STUDY AND APPLICATION OF RING-OPERATED NETWORK SUPPLY OF DISTRIBUTION SYSTEM

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Abstract: *Adoption of open looped circuit is the way for development of distribution network at present. Recently, the project combining sectionalizers and reclosers for radial distribution feeders has been matured comparatively. Use of 3 sets of reclosers for 2-section open looped circuit with two power sources has also gained fairly good operation experience. While use of 5 sets of reclosers for 3-section open looped circuit with two power sources is expected to have a higher reliability. Therefore, it is a better-looped circuit configuration.* ***B****ut in such circuit, the coordination of protections among the facilities is very difficult and the problem of multi-impulse of short circuit current toward the faulty spot has not yet been successively solved so far. The paper gives the solution of this problem through the operation experience as well as the criteria for the recloser action to faults, summarizes the methods of selecting and isolating single phase grounded section of the faulty line. The scheme given here has a sense of pioneer and comparatively great application value.*

Key words: *distribution network, looped circuit power supply, study , operational analysis*

1. INTRODUTION

Along with the development of urban construction, rapid increase of load demands improvement of quality of the existing distribution networks and reliability of power supply. A great part of the existing distribution networks in our country is radial system, which has a potential drawback. That fault once occurs on the line will result in service interruption of a large area for a fairly long time, so the reliability is inferior. In order to change such situation, the best way is to adopt looped circuit configuration in the near future and gradually form an interconnected network operated in open circuit mode in the future. As there is more than one power source, the reliability of network will be greatly improved.

In our country, the document Energy Dian [1990] No. 664 “SOME OPINIONS IN STRENGTHENING THE REFORMATION OF MEDIUM AND LOW VOLTAGE DISTRIBUTION NETWORK IN URBAN AREA” points out that overhead distribution network should adopt open type looped circuit configuration. In order to decrease the outage area during overhaul or occurrence of fault, sectionalizers should be installed to divide the trunk line into 2 to 3 sections in general. For each long branch line, line switch should be installed at the tee-off point too. Interconnecting switch should be installed between 2 sections of looped circuits to realize load transfer between them so as to improve the operation flexibility. The document Energy Dian [1993] No. 228 “GUIDLINE FOR PLANNING AND DESIGNING URBAN DISTRIBUTION NETWORKS” also points out that the medium voltage network composed of outgoing feeders from HV/MV substations should be properly interconnected to give enough tieing capacity, so that the load can be transferred during emergency.

For years, a great deal of research work on distribution automation has been done in our country. For instance, many automation devices, such as DM-series automatic switches, ESR type electronic-controlled reclosers and KFE-series reclosers etc., have been introduced from Japan, England and the United States successively. The application of these devices in our network has given us a lot of experience. The technical performances of these devices were confirmed as higher automation, but they are not necessary fully meeting the specific feature of our distribution network. Therefore, under the joint effort of manufacturers and power supply utilities, home-made reclosers, sectionalizers and load breakers for looped circuit have been developed one after another, including the auto-recloser of distributed type and FDKW drop-out sectionalizer developed by Zhengzhou Kai-Te Co. based on the controller introduced from Japan and the recloser developed by Pingdingsan Switchgear Works based on KFE recloser introduced from America Copper Co. Distribution automation devices are electromechanical integrated, high-tech products which should have the basic function of a high voltage circuit breaker and meet the requirement of intellectualization concurrently. Manufacture capability for those products will promote the development of our distribution automation and through continuous summarization of the experiences will realize the products wholly homemade. Further researching in trying to seek suitable automation schemes for our distribution network will be done. The number of above distribution automation devices operated on our country network has amounted to several thousands sets.

However, about distribution automation schemes, a great deal of research work has yet to be done. Recently, application of recloser for radial distribution line with single power source is quite satisfactory. Application of 3 sets of reclosers on 2-section open type looped circuit with double power sources is reliable, and coordination of protection is met too. If the scheme of using 5 sets of reclosers on 3-section open looped circuit with double power sources were more reliable, it would be a better structure for sectionalize circuit except the protection among devices are rather difficult to set. In order to achieve a most satisfactory result, this paper proposes a method to solve this protection problem.

2. SCHEME OF 5 RECLOSERS WITH DOUBLE POWER SOURCES

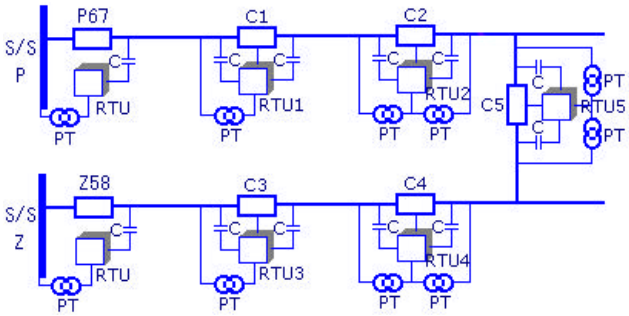

Figure 1: Line sections diagram

2.1 C1—C5: outdoor SF6 circuit breakers

Technical requirements: according to GB1984-89 "AC HIGH VOLTAGE CIRCUIT BREAKER" and SD132-89 "TECHNICAL REQUIREMENTS FOR AC HIGH VOLTAGE CIRCUIT BREAKER";
Mounting place: pole top;
Rated voltage: 10KV;
Rated current: 630A;
Short circuit interrupting current: 16KA;
C/T ratio: 600/5;
Control voltage: 48V/DC;
Operating mechanism: energy storage spring, motor operated mechanism;
Voltage for energy storage motor: 220V/AC;
Overcorrect tripping coil: 300-600/5, 2 phases.

2.2 RTU1—RTU5 (remote terminal unit)

2.2.1 Power source
Rated input voltage: 50Hz, 220V;
Rated output voltage: 48V, with built in chargeable battery for a 24 hours outage.
2.2.2 Remote measurement
5 voltages: U_{ac1}, U_{ac2} 220V;
U_{ab3}, U_{cb3} 110V;
3Uo, 100/3V.
3 currents: Ia, Ic 5A;
3Io = 5A(zero sequence C/T ratio, 100/5).
A/D conversion resolution: ≥10bit
Sampling speed: ≥32points per power cycle;
Conversion error <0.2%;
Remote measurement output: voltage, current, active and reactive power.

2.2.3 Remote indication

4-switch quantity inputs, optical-electro isolation.

2.2.4 Remote control

3-switch quantity outputs: controlling close, open of a circuit breaker and execution, upon receiving a remote control instruction. Checking the instruction first, if all correct, then sending out.
1-switch quantity output: used to transmit relevant switch positions, top-down transmitting out after change of position:
RTU1 YXX1=YX5 (after switch C5 closed, it's position signal transmitted to RTU1);
RTU2 YXX2=$\overline{YX1}$ and Y_{CV1} (C1 in open position and P/T alive, it's position signal transmitted to RTU2);
RTU3 YXX3=YX5 (after switch C5 closed, it's position signal transmitted to RTU3);
RTU4 YXX4=$\overline{YX3}$ and Y_{CV3} (C3 in open position and P/T alive, it's position signal transmitted to RTU4);
RTU5 YXX5=YX1 and YX3 (after both switches C1 and C3 closed, their position signal transmitted to RTU5).

2.3 RUT1-RUT5 (integrated automation part)

2.3.1 Protection

Function of overcurrent and instantaneous tripping protection

CPU needs calculating voltage, current waveform and time, calculating harmonic components and power flow direction. The protection categories and current setting can be revised by CPU or set up by portable PC via RS-232 interface locally.

2.3.2 Function of selecting faulty line of small current neutral grounded system in S/S

CPU in S/S carries out measuring and recording zero sequence current. Zero sequence voltage initiates the recording. Amplitude and direction of zero sequence current in several cycles before and after occurrence of single phase grounding fault is recorded and transmitted to CPU of DMS/SCADA.

2.3.3 Function of fault recording oscillograph

When current exceeds the setting value, the current wave form and time in several cycles before and after the occurrence of fault is put into a special memory device and transmitted to CPU of DMS/SCADA.

2.4 RTU1—RTU5 (communication part)

2.4.1 Disposition of communication

Communication interface: RS-232 (300-56K bit rate, optional)

Maintenance interface: RS-232 (auto-identification 300-19.2k)

Communication code: DNP3.0 code for supporting active reporting of RTU, concurrently considering CDT and Polling code.

2.4.2 Channels

2.4.2.1 Distribution line carriers (DLC): Taking 10KV distribution network as medium to transmit power carrier, using 5-20KHz carrier frequency which has less transmission attenuation in distribution network, adopting 4-phase relative phase modulation or expanded frequency modulation technology. Transmission speed 1200bps, forming medium voltage data exchange network in bus communication mode.

2.4.2.2 Communication between RTU of substation and CPU of DMS/SCADA adopts optical fiber or microwave to form the computer's communication network by ATM local network emulation method.

2.5 RTU1—RTU5 (controlling part of switches)

Motor-driven closing, opening;

Automatic closing, opening: operation characteristic, high speed; parameters of Amp-Sec. Curve complying with SD317-89 and JB7570-94 standards.
Auto-returning time setting for instantaneous fault: Z=20s;

Auto-locking time setting for permanent fault: (time for checking successful closing) Y≤20s.

2.5.1 RTU1, RTU3 (controlling part 1 of sectionalizers)

Auto-reclosing time setting: In order to coordinate with the single shot recloser in substation, X=30s (reckon of time starts when the system becoming alive and the recloser in open position).

Operating behavior: Single side power source, single side P/T. Normally in close position, high-speed tripped by inverse time overcurrent, high-speed tripped by no-voltage release. After checking that P/T alive, judging that C5 in open position, by the end of setting time X it auto-reclosers, then starting reckon of time Y. If the recloser tripped by overcurrent or no-voltage within the time limit, it's auto-reclosing function will then be locked.

2.5.2 RTU2, RTU4 (controlling part 2 of sectionalizers)

Auto-reclosing time setting: X=30s (starting reckon of time when the line section is becoming alive and the recloser is in open position).

Operating behavior: Single side power source, both sides P/T, normally in close position, high-speed tripped by inverse time overcurrent, or no-voltage release. After checking one of the P/Ts alive. It closes by the end of setting time X (additional criteria: If P/T11 alive and C1 in open position, C2 can not be closed; If P/T31 alive and C3 in open position, C4 can not be closed), starting reckon of time Y. If within the time limit Y, recloser tripped by inverse time overcurrent or no-voltage release, it's auto-reclosing function will be locked.

2.5.3 RTU5 (controlling part of interconnecting switch)

Auto-reclosing time setting: X=120s (starting reckon of time when either side loses supply and the recloser in open position).

Operating behavior: Both sides power sources, both sides P/T, normally in open position. Checking P/T on both sides, upon loss of power source on either side, by the end of setting time X, the recloser auto recloses (additional criteria: If both C1 and C3 in close position, the recloser C5 can not be closed). Starting reckon of time Y. If recloser tripped by inverse time overcurrent or no-voltage release within the time limit Y, it's auto-reclosing function will be locked.

2.6 PT: potential transformer

2.7 C: coupling condenser

3. ANALYSIS OF OPERATING ON SYSTEM FAULT

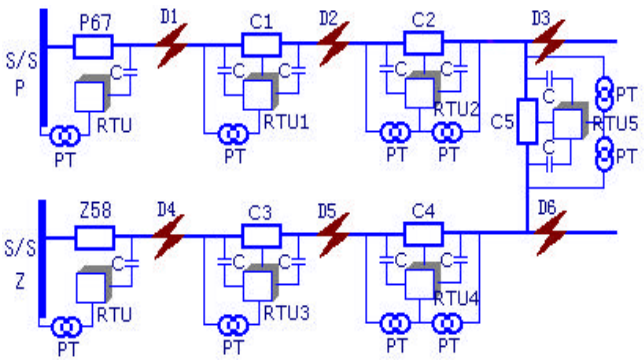

Figure 2: fault analysis diagram

3.1 Normal operation

The circuit breakers P67, Z58 in respective S/S P, S/S Z are in close position, line sectionalizing reclosers C1, C2, C3 and C4 in close position, interconnecting recloser C5 in open position. Two sections of lines constitute a looped network operated in open circuit mode. Closing and opening of these switches may be carried out either locally or by remote control.

3.2 Instantaneous fault

When instantaneous short circuit fault occurs at spot D1 (or D2, D3), circuit breaker P67 in S/S P will trip to eliminate the fault. After lost of supply, C1 and C2 trip automatically. 0.8 second later, P67 recloses successfully. At the 30th second, C1 recloses successfully. At the 60th second, C2 recloses successfully, thus the system goes back to normal.

3.3 Permanent fault

3.3.1 When permanent short circuit fault occurs at spot D1, circuit breaker P67 in S/S P trips. After loss of supply, C1 and C2 trip automatically. 0.8 second later, P67 recloses but fails, and trips again. At the 120th second, C5 recloses successfully. At the 150th second, C2 recloses successfully. The faulty section D1 is thus isolated.

When permanent fault occurs at spot D4, analysis is the same as above.

3.3.2 When permanent short circuit fault occurs at spot D2, whether circuit breaker P67 trips or not depends upon the magnitude of short circuit current (If it trips, it will reclose successfully after 0.8 sec.). C1 trips due to overcurrent or no-voltage, and C2 trips due to no-voltage. At the 30th sec., C1 recloses but fails, and being locked. If P67 trips and recloses successfully, then at the 120th sec. C5 closes successfully. At the 150th sec., C2 can not be closed and being locked. The faulty section D2 is thus isolated.

When permanent short circuit fault occurs at spot D5, analysis is same as above.

3.3.3 When permanent fault occurs at spot D3, whether circuit breaker P67 in S/S P trips or not depends upon the magnitude of short circuit current (If it trips, it will reclose successfully by the end of 0.8 sec.). C1 and C2 trip due to overcurrent or no-voltage as the case may be. At the 30th sec., C1 recloses successfully. At the 60th sec., C2 recloses, but fails and being locked, At 90th sec., C1 recloses successfully. At the 120th sec., C5 can not be closed and being locked due to the fact that at this time both C1 and C3 are in close position (see additional criteria in section 2.5.3). Thus the faulty section D3 is isolated. Same analysis can be applied to permanent fault in spot D6.

4. SINGLE PHASE GROUNDING FAULT

When single-phase grounding fault occurs on a line in small current neutral grounding system, the fault is allowed to continuously operate for a certain period of time. Therefore, it is not necessary to isolate the faulty section at once, but fault signal should be sent to substation. So that the attendant can isolate the faulty section by remote switch

operations or by means of trial opening the circuit breaker momentarily to select the faulty line, section and isolate it. The switching operations are as follows:

4.1. Opening circuit breaker P67 (Z58), if the single phase grounding fault is not eliminated, it is sure that the fault is not on this section. Circuit breaker P67 (Z58) then should be closed within 60 sec. to let the system back to normal.

4.2 Opening circuit breaker P67 (Z58), if the single phase grounding fault disappears, then, the fault is on this section. Closing circuit breaker P67 (Z58) within 60 seconds, if fault signal appears immediately after close of circuit breaker P67 (Z58), D1 is the faulty section. If fault signal appears at the 30th second after close of circuit breaker P67 (Z58), D2 is the faulty section. If faulty signal appears at the 60th after close of circuit breaker, D3 is the faulty section. After completion of these switching operations, the line returns back to its initial operation mode, but with the single phase grounding fault.

4.3 If it is required to isolate the faulty section and keep the remaining sections continuously operating, the following switching operations should be done. Opening circuit breaker P67 (Z58), if the grounding fault disappears, it can be judged that the fault is on the line. Closing the circuit breaker P67 (Z58) in 30 seconds and watching the fault signal. If the signal appears immediately after close of P67 (Z58), D1 is the faulty section. In this case, P67 (Z58) should be opened within 20 seconds and left in open position, then the line sectionalizers will automatically isolate the faulty section D1. If the fault signal appears at the 30th second after close of P67 (Z58), circuit breaker P67 (Z58) should be opened within 20 seconds after receiving of signal and closed back immediately, then the line sectionalizers will isolate the faulty section D2 or D3 automatically.

5. ANALYSIS OF OPERATION RESULT

This automation system was installed on P67-Z58 looped line on February 25, 1998 and operated since then. The statistics during this period shows that the system has encountered faults 3 times and preventive test of circuit breaker P67 once. In all cases, the switches operated correctly.

On March 22, single phase grounding fault occurred on P67 line, through selection, the faulty section was located between C1 and C2 sectionalizer of B67-Z58 tie line. This section is a 150m length of trunk line with a branch. Because of sectionalization of the line, the scope of fault was reduced, so that through line patrol, the fault was found and eliminated within 10 minutes instead of patrolling 6.6km length of whole P67 line according to original practice.

On April 20, ZhengJiasan substation met with a fault, circuit breaker Z58 tripped. The recloser on the looped line operated correctly and the load on Z58 was transferred to P67 automatically.

On May 22, the circuit breaker P67 in S/S P was required out-of-service for a period of 8 hours for preventive test. By means of automation operation, the load on P67 was transferred to Z58 automatically, so the supply was not interrupted.

On June 7, consumer's fault occurred on section D1 of P67-Z58 looped line, P67 tripped instantaneously and reclosed correctly, thus the fault was isolated at section D1 and the supply for sections D2 and D3 was automatically transferred to Z58.

During the above three faults and one switching operation for preventive test, due to that faults were automatically isolated within faulty section and the statuses of the five reclosers transmitted remotely to the control center. The speed of discovery and handling of faults were three times quicker than before, while the area of outage was decreased three times, greatly improved reliability of supply for consumers. During these six months, examination result showed that the reliability of supply amounted to 99.98% above. If it were not such a looped network with sections, the reliability of supply would decrease to 99.5% below for the same period.

6. NEXT PLAN CONCERNING REFORMATION OF URBAN NETWORK

After trial operation of this automation scheme for a year, our bureau plans to spread this scheme to vast area of urban network in XiangFan municipality. At present, there are 117 circuits of 10kv lines in the network; every two of them will be interconnected to form a looped circuit. Between the looped circuits further interconnection will be done to form a lattice network step by step, and 300 reclosers for looped circuits and 100 reclosers for branch lines will be installed. RTU of each recloser will communicate with base station of host substation by power line carrier added with optical fiber and microwave. The communication between controlling host substation and on-site terminals adopts ATM and asynchronous frequency duplex polling mode. DMS/SCADA of the controlling host substation interfaces with MIS and GIS. DMS/SCADA sends additional criteria of close permission to each RTU via top down channels. Each recloser can operate automatically according to system condition and the additional criteria sent from DMS/SCADA. Single phase grounding fault can be judged and settle by DMS/SCADA.