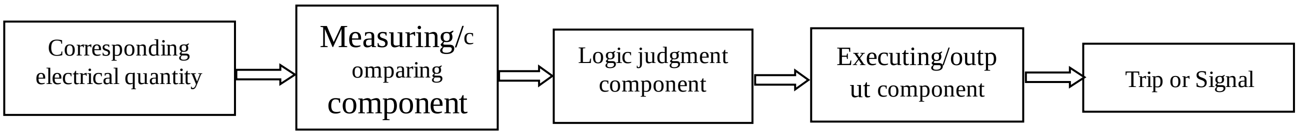


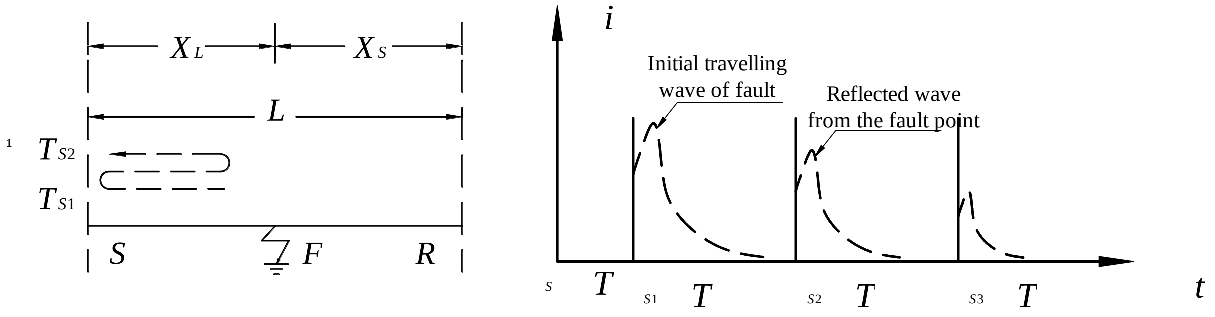
Fig. 1 The integrated automation system of relay protection.

4.2 Functions of the comprehensive automation system for relay protection

4.2.1 The method of realizing fault localization

There are three types of methods to localize various complicated faults in the comprehensive automation system of relay protection:

(1) The A-type ranging method: The method is also known as the single-terminal travelling wave ranging method. This method measures the reflection time of the travelling fault pulses between the bus and the fault points to realize the distance measurement. Fig. 2 shows the propagation sketch map and waveform diagram of travelling wave. This method achieves the distance measurement according to time difference Δt between the bus arriving time of the initial fault travelling wave pulse S1 and that of the reflected pulse S2 from the fault point.



(a) Sketch Map (b) Waveform

Fig. 2. Sketch map and waveform on the distance measurement of a travelling wave.

(2) The D-type ranging method: The method is also known as the double-terminal travelling wave ranging method. It performs ranging according to the difference of time taken by the fault traveling wave to reach two terminals of the bus. This method requires the installation of equipment at the two positions of the line and communication between the equipment. Also, the distance of fault can only be obtained if the arrival time of the initial travelling wave is obtained by the communication exchange equipment. The sketch of this method is depicted in Fig. 3.

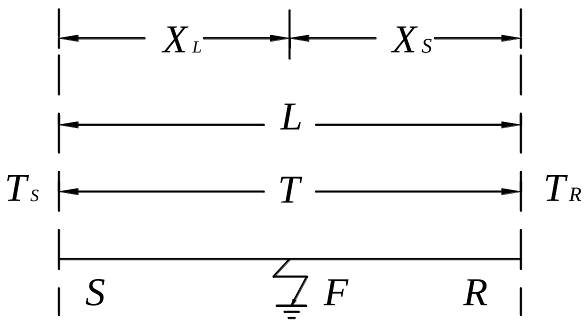


Fig. 3. The sketch diagram of propagating travelling wave to two terminals of the bus from point F.

(3) The E-type ranging method: In this method, the distance measurement is based on the waveforms of travelling waves of the transient current generated by fault reclosing.

The advantages and disadvantages of above-mentioned three methods are listed in Table 2.

Table 2. Three types of Methods on Realizing Fault Localization

The Ranging Method	Advantages	Shortcomings
The A-type ranging method	Has low investment and no requirement of communication.	The measurement result is not stable enough.
The D-type ranging method	Simple and reliable.	It needs the facilities of both communication and time synchronization and the investment is relatively large.
The E-type ranging method	Low-cost on investment.	Limited scope of applications (mainly suitable for high- voltage transmission lines with installment of reclosing).

There are mainly two types of fault localization methods in the power system: the impedance method and the travelling wave method. According to Section 3, the impedance method is easily affected by factors such as fault resistance, line load, transformer errors and parameters of the power supply. However, its practical application effect is satisfying. While the travelling wave method adopted by the comprehensive automation system of relay protection for fault localization, has simple principle and is not affected by factors such as system parameters and operation mode. Therefore, its accuracy is also high.

4.2.2. Failure factors analyzing and troubleshooting method establishment

If a relatively large fault accident occurs in a power system within a certain period, there will be relatively more cases of tripping lines that may cause the relay protection device unable to perform self-adaptation to the faulty running status of the system. If the protection device fails to cut off the fault point in time, it may cause unexpected large-scale blackouts or accidents. Therefore, the corresponding reliable solutions need to be automatically formulated according to the specific circumstances of an accident. The comprehensive automation system of relay protection is able to analyze the running status, the parameters of equipment, the degree of sensitivity and the coordination relations under the running status. Through remote modifications of the value, the self-adaptation of the protection device according to the running status can be accomplished.

4.2.3. Conditional maintenance of relay protection device

Unreasonable design of relay protection, immature principle, incorrect calculation of setting values, defects of the secondary equipment at a substation (Type I, Type II and Type III defects), poor maintenance of secondary circuits and lack of rigidity on background monitoring all will cause malfunction and refusal of movement of the protection. Through the investigations on the report tables of Type I, Type II and Type III faults, it is found that most damages occur at various types of plug-ins of the protection, measurement and control devices, the remote/local operating handles and the tripping coils. There are two reasons: (1) long service time of the devices; (2) poor quality of the elements. The cause of faults on secondary circuits includes: abnormal fiber channel, abnormal high-frequency channel, the defects of the protection circuits and the control circuits due to the unexpected switch-on or cut-off of the secondary circuits and the defects resulting from events such as DC grounding, plug loose, terminal loose, etc. [7]. The comprehensive automation system of microcomputer-based relay protection has the capabilities of self-checking, storage and reporting that can perform simulations and comprehensive analysis towards the faults. Moreover, it is also capable of transmitting accurate information to the working staff.

4.2.4. Reliability analysis on the in-service relay protection device

The comprehensive automation system of relay protection can realize the practical performance analysis and reliability analysis of the devices by obtaining information such as protection configuration, service time, the positive acting rate and the abnormal rate of all kinds of protection devices from the information management system of relay protection. If it is unable to solve the protection issues or a fault occurs on the signal transmission device, the system dependence on the device can be reduced using the evaluation of reliability and hence the expansion of an accident can be prevented.

4.3 The characteristics of integrated automation system for relay protection:

The comprehensive automation of relay protection has the advantages of microcomputer protection, such as convenience of maintenance and debugging, high reliability, high expandability, easy access to additional functions, large range of flexibility and high performance of protection device.

The comprehensive automation system is also capable of communicating with the dispatching center, breaking the boundaries of each subject in the traditional secondary system and the principle of equipment division. The traditional relay protection devices are unable to cope with the higher levels of intelligence needs of the power grid operation because they cannot communicate with the dispatching center and hence needs to be updated. For example, according to a typical accident in Ningbo power grid, Wei Gu *et al.* [8] discussed two types of major transformer faults, four types of bus faults, and two types of line faults. They analyzed the harmful damages caused by various faults and then proposed the corresponding feasible solutions with respect to the fault under that running status. In the dispatching center, totally different plans should be executed according to different information from the communication system. The system performs setting adjustment and self-adaptation according to the information in order to complete the action of protection.

4.4 Research summary

The demand for electrical power in China is rapidly increasing and the frequency of power accidents is also correspondingly increasing. In order to ensure the reliable performance of the relay protection devices, it is necessary to perform setting adjustment strictly. The comprehensive automation on relay protection is the inevitable trend on the current development of power grids, where the organic coordination of each part not only matches the requirements of relay protection, but is also capable of handling the faults of relay protection, which greatly improves the system reliability. Its technology is continuously developing. Especially in the aspects of fault analysis, positioning and processing, outstanding achievements have been obtained. The comprehensive automation of relay protection is the inheritance and development of the microcomputer-based protection in early stage, where the most important thing is to realize the condition-based maintenance on the relay protection devices and enhance their capability of self-adaptation. However, the mathematical models associated with visible faults still need to be simplified in order to improve their accuracy. With the unremitting efforts from researchers and the continuous development of science and technology, many technical difficulties will finally be solved benefiting all mankind.

5. Conclusion

The quality of power energy is closely related to the performance of relay protection devices. The relay protection faces technical and external unpredictable disturbances and artificial mistakes. It is essential to analyze the principle of relay protection and the directions of prospective progress more thoroughly and implement the working duty to each position. At present, the automation system of relay protection, whether in medium or high-voltage distribution power network or ultra-high voltage power system, is capable of effectively solving the problems under faulty cases and in abnormal running status. There are also many problems that require attention in the settings of relay protection for electric equipment. This system involves many fields and requires high level of cooperation from various specialties. Despite that the technical problems are inevitable, there are enormous potential capacities on the development of self-adaptive capability in the comprehensive automation system of relay protection. The rapid development of science and technology along with the unremitting investigations from professionals will eventually solved many technical difficulties and will benefit many human beings.

Acknowledgements

This paper is sponsored by Keynote Project of Scientific and Technology Research from the Department of Education in Henan Province (12A470005); Natural Science Funding Project from the Department of Education in Henan Province (2011A470005).

References

[1] Jia-Jun Liu, Chun-Ju Li, and Wen-Ling Li. Research on the impedance method of fault component current in fault localization. [J]. Electric Railway, vol. 5, pp. 1-4, 2003.
[2] Ping Chen, Bing-Yin Xu, and Jing Li. Modern fault localization device on travelling wave and its experience on operation [J]. Automation of Electric Power Systems, vol. 27, no. 6, pp. 66-69, 2003.
[3] Feng Yan, Qi-Xun Yang, Zheng Qi. Study on fault localization method of distribution power network based on the theory of travelling waves [J]. Proceedings of the Chinese Society of Electrical Engineering, vol. 24, no. 9, pp. 37-43, 2004.
[4] Jing-Han He and Ying-Ye Ji, Investigations on the single-phase grounding fault localization method in small current grounding system [J]. North China Electric Power, vol. 1, pp. 1-3, 2004.
[5] Xue-Ling Zhu, Cong-Mei Cha, Qiang Xu. Principle of relay protection in power electrical system [M]. China Electric Power Press, 2009.

[6] Zhi-Jian Zhong. Analysis of power comprehensive automation system and relay protection on substations [J]. Modern Manufacturing, vol. 6, pp. 68-69, 2013.
[7] Meng-Chao Li and Xiao Han. Relay protection, analysis and processing of typical defects on secondary circuits [M]. Power Electrical Publisher of China, 2011.
[8] Wei Gu, Lei Ren, and Gang Liu, et al. Analysis on the treatment of typical accidents in Ningbo power grid [J]. Mechatronics Engineering, vol. 29, no. 9, pp. 1108-1110, 2012.

Brief-introduction of Author: Piao-Piao You (1994 -), female, pursued undergraduate study in the College of Electronic Power, North China University of Water Conservatory and Electric Power.