Application of Multi-terminal Pilot Protection Algorithm in Network Information Big Data for New Feeder Automation Terminal

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Abstract. With the development of big data and Internet of Things technology, society has put forward higher requirements for the safety and reliability of the power grid. In order to improve the overall power supply quality, the State Grid Corporation changed the previous concept of focusing on power transmission and light distribution, and increased its investment in the field of distribution network, which ushered in its own spring for the entire power distribution industry. This article aims to study the application of big data-based multi-terminal longitudinal directional protection algorithm in the new feeder automation terminal. Based on the introduction of the development status of feeder automation, the existing problems and the workflow of the multi-terminal longitudinal protection system, the multi-terminal longitudinal protection system is analyzed. The application of the directional protection algorithm in the feeder automation terminal. Finally, the treatment of abnormal situations is studied. The research results show that the new type of feeder automation terminal only needs to exchange the comprehensive information of the fault to independently detect and isolate the fault. This multi-terminal protection the structure has high flexibility and can quickly isolate faults, which can meet the protection requirements of the new feeder automation terminal.

Keywords: Big Data, Multi-terminal Pilot Protection Algorithm, Fault Isolation, Feeder Automation.

1. Introduction

With the continuous deepening and advancement of the marketization and development of our country's modern power transportation in recent years, as well as the continuous improvement of technical requirements for the reliability and service quality of our country's modern electric power by users, this determines that our country's modernized power grid must work hard in the future to be able to provide customers and enterprises with safer, more reliable, cleaner, and high-quality services as soon as possible, and to provide more refined and efficient power services [1-2]. Therefore, how to build a new generation of smart grid is gradually developing into a beautiful vision of many countries and regions in the world today, and it will further promote the transformation and innovation of the development model of our country's power industry [3-4].
As an important part of the global smart grid in the future, the intelligentization of information technology in the distribution network has gradually become a new trend in the development of the global power grid industry in the future, which is of decisive significance for the further realization of the overall goal of global smart grid construction. Technology and automation systems regard it as the last project of the distribution network for power users around the world, and its significance is self-evident [5-6], ensuring the reliable and stable supply of electrical energy, which is considered to be completely intelligent. The future of the distribution network says that our development is the top priority. The various real-time data of the distribution automation system, equipment operation status and other information must be derived from our distribution automation terminal, and for fault judgment, isolation and the restoration of non-faulty areas and power supply must also be manipulated by a distribution automation terminal. Therefore, the distribution automation terminal plays a vital role in the construction of distribution automation and even the global smart grid [7-8].

Based on the introduction of feeder automation development status, existing problems and the work process of the multi-terminal pilot protection system, this paper analyzes the application of the multi-terminal pilot protection algorithm in the feeder automation terminal, and finally studies the handling of abnormal situations. The research results show that the new type of feeder automation terminals can independently detect and isolate faults only by exchanging comprehensive fault information. This multi-terminal protection structure has high flexibility and can quickly isolate faults, which can meet the protection requirements of the new feeder automation terminals.

2. Application of Multi-terminal Pilot Protection Algorithm Based on Big Data in New Feeder Automation Terminal

2.1. The Development Status of the New Feeder Automation System
(1) The distribution network of sectioner + recloser has carried out an automatic mode, that is, an automatic coordination is carried out in the distribution network between the sectioner and the recloser. The delay operation of the recloser requires that the sectioner can well meet the delay operation requirements that need to be set. After all the segmenters have met the delay, it is allowed to operate freely on all segments. After the switch is closed [9-10], the current detection value of the sectionalizer is obtained after the delay operation is closed, and the corresponding voltage is registered. After a certain delay operation, the sectionalizer will soon be possible again. The closing of all sectioners, but one place that needs special attention is that in the entire operation process of closing all sectioners, if the sectioner close to the location where a fault occurs, it will pass the detection method. Get all the relevant information about the possible failure of the sectioner. The sectioner is the second trip and jumps and soon no longer needs the first jump to close, and the sectioner is the second Jumps. The recloser is closed again at a location or particularly a location that has been reopened. After a certain duration and current delay, the recloser recloses the power supply for the second time, thereby effectively isolating and isolating the power supply system at the fault location. Repair and provide power to the location where the failure may occur [11-12].

(2) The automatic mode of recloser + recloser. This model is the coordination between the recloser in the restructure and the recloser in the restructure. On the feeder or cable line, when a short circuit or fault occurs between two components, even if one component has a voltage drop or another component has an excessive current, the two reclosers on the power supply side will be the first. Tripping is automatically performed, and then according to the distance or the direction of the fault location or the distance between the other two components, the recloser is also automatically tripped; when the recloser is automatically closed or the closing operation is running incorrectly later, it may switch to the mechanical manual, and only through manual operation can the recloser be switched.

2.2. Problems of the New Feeder Automation System
(1) The basic structural feature of this microprocessor is that it has a single function and cannot be expanded in any way; the vast majority of the various controllers used in various power systems in my
country at that time adopted the coded boundary switching controllers, this type of controllers are limited due to their own design functions and their structural characteristics. Not only are they easy to read, but they also cannot meet the needs of future power system automation improvements and upgrades. Because many parameters of this type of equipment cannot be adjusted or modified, it can only be used as a discrete measurement predetermined by a product in the factory process. The achievable operation is that only an automated switch can be activated and closed. If a fault is found, the operator must deal with it now. Compared with the information collection and feedback required by traditional automation, these All require operators to have a large technical gap.

(2) The lack of self-monitoring function on the start switch line. Moreover, the working principle of the switch accounts for a considerable proportion of the accident rate caused by the switch itself in the feeder automation system. At present, some instruments that are being developed and used in China have tested the normal working conditions of the feed switch itself, and basically just stayed at the factory inspection, before installation, or during power outage maintenance. After the subsequent construction projects are completed and put into use, the operational stability of the switch components may directly affect factors such as work intensity and daily disassembly, maintenance and overhaul. And as the final terminal of an automation system, it is also very important to comprehensively detect the state of its operation and to give an alarm when it fails.

(3) The vast majority of terminal ftu currently in use is due to the lack of protection functions for communication security, and data communication with the terminal has a strong dependence, and there are many risks. With the gradual deepening of the intelligent construction of our country's power grids, there are more and more potential safety hazards in the distribution network. There is no terminal ftu that has the functions of communication security and protection. Moreover, because the data communication carried out by these terminals is carried out by the public Internet, there is no way to obtain the security of the equipment and its data transmission. The above factors will provide very important potentials and risks for the safe implementation and operation of feeder electrical automation systems.

2.3. Work Flow of Multi-terminal Pilot Protection System

(1) When the system is operating normally, the management host determines the protection scope of each SDTU and other SDTUs associated with each protection scope according to the requirements of the multi-terminal pilot protection system, combined with the current network topology and operation mode and other information, then send this information to each SDTU. Once the system fails, the relevant SDTU exchanges fault direction information with the corresponding SDTU based on the associated domain information to achieve the purpose of rapid detection and isolation of the fault.

(2) SDTU monitors the current of each outlet and bus voltage in real time to determine whether the system is malfunctioning. During the normal operation of the power distribution system, the multi-terminal pilot protection system only stays in the fault judgment procedure to monitor whether the fault occurs in real time; once a fault is detected, it immediately enters the fault location and isolation procedure.

(3) After the power distribution system fails, the SDTU queries the SDTU associated with itself for the fault judgment result according to the obtained exact judgment result (fault direction + overcurrent information) and the associated domain issued by the management host.

(4) If the SDTU information in the correlation domain is successfully obtained, go to step (6); if the SDTU failure judgment result in the correlation domain is not successfully obtained within the specified time, then go to step (5).

(5) Expand the scope of an information exchange according to the associated domain. If the failure judgment information is successfully obtained, go to step (6); otherwise, after a delay, the corresponding section switch and interface switches will be turned off.

(6) The SDTU performs fault location and isolation calculations based on the acquired local fault information and the fault information of other SDTUs in the protection area. If the fault occurs in the
protection area of the SDTU, it will trip the associated section switch and each interface switch isolates the fault to ensure that the normal area of the distribution network continues to operate.

3. Experiment
Take the AC phase-to-phase short-circuit fault on line L4 in Figure 1 as an example to introduce the multi-terminal longitudinal directional protection algorithm proposed in this article.

![Figure 1. Simple distribution network with DG.](image)

For the distribution network, when the communication fails, the information will be under-reported or misreported. In order to improve the reliability of protection, the new feeder automation terminal itself should have the function of finding and correcting misreporting or missing information in this case. In order to make the information used as accurate as possible, the fault information on the switch needs to be corrected or merged.

There are mainly the following three situations:

1. The terminal faults in the main protection associated domain of the new feeder automation terminal cannot provide comprehensive fault information.

   After a fault occurs, the new feeder automation terminal that starts the protection must communicate with the new feeder automation terminal in the protection associated domain. If the new feeder automation terminal in the associated domain does not communicate with the local side within a certain period of time, the node is considered to be faulty. Expand the scope and exchange information of the new feeder automation terminal in the associated domain of backup protection.

2. The new type of feeder automation terminal’s own node information is missing

   When the local new feeder automation terminal cannot determine the comprehensive fault information due to the lack of fault direction information, it needs to send request information to the new feeder automation terminal in the forward and reverse protection associated domains to infer the local direction information. Since the new feeder automation terminal and the new feeder automation terminal in the protection association domain only exchange comprehensive fault information and exchange direction information under special circumstances, the amount of communication data is less and the efficiency is higher.

   When the local direction information is missing, request information can be sent to the new feeder automation terminal in the forward and reverse protection associated domains to obtain the direction information on both sides of the new feeder automation terminal, and then use equation (3) to infer the local direction.

\[
\begin{align*}
\sum_{k=1}^{n_r} 1 \bigcirc d_k &= 2, \text{then} \ d = \sum_{k=1}^{n_f} d_k \\
\sum_{k=1}^{n_r} 1 \bigcirc d_k &= 1 \land \sum_{k=1}^{n_f} d_k = 1, \text{then} \ d = 1 \\
\sum_{k=1}^{n_r} 1 \bigcirc d_k &= 1 \land \sum_{k=1}^{n_f} d_k = 0, \text{then} \ d = 0 \\
\sum_{k=1}^{n_r} 1 \bigcirc d_k &= 0, \text{then} \ d = 0
\end{align*}
\]

Where \( n_r \) is the number of reverse protection associated domains; \( n_f \) is the number of forward protection associated domains; \( d \) is the direction information of the local protection;

3. Node information error
When the direction information and overcurrent information of the local new feeder automation terminal are \((0, 1)\), it means that the directional element judges that there is no fault and the overcurrent element judges that there is a fault. At this time, the two information contradicts and does not conform to the convention. At this time, the new feeder automation terminal can request to obtain the fault information of the forward and reverse protection associated domains for correction. If the forward and reverse protection of the new feeder automation terminal in the associated domain (if there is no forward new feeder automation terminal, the direction information is 0), indicating that the overcurrent information is wrong at this time, the comprehensive information of this new feeder automation terminal Equal to 0. Otherwise, the direction information is the same as the direction information of the reverse protection associated domain at this time. If it does not belong to the above situation, the comprehensive fault information will be processed as 0.

After a fault occurs, each new feeder automation terminal with a comprehensive fault information of 1 needs to interact with the new feeder automation terminal in the forward protection associated domain to determine whether the fault has occurred. If no new type of feeder automation terminal with fault comprehensive information of 1 is found in the forward protection associated domain, it can be determined that a fault has occurred within the protection range of the new type of feeder automation terminal. At this time, the new feeder automation terminal must trip and issue a trip command to the new feeder automation terminal in the forward protection associated domain.

According to the longitudinal protection algorithm formula, the tripping action values of the feeder automation terminal 2 and the feeder automation terminal 4 are calculated as equations (1) and (2).

\[
b_2 = \sum_{k=1}^{1} s_2 \odot s_k = s_2 \odot s_4 = 1 \odot 1 = 0 \tag{2}
\]

\[
b_4 = \sum_{k=1}^{3} s_4 \odot s_k + s_4 \odot s_6 + s_4 \odot s_7 = 1 \odot 0 + 1 \odot 0 + 1 \odot -1 = 1 \tag{3}
\]

From equations (1) and (2), it can be seen that the terminal 2 does not operate, and the terminal 4 needs to trip and send a trip signal to the terminals 5, 6, and 7. The calculation result of this multi-terminal longitudinal direction protection algorithm is in line with the actual situation.

4. Discussion

Build the above model in PSCAD, the ABC three-phase short circuit fault occurs at the end of line L4, where \(z=(0.27+j0.4)\Omega/km\), the system voltage is 10kV, and the system impedance is 0.5Ω. The working voltage, reference voltage and output results of the directional components of each protection in Figure 1 are shown in Table 1:

| New feeder automation terminal | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| \(\Delta U_{op}\)             | 0.3768| 2.225 | 0.0426| 7.7121| 0     | 0     | 0.2103| 0     |
| \(\Delta U_{m}\)              | 0.2042| 1.1123| 1.1123| 3.8617| 0     | 0     | 5.49  | 0     |
| \(d\)                         | 1     | 1     | -1    | 1     | 0     | 0     | -1    | 0     |

The overcurrent setting value of each protection, the measured current value after the fault occurs, and the output result of the overcurrent element are shown in Figure 2:
Figure 2. Overcurrent element.

The direction information and overcurrent information of the relevant feeder automation terminal and the calculation of the comprehensive fault information are shown in Figure 3.

Figure 3. Comprehensive fault information.

It can be seen from Figure 3 that the integrated fault information of the feeder automation terminal 2 and the feeder automation terminal 4 is 1, so each needs to exchange information with the feeder automation terminal in its forward protection associated domain.

The multi-terminal longitudinal direction protection algorithm does not require the master station to collect fault information for detection and judgment. The master station only needs to calculate the protection correlation domain matrix for the new feeder automation terminal. The communication capacity is low and it is suitable for distribution networks of different scales. The new type of feeder automation terminals can independently detect and isolate faults only by exchanging comprehensive fault information. This multi-terminal protection structure has high flexibility and can quickly isolate faults, which can meet the protection requirements of the new type of feeder automation terminals.

5. Conclusions
As users have higher and higher requirements for power supply quality and power supply reliability, fault isolation and fault recovery of the distribution network have become an increasingly important
part of the transformation and construction of the distribution network. It is of great significance to improve the speed of the isolation fault of the distribution network and restore the power supply to users quickly and effectively. This paper focuses on the application of the multi-terminal longitudinal directional protection algorithm in the new feeder automation terminal. The research results show that the new feeder automation terminal only needs to exchange the comprehensive information of the fault to independently detect and isolate the fault. This multi-terminal protection structure is highly flexible. It can quickly isolate the fault and meet the protection requirements of the new feeder automation terminal.

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