Research on Single-phase Grounding Fault Method for Urban Distribution Network Cable Network

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Abstract. This paper proposes a system-level overall solution that includes three levels of substation, distribution line and distribution automation master station. Through the transformation of power distribution and power distribution, the substation small current grounding line selection device, arc suppression coil automatic control equipment, power distribution terminal, and distribution automation main station are integrated. With a variety of comprehensive criteria as the core of technology, the operational effects of information interoperability, resource sharing, functional readiness, and unified monitoring are achieved. It can provide the production management department with the closed-loop processing method of "fault identification-isolation processing-data management-analysis promotion". At the same time, different solutions can be configured for different site requirements, which can meet the needs of different regions and different site conditions, and effectively improve the site. Applicability solves the problem of single-phase grounding identification of cable lines.

1. Introduction

At present, the neutral point operation mode of China's distribution network is mainly the operation mode of small current grounding. The randomness of load fluctuation is very large, the structure is complex, and there are many branches, which leads to a high failure rate of the distribution network [1-2]. In recent years, with the expansion of urban distribution network, in view of the excessive space occupied by overhead transmission lines and the safety considerations, the overhead lines of distribution networks in urban areas below 110kV are gradually replaced by cable lines. Compared with overhead lines, most of the cable lines are buried underground, with a small footprint, and their laying is not affected by the ground buildings, This can greatly provide power supply reliability. As an important part of the power system, the cable's working state affects the safe and stable operation of the distribution network [3]. As the scale of the power grid system continues to expand, the number of cables increases, the load becomes larger, and the length of operation increases, resulting in a greater incidence of cable failures in the power system [4]. At present, in the fault of the distribution network cable line, the single-phase ground fault accounts for about 80% of the total number of cable line faults. Therefore, it is urgent to improve the single-phase ground fault judgment capability of the cable. The traditional fault location method of China's distribution network is a combination of switching operation and manual inspection line to locate faults [5-6]. At present, cable fault ranging is mainly the traveling wave method and fault analysis method [7-8]. This paper proposes a system-level overall solution that integrates three levels of substation, distribution line and distribution automation master station.

2. Single-phase grounding fault diagnosis of cable network

The overall solution for the single-phase ground fault of the distribution cable network is shown in the figure below.

(1) Line selection within the substation station;
(2) Selection of substations outside the station;
(3) Fault location;
(4) Troubleshooting.

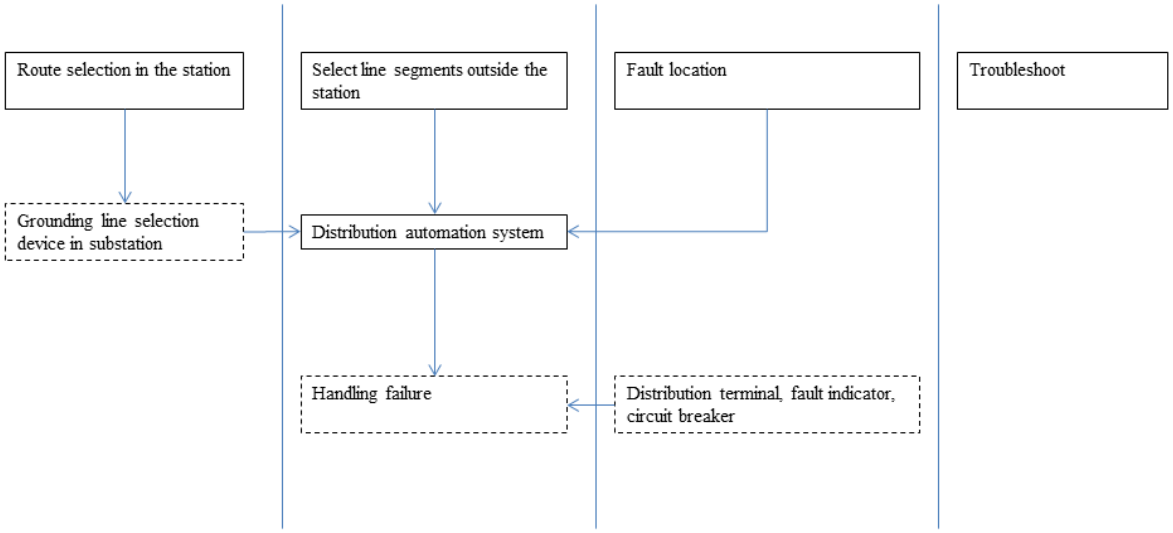

Figure 1. Overall solution

2.1. Fault diagnosis of neutral point via small resistance grounding

When the grounding fault occurs in the small resistance grounding mode, the zero-sequence current is large, which is a single-phase short-circuit fault. The main station receives the fault information according to the feeder automatic processing flow, and the system fails according to the fault-related information acquired from the EMS and the power distribution terminal. Judge and locate, isolate, and restore power to non-faulty areas.

(1) When the low-resistance system is single-phase grounded, the substation outlet protection combined branch line protection and user demarcation switch protection three-stage zero-sequence current protection. When a line fails, the protection selectively isolates the fault based on the location of the fault.

(2) The distribution automation main station receives the substation outgoing protection action information sent by the EMS system and the zero sequence fault information sent by the distribution terminal on the line, and the main station starts the feeder automatic processing flow, and the fault processing function can support the distribution network. The topology structure can automatically locate the fault zone according to the feeder topology and fault related information, determine the isolation scheme according to the fault location result and the switch, and split and restore the power supply according to the load capacity of each power point. After the accident processing is completed, Give an operational strategy to restore the feeder operation mode before the accident.

(3) Fault handling Automatically design the recovery power supply scheme of the non-faulty section to avoid overloading of other lines, main transformers and other equipment. When multiple backup power sources are available, the minimum action switching strategy can be preferentially supported according to the load capacity of each power point. It has the ability to set fault handling blocking conditions and safety blocking to ensure that the fault handling process is not interfered by other operations.

(4) For equipment with “three remote” conditions, after the system determines the fault interval, the dispatcher can select the remote control device or rely entirely on the system to automatically handle the fault. For equipment with "two remote" conditions, the system can provide fault recovery and non-fault area recovery schemes, and manual intervention for fault handling. When the feeder is equipped with the local fault handling function, the main station fault handling function should be able to cooperate with the local processing.

(5) When the isolation operation is performed, the rejection occurs, the rejection switch is treated as the operation prohibition switch, and the load transfer process is entered to perform the load calculation. The isolation operation of the extended interval is performed only after the transfer policy exists in the to-be-transfer interval.

2.2. Fault Diagnosis of Neutral Point Grounding Mode of Arc Suppression Coil

The single-phase ground fault processing mode of the arc suppression coil grounding system mainly uses the substation line selection device and the distribution automation to perform the station selection and the off-site fault isolation.

(1) The distribution automation master station system starts the fault diagnosis process according to the single-phase ground line selection result signal forwarded by the EMS and the single-phase ground fault signal sent by the distribution network fault information collection device, and performs fault analysis.

(2) The system retrieves the recorded information of the terminal on the relevant line, judges and analyzes the ground fault according to the information of the transient recording of the power distribution terminal, including:

Fault recording data acquisition and processing, active call, receive and save fault recording information; read the recorded data in Comtrade-1999 standard format. Analysis and display of fault recording information, and display of electric quantity waveforms such as three-phase voltage, three-phase current, zero-sequence voltage, and zero-sequence current collected in the fault recording. Multi-curve information can be superimposed and displayed in units of selected devices.

(3) Single-phase grounding positioning analysis of the line: The main station system performs the analysis of the amplitude and phase angle of the single-point zero-sequence voltage and the zero-sequence current according to the recorded information; it can be between multiple lines of the same line and multiple lines of the same bus line. Comparison and analysis of fault recording information; through multi-source information such as 10kV bus voltage of integrated line, grounding line selection information of plant station, fault recording of power distribution terminal, line selection analysis and fault section positioning analysis and judgment of single-phase grounding.

(4) After the single-phase grounding positioning analysis of the line is completed, according to the system topology relationship, the primary station system performs fault isolation and restores power in the non-faulty area. Fault isolation: The system will give a fault isolation operation assist decision based on the ground fault location result and prompt the dispatcher to operate the switch. Non-faulty area recovery: The system performs comprehensive analysis based on the topology relationship of the whole network, line load, and main transformer capacity, and automatically generates an optimal recovery strategy.

2.3. Terminal method for judging neutral point grounding by arc suppression coil

This scheme is suitable for on-site three-phase current measurement without zero-sequence voltage measurement, with zero-sequence current measurement or can be transformed into a cable line site with three-phase current measurement.

Device parameter configuration range:

(1) Secondary accurate measurement range: 0.002~5In.

(2) Overcurrent protection, fixed value range: 0.1~4In, 0.02~100s.

(3) Single-phase grounding line protection, fixed value range: 0.002In~1In, 0.02~100s.

Device hardware interface configuration:

The device has 8 channels of opening and 4 channels of opening. Analog acquisition of feeder three-phase current. 2-way 485 interface, support serial port 103 or 104 protocol. Support for standard rail mounting.

Power distribution terminal hardware transformation plan:

In order to ensure accurate line selection when high-resistance grounding is required, the three-phase CT ratio needs to be less than or equal to 300/1, and the recommended CT ratio is 50/1~200/1. If the existing CT ratio and capacity meet the requirements, the device can be connected in series. If the original CT cannot meet the requirements, the optional device can be installed at the same time. The CT is an open CT, which is convenient for live installation.

As a sensor device, the device uses a serial port to access the power distribution terminal, and the power distribution terminal allocates a reserved remote signal point number to the device. When a single-phase ground fault occurs, the device passes the single-phase ground fault monitoring and judgment result through the remote signaling initiative. Send it to the distribution terminal.

The processing steps are as follows:

(1) When a single-phase ground fault occurs, the substation line selection device selects the fault line and sends it to the main station.

(2) The upstream switch of the fault point trips according to the time difference value. Configure the level difference strategy:

Each outlet switch (user boundary) is protected to one level and the time is set to ΔT.

The outlet switch of the ring network cabinet is protected to one level, and the time is set to 2ΔT.

The substation outlet switch protection is one level, and the time is set to 3ΔT.

Substation line selection switch, if the level difference mode is configured, it should be used as feeder grounding trip backup.

(3) The primary station receives the single-phase ground fault signal of each terminal to realize fault location; and simultaneously isolates faults according to the global situation.

(4) Finally, the power supply can be restored to the non-faulty line according to the overall situation.

3. Terminal equipment transformation principle

3.1. Principles for the transformation of neutral points through small resistance grounding related equipment

(1) The power distribution segment switch, tie switch and branch switch should be equipped with zero-sequence current transformer, or zero-sequence current can be obtained through the secondary circuit of the three-phase current transformer.

(2) Adopt three-level protection strategy for substation outlet switch, branch switch (or ring network cabinet outlet switch) and user demarcation switch.

(3) The transformation of the distribution ring cage should give priority to the application of one-time fusion complete ring cage. The ring cage has zero-sequence voltage output and acquisition function. The three-phase protection-level current transformer and zero-sequence current mutual inductance are arranged in the interval between the input and the exit. The distribution automation terminal shall have transient recording and zero sequence protection.

(4) Distribution cable network Switching equipment does not have the ability to collect zero-sequence voltage and zero-sequence current. It may be considered to modify the terminal, and use the zero-sequence overcurrent to directly remove the fault.

3.2. Principles for equipment modification of neutral point via arc suppression coil grounding method

(1) The distribution cable network switch type equipment is of a secondary fusion type, and the fault can be judged locally by using the transient electric quantity or the unbalanced current method.

(2) Distribution cable network switch equipment is not equipped with zero-sequence voltage sensor or the power distribution terminal does not have the function of collecting zero-sequence voltage. It

can be equipped with external three-phase current sensor and control terminal, and use the unbalanced current method to judge locally.

(3) If the field device is unconditionally modified, it can be modified by an external scheme.

(4) The distribution automation master station determines the fault area by using the fault information sent by the terminal in combination with the topology structure, sends a trip command to a specific switch to isolate the fault, and restores the power supply in the non-faulty area.

4. Conclusion

This paper proposes a single-phase grounding solution for the distribution cable network of the integrated substation, distribution line, distribution automation main station and distribution terminal. This method greatly improves the fault diagnosis efficiency of the single-phase grounding of the cable network and improves the reliability of the power supply.

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