Research on Single-Phase Grounding Fault Location Technology

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Abstract. In view of the complex structure, large scale and high failure rate of distribution network, as well as many branch lines, large transition resistance, difficult to detect fault signals and difficult to locate accurately, a single-phase grounding fault location method based on single-terminal measurement for distribution network with multi-dominant transmission lines is proposed. This method can solve the problem of reliable monitoring of small current grounding fault through data processing and analysis of measuring units installed at substation equipment and line end, find grounding fault line in time, find fault point, and adopt corresponding treatment measures to block the impact scope of user branch line accident, restore the power supply of non-fault line as soon as possible, and reduce the outage time. Providing further reliable power supply fundamentally solves the problems of reliability and safety of power supply in distribution network. This method only needs to synchronously measure the voltage and current at each end of the line when the parameters of the line are known. The method is simple and the measurement accuracy is high. By locating the single-phase-to-ground fault of multi-dominant power lines, the results show that the method is correct and accurate.

1. Introduction

Distribution network has complex structure, huge scale and high failure rate. According to statistics, the failure of distribution network accounts for more than 80% of all kinds of faults in power system, which not only affects the normal power supply of users, but also destroys the safe operation of power system and causes great economic losses. When single-phase grounding fault occurs, although the regulation permits two hours of operation with fault, it may still cause accidents due to overvoltage which endangers insulation. Fault statistics of power supply and distribution system show that the probability of single-phase grounding fault accounts for more than 66%. At present, in the field operation, especially after the wide application of arc suppression coil, the usual characteristics of small current grounding fault are not obvious, which makes it difficult to select and locate the grounding fault. Especially, the technology of locating and locating the grounding point is difficult to implement. After grounding, the existing fault indicators have poor accuracy and heavy maintenance workload. The fault location of distribution automation is slow to popularize due to huge
investment. Based on the distributed parameter model of transmission line, this paper presents a single-phase grounding fault location method for distribution network with multi-dominant lines based on single-terminal measurement. The voltage of the fault points obtained from the voltage and current of the two terminals of the line is unique. Based on this method, the location of the fault points can be obtained, which can be extended to the single-phase grounding fault location of multi-dominant lines. The simulation results show that the method can be applied to the fault location of multi-dominant lines. The correctness and accuracy of this method are proved, which provides a theoretical basis for fault location of distribution lines.

2. System composition
Fault location and overvoltage suppression technology for distribution network based on single-source and single-end measurement point consists of control panel installed in substation control room, high-voltage inductance-free resistor installed outdoors in parallel with the original arc suppression coil, and corresponding auxiliary equipment (such as vacuum switch, outgoing current transformer, etc.). The device also has overvoltage suppression for distribution network. The comprehensive function of grounding fault location and location focuses on solving the technical problems of the low sensitivity and accuracy of the device and the unification and coordination of these functions.

2.1. Realization of Grounding Fault Location
When a branch of distribution network is grounded, relying on the installation equipment inside the substation, the location of the fault point is determined by traveling wave and network analysis; the installation equipment is few, the line is not equipped, and the maintenance workload of the grounding fault indicator is greatly reduced compared with the usual maintenance workload, and the input is less than one fifth of the input of the similar functional equipment in distribution automation, which has a high degree of practicability. At present, the difficulties of distribution network in China are discussed.

2.2. Overvoltage suppression
Aiming at the problem of excessive internal overvoltage in neutral ungrounded system, which is widely used in China at present, the device can effectively suppress series resonance overvoltage, arc grounded overvoltage and most ferroresonance overvoltage through combined design. On the basis of the existing operation level of domestic distribution network, the device can further reduce the overvoltage in series resonance, arc grounded overvoltage and ferroresonance overvoltage. Less damage caused by over-voltage in distribution network reduces the requirement of insulation for equipment.

Power system overvoltage is mainly divided into lightning overvoltage, switching overvoltage and temporary overvoltage. Temporary overvoltage includes power frequency overvoltage and harmonic overvoltage. In distribution network, lightning overvoltage is limited by lightning arrester, which does little harm to the insulation of electrical equipment; the operating overvoltage of distribution network generally does not exceed 4.0pu, which does little harm to the electrical equipment of distribution network with higher insulation level; however, the overvoltage with higher amplitude and longer duration often occurs in distribution network does great harm to electrical equipment, and the common overvoltage mainly includes inter-voltage. Intermittent arc grounding overvoltage and various resonance overvoltage, etc.

3. Location of Several Grounding Faults
The high-voltage inductance-free resistor parallel to the arc suppression coil is equivalent to establishing a charge release path for the neutral point of single-phase grounding in the distribution network, which can restrain arc grounding and resonance overvoltage for a long time.

The equipment for fault location and overvoltage suppression in distribution network based on single-source and single-end measurement points consists of control panel installed in substation control room, high-voltage inductance-free resistor installed outdoors in parallel with the original arc
suppression coil, and corresponding auxiliary equipment (such as vacuum switch, outgoing current transformer, etc.).

According to the normal operation of power grid, transient single-phase grounding fault or disturbance of power grid, permanent single-phase grounding fault of power grid, the basic working principles of fault location and overvoltage suppression technology in distribution network are analyzed respectively.

3.1. Normal operation of power grid
When the power grid is in normal operation, the source device does not move; the neutral point is connected to the arc suppression coil, and the neutral point high-voltage inductance-free resistor is connected in parallel for a long time at both ends of the arc suppression coil, so as to give full play to the role of the high-voltage inductance-free resistor in restraining the series resonance overvoltage; if the device adopts the pre-regulation mode, it can track the changes of the parameters of the power grid in real time, and when it needs to be Adjusting the gear of the arc suppression coil, always ensuring that the arc suppression coil works at the optimum working point with minimum residual current, waiting for the occurrence of the grounding fault of the power grid; if the device adopts the tracking regulation mode, the device only tracks the changes of the parameters of the power grid in real time, does not need to adjust the gear of the arc suppression coil in real time, only adjusts the gear of the arc suppression coil to the residual current rapidly when the single-phase grounding fault occurs in the power grid. Minimum optimal compensation gear.

3.2. Transient grounding fault or disturbance
When transient single-phase grounding fault occurs or three-phase closing is seriously disturbed in different periods, the regulating circuit of arc suppression coil will be automatically blocked if the device adopts pre-regulation mode, and the arc suppression coil will work at the optimum working point with minimum residual current if the tracking regulation mode is adopted; the compensation and voltage limiting function of arc suppression coil and neutral grounding resistance will be fully exerted to promote instantaneous operation. The automatic disappearance of the fault effectively limits the harm of ferroresonance and arc grounding overvoltage to the power grid, and avoids the abnormal phenomena such as insulation weak link breakdown, arrester explosion, cable-to-ground breakdown short circuit, illusory grounding and so on.

When permanent single-phase grounding fault occurs in power grid, the controller can locate and locate single-phase grounding fault. The decrease of neutral point resistance limits the magnitude of arc grounding overvoltage, and enables the controller to get sufficient information of fault line and fault point, so as to make accurate and fast judgment of fault line, give alarm signal or make corresponding circuit breaker tripping to remove fault line; after that, according to the traveling wave generated by grounding fault at the beginning of the fault, the controller can remove the fault line. And the traveling wave change caused by the change of neutral point resistance value, through the traveling wave change signal caused by the fixed time of the controller installed in the substation, the zero-mode wave velocity is determined, the pseudo-grounding point is removed, the final single-phase grounding fault section is determined according to the network topology diagram, and the fault location information is displayed on the display screen of the controller, and uploaded to the dispatch according to the need. The main station is convenient for dispatchers, operation and maintenance personnel to find fault points and quickly remove them, thus improving the reliability and safety of distribution network operation.

Based on the over-voltage equipment in distribution network, this project develops and integrates the intelligent analysis technology of single-source downlink wave, real-time network state analysis technology and on-line monitoring and tracking technology of system compensation status into a unified analysis platform to form a single-phase grounding fault location system for distribution network based on single-source.
According to the structure of distribution network, the law of traveling wave reentry is studied, and the method and technology of distinguishing the wavefronts at single-end measuring points are studied by using wavelet analysis, which provides basic data for locating and locating fault points of distribution lines with more branches.

Through a lot of calculation and analysis, the rated parameters and range of the neutral point high voltage inductance-free resistor equipment and the control strategy in the grounding process are finally determined.

To improve the electromagnetic compatibility (EMC) performance of the controllers installed in substations, including lightning impulse interference, high frequency discharge radiation interference, harmonic interference, electrostatic discharge, etc., the measurement, data acquisition and processing, control, signal transmission circuits are optimized to ensure the reliability of the developed equipment in harsh electromagnetic environment.

Choose a substation as a pilot (such as Huayan Substation), implement the research results of neutral grounding mode through arc suppression coil parallel resistance and grounding and short-circuit fault location monitoring system, install and debug all equipment, mainly: neutral grounding high-voltage inductance-free resistor, zero-sequence current transformer, measurement controller and so on.

Aiming at the selected pilot substation, the artificial single-phase grounding test is carried out to simulate the grounding situation of different grounding points, and to test the main performance of the grounding fault location system.

4. Conclusion

In this paper, a single-phase-to-ground fault location system based on single-end measuring points for distribution network multi-dominant lines is designed. By analyzing the normal operation of the power grid and the occurrence of grounding faults, the characteristics and rules of the distribution network grounding faults through different transition resistors are simulated, analyzed and calculated, and the law of traveling wave reentry is studied. By using wavelet analysis, the method and technology of distinguishing each wave head and removing pseudo-fault point at single-end checkpoint of transmission line are studied. According to the experimental test and actual operation effect, when a grounding fault occurs, the grounding point can be quickly found after a single-end grounding fault occurs. The system has strong stability and high positioning accuracy, and has good applicability.

References

[1] Fang Weiming, Cheng Hanxiang, Li Yong, et al. A kind of fault location method for multi-terminal power distribution network not affected by wave speed[J]. Guangdong Electric Power, 2016,29(4):79-83

[2] Zhou Gaiyun, Zhang Guoping, Ma Li, et al. A fault Location method in distribution networks based on impedance analysis and traveling wave analysis[J]. Power System & Clean Energy, 2015,31(9):21-26

[3] Liao Xiaohui, Zhao Xiaojian, Liang Hengna. A power cable fault location method based on Hilbert-Huang transform[J]. Power System Protection & Control, 2017,45(9):21-26

[4] Yang Luoyuan, Shu Qin. A new multiterminal detecting location method of single-phase grounding to the overhead-line for distribution network based on travelling-wave mutation of line-mode[J]. Power System Protection & Control,2016,44(9):22-28

[5] Shen Y W, Cui M J, Wang Q,et al. Comprehensive reactive power support of DFIG adapted to different depth of voltage sags[J]. Energies, 2017,10(6):808-827

[6] Zhang J, Cui M J, Fang H L, et al. Smart charging of electric vehicles penetrating into residential distribution systems based on the extended iterative method[J]. Energies,2016,9(12):985-999