Research on Feeder Automation System for Urban Distribution Network

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Abstract: With the development of society, the demand for power supply reliability is also increasing, and the proportion of terminals with feeder automation function in the distribution network is increasing. It has become a research hotspot to find more optimized feeder automation strategy. This paper introduces three kinds of feeder automation schemes: centralized control type, local control type and distributed control type and expounds the fault isolation, non-fault section power supply self-healing strategy in detail. The comparison of several control schemes provides reference for choosing feeder automation scheme according to system architecture.

1. Feeder automatic control method

1.1. Centralized control
Centralized control of feeder automation is based on the built and running master station, communication system and distribution network terminal equipment. The dispatching master station analyzes the real-time data uploaded by the terminal in real time. When a fault occurs in the system, it is quickly located and the remote area is used to isolate the fault area and restore power to the non-fault area.

1.2. On-site automatic control
According to whether it depends on the communication network and the number of switching actions, the on-site automatic feeder automation can be divided into recloser type and intelligent distributed[1]. Recloser feeder automation can also be divided into voltage-time feeder automation, voltage-current time feeder automation, and adaptive integrated feeder automation according to the switching characteristics used in the strategy and the fault line selection method in the strategy[2].

1.2.1. Recloser type "voltage-time" feeder automation.
When the line fails, the outgoing circuit breaker CB1 opens, and the "voltage type" automatic load switch at FS1-FS6 automatically opens when the "loss of voltage" is released. After the outlet circuit breaker is closed, the terminal detects that the pressure on one side of the sectional switch meets the delay and closes. When the subsection switches on both sides of the fault section are closed, the system fails again, and the closing fails to close. The switch on the standby power supply side detects that the one-sided voltage loss avoids the fault handling time and closes[3].

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1.2.2. Recloser type "voltage-current-time" feeder automation.

Through multiple reclosing of the outgoing switch, the terminal counts the number of voltage loss and overcurrent during the fault handling process to isolate the fault and restore the power supply. According to the fault type, it can be divided into short-circuit fault and ground fault. When the location of the fault is different, the action process of automatic power supply recovery is different. Take the system shown in the following figure as an example[4].

![Figure 1. Multi-segment single-link overhead feeder](image)

Take the short-circuit fault as an example of a permanent short-circuit fault on the main line, that is, when a fault occurs between the terminals FS12 and FS13, the terminals along the line detect a voltage loss and no current, and the outlet circuit breaker CB1 opens. If it is a transient fault, a coincidence is successful. If it is a permanent fault, the circuit breaker CB1 opens again. The terminal along the line counts that the line voltage loss and overcurrent times are 2 to reach the trip condition, and the terminals FS11, FS12 and FS13 are opened. The circuit breaker recloses for the second time, and the section switches along the line reclose in sequence. After the terminal FS11 is closed, the closing is successfully blocked and opened. After the terminal FS12 is closed, it closes to the fault. When the FS12 detects a loss of pressure, it immediately trips and locks the closing. The terminal FS13 detects the contralateral residual pressure to close the lock. The third reclosure restores the power supply in the non-fault area. When a transient fault occurs in the system, no matter the fault point is located on the main line or branch line; the power supply can be restored through a reclosing. When a permanent fault occurs in the system, the branch circuit breaker closes after the circuit breaker is closed, and the branch circuit breaker quick-break protection action cuts off the faulty line.

The ground fault is taken as an example of the permanent ground fault of the main line, that is, a single-phase ground fault occurs between the terminals FS12 and FS13. When the terminal along the line detects a single-phase ground fault, it delays to trip, and manually operates the contact switch LS to close. After coincidence, the terminal F13 detects a single-phase ground fault to delay trip, and the third reclosure restores the power supply in the non-fault area.

1.2.3. Recloser type "adaptive comprehensive" feeder automation.

The terminal's closing delay cooperates with each other to realize the self-healing of the system's adaptive power supply. According to the difference between the location of the fault point and the type of fault, the fault can be divided into trunk line short circuit fault, trunk station line ground fault and branch short circuit fault. When the location of the fault is different, the process of automatic power supply recovery is different. Take the system shown in the following figure as an example.

![Figure 2. Line Fault Action Diagram](image)

Among them, CB is a feeder circuit breaker with time limit protection and reclosing function. Terminals FS1 to FS6 monitor the status of the "voltage-current-time" segment switches, and
terminals LSW1 and LSW2 monitor the status of the contact switches. Terminals YS1 ~ YS2 are used to monitor the user boundary switch of the branch line.

Take the example of a permanent short-circuit fault on the trunk line, that is, a fault occurs between FS2 and FS3. Outgoing circuit breaker CB1 opens, and terminals FS1 and FS2 detect no current. After the circuit breaker is closed, the terminals FS1, FS2, and FS4 detect a voltage on one side. Due to the short-circuit fault memory, the terminals FS1 and FS2 are closed for 7 seconds, and the terminal FS4 has no short-circuit fault memory. It starts a long delay and waits for fault handling. When the fault is an instantaneous fault, the terminal will sequentially overlap according to the set action delay. When the fault is a permanent fault, the circuit breaker will open when the reclosing fails, and the closing time of the terminal FS1 switch meets the requirement to successfully confirm the delayed blocking and opening. The closing time of the FS2 switch at the terminal does not meet the delay of successful confirmation, because of the failure, it will trip again and lock the closing. Terminal FS3 closes the lock due to the detection of short-time incoming residual voltage. After the above fault treatment is completed, the second reclosing is performed to realize the self-healing of the power supply in the non-faulty section.

The ground fault of the main station line occurs in the system. FS1 should be set to the line selection mode, and the remaining switches should be the segment selection mode. It is assumed that the terminal FS5 feeder line has a single-phase ground fault. Outgoing circuit breaker CB1 opens, and terminals FS1, FS4, and FS5 detect a ground fault at its rear end. After the circuit breaker is closed, the terminals FS1, FS2, FS4, and FS5 detect a voltage on one side. Due to the short-circuit fault memory, the terminals FS1, FS4, and FS5 are closed for 7 seconds. The terminal FS2 has no short-circuit fault memory and starts a long delay to wait for fault handling. When the fault is an instantaneous fault, the terminal will sequentially overlap according to the set action delay. When the fault is a permanent fault, it needs to be closed when the failed circuit breaker is opened, and the closing time of the terminals FS1 and FS4 meets the requirement to successfully confirm the delay blocking and opening. The closing time of the FS5 switch at the terminal does not meet the delay of successful confirmation, because of the failure; it will trip again and block the closing. Terminal FS6 closes the lock due to the detection of short-time incoming call residual voltage. After the above fault treatment is completed, the second reclosure is performed, and the terminals FS2 and FS3 meet the delay and close in turn to restore power.

A branch short-circuit fault occurs in the system. It is assumed that the feeder after the boundary switch YS1 has a short-circuit fault.

After the terminal detects that the boundary switch YS1 has no pressure and no current, the boundary switch is opened. After the fault treatment is completed, the circuit breaker recloses the non-fault section to restore power.

1.2.4. Intelligent distributed control

Intelligent distributed feeder automation (referred to as "intelligent distributed FA") uses local optical fiber communication to communicate fault status information between terminals in the network, avoiding the impact of re-failures on the system during the transfer process. The terminal shall have the function of automatic conversion of the control mode when the communication is abnormal, and can automatically switch to the recloser type control mode when the communication is abnormal. Based on the above advantages, intelligent distributed FA is mostly used in power distribution networks with high power supply reliability requirements[5].

2. Advantages of various control methods

In the centralized control mode, the transfer in the non-fault area is more efficient, reasonable and accurate, and the load distribution is more reasonable. However, the large number of terminals is likely to cause congestion in the communication network and complicated topology logic, and the fault isolation time is long.
The local automatic control terminal realizes the automatic opening and closing control logic that does not depend on the master station at all. If the recloser type is selected, the number of switching operations is large, the isolation fault time is long, the non-fault section has a long power outage time, and the outlet circuit breaker of the substation needs to be reclosed multiple times. But there is no need to build a communication network architecture, which greatly reduces the cost of network racks.

Intelligent distributed use of communication network for information interaction can directly locate and isolate the fault, avoiding multiple actions of the switch and the action is faster than the recloser type.

3. Application scenarios of various control methods

For the urban center area and the area where the supporting communication facilities in the overhead cable line are relatively complete, the distribution control system uses a centralized control type to ensure higher power supply reliability, and can also achieve faster and reasonable load transfer in the event of a failure.

Most of the cable lines and backbone lines with sensitive loads in the city are intelligently distributed, and the fault can be isolated and the power supply can be self-healing in the non-fault section with one switch.

For the rural and suburban overhead lines with relatively low power supply reliability requirements, the recloser feeder automation method is mostly used to achieve fault isolation and self-healing of the power supply in the non-fault section by virtue of the action characteristics of the switch.

4. Conclusions

This article introduces a variety of implementations of feeder automation, and each implementation strategy has its own advantages to complement each other. In the actual application process, according to the system architecture, budget and user's requirements for electricity reliability, they can cooperate with each other, concentrate resources, protect important areas and maximize social benefits.

References

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