Application of FA in intelligent distribution network

Lingkai Zhu 1, *, Qian Wang 1, Weishuai Wang 2, Haijing Zhang 2

1 State Grid Shandong Electric Power Research Institute Jinan, China
2 State Grid Shandong Electric Power Company., Ltd, Jinan, China

*Corresponding author e-mail: zhulingkai@woyoxin.com

Abstract. As the nerve end of power system, distribution network is a user oriented window for power enterprises. Feeder automation (FA) is an important part of intelligent power distribution, which can monitor line operation, find line faults in time, diagnose fault areas quickly, isolate faults and restore power supply in non fault areas. This paper analyzes FA from the aspects of FA realization mode and start-up strategy, and takes FA usage in Shandong distribution network as an example to illustrate the role of FA in intelligent distribution network.

Key words: power supply reliability, intelligent distribution network, feeder automation (FA), fault diagnosis.

1. Introduction
Under the condition of market economy, reliable power supply to users is the pillar of power enterprises to ensure their own economic development. The distribution network is the part of the whole power system directly connected with the scattered users, and it also has the most direct and significant impact on the reliability of users' power supply [1, 2]. The intelligent distribution network system uses modern electronic technology, communication technology, computer and network technology to integrate the online data and offline data of distribution network, distribution network data and user data, grid structure and geographic graphics for information, so as to realize the intelligent monitoring, protection, control, power consumption and distribution management of distribution system under normal operation and accident conditions, and its automation level is of great significance to the safe and reliable operation of distribution network system and is the key to the development of distribution system [3]. Feeder automation (referred to as FA) is an important part of distribution line automation. It uses automation devices to monitor the operation of distribution lines, find out line faults in time, quickly diagnose fault areas and isolate fault areas, quickly restore the power supply to non fault areas, shorten the outage time and reduce the number of outage households, and improve the reliability of power supply [4].

2. FA implementation mode
FA refers to the automation of the feeder line from the outgoing line of the substation to the user's electrical equipment. The content of FA can be summarized into two aspects: one is user detection, data measurement and operation optimization under normal conditions; the other is fault detection, fault isolation, transfer and restoration of power supply control under accident conditions. FA can be realized
in three ways: main station centralized mode, local distribution mode and current voltage hybrid mode [5].

2.1. Main station centralized mode
The main station centralized is also called current type, which is realized by using distribution automation main station system and adding distribution measurement and control terminal. The master station collects the information of all terminal devices through the communication system, determines the fault location through the network topology analysis, and then sends the remote control command to control the switch action to complete the fault isolation and restore the power supply in the non-fault area.

When the centralized line fails, the switches at the front end of the fault can detect the fault current, and the switches at the back end of the fault can not detect the fault current.

![Figure 1. Example of centralized line failure](image)

For the line shown in Figure 1, if the fault occurs in Section C, FCB1 trips when detects the fault current, and the fault current is detected by FTU corresponding to PVS2 and PVS2 before FCB1 tripping, and the fault current is not detected in FTU corresponding to PVS3. According to the fault information uploaded by FTU, the master station gives the fault section between PVS2 and PVS3, and then sends the execution command to the relevant RTU to isolate the fault.

2.2. Local distribution mode
Local distribution is also called voltage type. It mainly relies on the switch with certain functions to complete simple automation. It cooperates with the pre-test switch of the power to automatically opening in case of voltage loss or no current, so as to achieve the purpose of isolating the fault and recovering part of the power supply. This kind of switch usually has the characteristic of "voltage time", that is to say, it controls its action by the time of pressurization and voltage loss. After voltage loss, it opens, after pressurization, it closes or locks. The local distributed line fault handling process is shown in figure 2.

![Figure 2. The local distributed line fault handling process](image)
2.3. Voltage-current mode
The implementation strategy of voltage-current FA refers to the realization of fault detection, location, isolation and other functions using current detection criteria, while the operation of switch uses AC operation power supply. In case of line fault, the main station of distribution network collects the fault information of related FTU through GPRS, analyzes the fault and locates the fault according to the line topology. As the voltage type automatic load switch has the characteristics of "decoupling when loss of voltage", at this time, the switch in the loss of power is in the opening position. The remote master station only needs to send out the switch locking and opening command to lock the switches on both sides of the fault point at the opening position, so as to realize the isolation of the fault area.

3. FA strategy of distribution automation master station

3.1. FA starting conditions
The breaker switch at the outlet of the substation is open and the protection signal (including general accident signal, over-current signal, quick break signal, etc.) acts. When the protection action signal is received first and then the switch opening signal, the time difference between them shall be within 30 seconds. When the switch opening signal is received first and then the protection action signal is received, the time difference between them shall be within 5 seconds. If the time limit is exceeded, the fault processing program will not be started.

3.2. Fault interval determination
The fault section of the current type line is determined according to the fault signal sent by the automatic section switch or fault indicator on the line. The judgment result of fault section is the load side section of automatic section switch or fault indicator at the end of fault signal sent on the line, which is bounded by automatic section switch or fault indicator with normal communication.

The fault determination of voltage type line is that after the power supply of the non fault section on the power side is transmitted, the master station actively calls the terminal switch position and locks the remote signal, and judges the fault section by dividing the blocking signal of the voltage switch. The fault section determination must have at least one reclosing. When there is no reclosing, the system cannot determine the fault section. When the reclosing is successful and there is no power cut interval, it is an instantaneous fault. After successful line reclosing, the system issues the terminal data call of the whole line. If the terminal section of the charging range has a sub blocking voltage switch, the fault section will be determined. The section is the load side section of the sub blocking switch, and the section is bounded by the automatic switch or fault indicator. If the time difference between the second tripping and the last closing of the outgoing switch is less than 5/7 of the X-time limit of the first voltage type switch, it is determined as the first section fault. For the non first section fault, the system issues the control and closing order of outgoing line switch to carry out the secondary closing. After the successful reclosing, the fault section is determined according to the successful reclosing fault.

For the circuit with both voltage type switch and current type switch (including interconnection switch), it is defined as hybrid circuit. Principle of fault section determination of this kind of line: first, according to the principle of fault section determination of voltage type line, determine a large section range; then check whether there is fault signal from current type switch within the section range, and then determine the fault section again according to the fault signal of current type switch.

3.3. Fault section isolation and non fault section recovery power supply
After the determination of fault section of current type line, only the line with the system fault processing mode set to "full automatic" can the system automatically isolate and restore power supply at the power side. The preparation principle of isolation operation order in self-healing mode is to disconnect all automatic switches at the boundary of fault area, so as to realize effective identification and isolation [6]. After the fault section is removed, the line shall be used for power supply preferentially. If it is
found that the line does not meet the conditions of load transfer inspection during load transfer calculation, the load side transfer path shall be considered for transfer.

The voltage type switch locally realizes the section isolation and the non fault section power supply at the power side. The strategy of switching operation in the non fault outage section on the load side is to first close the interconnection switch, and then successively open, lock and close the voltage type switch in the non fault outage section. The purpose of this operation is to avoid the X-time delay closing of voltage type switch, which leads to the failure of fast power supply recovery in the outage area. It can also prevent the voltage type switch at the load side of the fault section from sending power to the fault section after the failure of locking, which will cause the line at the supply side to trip.

The mixed type line operates the current type opening operation sheet first, then the current type closing operation sheet, and then the voltage type operation sheet.

4. Conclusion
At present, there are more than 24000 distribution lines in Shandong Province. From 2011, State Grid Shandong Electric Power Group Co., Ltd. carried out the construction and application of distribution automation in an all-round way, to 2014, it has realized the full coverage of line distribution automation in 17 prefecture level cities and 98 County Center areas under the jurisdiction of the whole province [1]. Combined with FA action information of web master station of distribution automation, SOE record of automation device on the line and word record of offline data, users can quickly grasp the operation, trip and fault recovery of each distribution line, effectively ensuring the safe and reliable operation of distribution line.

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