Analysis of optical fiber differential protection based on relay protection

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Abstract. In order to prevent grade-jumping tripping in coal mine distribution network, based on the analysis of the causes of grade-jumping tripping, several schemes to prevent grade-jumping tripping are compared and analyzed, and the fiber current differential protection scheme is suitable for application in working environment. In this paper, the main technology of optical differential protection, in the process of 6 KV power distribution system reform is how to apply this situation are introduced in detail, at the same time, a detailed description of the relative performance for the optical fiber differential protection, a comprehensive discussion of PCS-9613D fiber protection setting calculation and adjustment method, look forward to applying the experience of the use of short transmission optical differential protection.

Keywords: Optical fiber differential protection, The line, Setting calculation.

1. Introduction
In daily life, the stability of power supply system is very important. However, as the actual power supply situation is affected by environmental and geographical factors, three-level power supply is usually used in order to ensure normal production and daily life. That is, to show the ground substation, then to the central substation, and then to the various mining areas, the special working environment determines the vertical multiple levels of power supply. In this mode, the distribution network has a single structure, easy to influence each other, and short transmission distance, resulting in power supply failures and other problems. For example: when a short circuit fault occurs in a part of the distribution network and the fault is detected by the bus switch, the general line switch may be started before the downhole feeder due to the short circuit protection time set by the above-ground substation. This could lead to large-scale power outages and could affect normal mining and production activities of coal mines. Therefore, it is of great significance for coal mine production to carry out in-depth research on leapfrog tripping technology.

2. The analysis of the cause of the line trip
2.1. Relay protection
Most power lines are short - line power sources of 1-3km. Because the current difference between each line of the short-line power supply is not big, so the current value of the line cannot be fully determined,
which cannot be used as a standard to distinguish. Compared with the previous protection in the abnormal area of power supply line, the phased delayed trigger is more suitable to protect the overcurrent of underground power supply system. Due to the large number of protection segments and long delay time, the overall short-circuit protection time of the power system is relatively short, so when the current fault occurs, the protection switch is immediately executed when the system bus is switched, resulting in the generation of step-off tripping.

2.2. Switching power supply

Although the explosion-proof switching power supply used is mostly the main circuit of the switch, but because there is no special power supply, the main circuit has harmonics, voltage loss, three-phase imbalance, short circuit and other reasons, the power supply that originally has the protection and control function will have problems, so the power supply cannot be carried out normally, the switch action is rejected. Wrong action, also can result in the generation of step-off tripping.

2.3. Loss of voltage protection mode

Many high and low voltage switches used in power systems are equipped with voltage loss drag-and-drop. If the supply voltage exceeds 65% of the rated voltage, the cutoff voltage can be absorbed and released. When the rated voltage is less than 35%, the power supply is cut off, but the reliability is low when the rated voltage is 35%-65%. The mechanical rapid quenching action is carried out quickly by relieving the pressure loss. Overcurrent time delay protection is invalid, and overcurrent time delay tripping will occur.

2.4. Line voltage fluctuation

In the power supply system, due to the start of large equipment, grounding, interference from external factors, the voltage may change dramatically in a short period of time. If the value of the variable voltage is lower than 65% of the rated value, the disconnection voltage release will occur, and the disconnection voltage protection trigger of the switch will occur.

3. Application of optical fiber differential protection based on relay protection

3.1. Basic principle of optical fiber differential protection

Optical differential protection is a protective device, often used to indicate the adoption of a communication channel so that the wires at the end of the protective device can be vertically connected to each other. The wires can then be connected through the ports for interception. The electric quantity here is mainly to compare the current and power, etc. According to the data obtained and the electric quantity at both ends of the wire is compared, it can calculate whether the wire is within the protection range value or beyond the protection range value, and continue to judge whether the wire is protected or not according to the judgment result. In order to achieve the goal of eliminating all line failures in an instant, the lines need to be cut off. Theoretically, the differential protection of optical fiber is completely selective, and the calculation as a whole does not need to cooperate with the adjacent lines, so as to carry out protection adjustment. This is also a significant feature and operational advantage of optical fiber differential protection compared with single-terminal measurement protection. The protection range of the fiber differential protection is the full length of the line between the CT (current converter) on both sides. FIG.1 shows the principle of optical fiber differential protection for transmission lines. The reference direction of the current at both ends is from the total lines to the dividing lines, the total lines are M and N respectively. The secondary current of the current transformer is marked with depolarization to ensure normal operation. The secondary currents on both sides of a current transformer must be equal. If the same type of current transformer can be used on both sides of the current transformer, the errors caused by the current transformer can be reduced, while the error can be controlled to the minimum, ensuring safety. According to the analysis of FIG.1, when the short-circuit is at the position of line K1, the current flowing into the differential relay from the secondary side is
The data expressed by this calculation result can be used as the vector of the secondary measured current of current transformers on both sides. When the circuit shorts at line K2, the current flowing into the relay is \( I_r = |I_m + I_n| \). (\( I_r \): the current flowing into the relay; \( I_m \): M side phase current; \( I_n \): N side phase current). In this case the relay does not operate. The difference elements mainly include the following contents. First, the differential of the ratio, followed by the differential of the zero sequence. The main feature of the differential element is that the operation prerequisite must be short circuit in the protection area, and the load current will not affect it. In addition, since there is no need to protect and selectively cooperate the adjacent elements in the system to deal with the short-circuit fault of the line, the detection can be carried out first, and then the rapid action can be realized.

**Figure 1.** Schematic diagram of short circuit outside and inside the current longitudinal differential protection area

### 3.2. Selection of optical fiber differential protection

The 6KV substation is earthed neutral through ARC suppression coil. The protection system of the upper main substation adopted here is PCS and RCS series from Nanjing NARI-RELAYS Co. LTD, which are also commonly used devices in the market. Then a comprehensive comparison can be made with the actual application of the equipment in Sinopec Qilu Company. On September 18, 2013, the line longitudinal differential protection device PCS-9613D produced by Nanjing NARI-RELAYS Co. LTD was installed in the 6KV power distribution system of Qilu. However, in the process of operation, line problems occurred, causing an accident. The original protection device did not play its due role to eliminate the fault and protect the line. In this case, from May to July 2017, the distribution system of Qilu 6KV substation underwent a second upgrade of the previously used protection device through a comprehensive overhaul and the introduction of new technology. On the one hand, PCS-9613D protection is mainly used for non-directly grounded systems or lowland connections. In the resistance grounding system below 110KV, the function of digital substation is fully supported. At the same time, it can also protect a variety of components, with a strong inclusive. In addition, the protection function of PCS-9613D protection equipment is used for differential protection, 3-stage overcurrent protection, 1-stage reverse time limit protection, 3-stage zero-sequence overcurrent protection and other line protection, automatic re-closed-circuit function, overload protection, etc, all of which can play a very good role in protection.

### 3.3. Practical application of optical fiber differential protection device

1. **Installation of PCS-9613D**

The general composition of PCS-9613D protection device is shown in FIG.2. At the two ends of the wire, there is a corresponding wire component protection device, and the protection device is also connected to the wire. At the same time, the amount collected on the side of the secondary current line is compared with the amount collected on the opposite side. The direction constitutes differential protection, and a two-stage ratio braking differential mode is adopted. The action curve of differential protection is shown in FIG.3, and the protection logic of PCS-9613D is shown in FIG.4.
As shown in FIG.4, the ratio differential I is the speed socket with no time limit, and the ratio differential part II is the delayed action output of 25 ms, and the fuzzy protection error action due to the large capacity and current. The phase ratio of the brake greatly improves the reliability of the protective action in case of failure.
2. Fixed value setting of PCS-9613D

(1) Startup conditions

PCS-9613D protection can carry out different protection modes according to the differences of protection components, and then different starting components are developed. Moreover, in this device, different starting elements are protected by one to one characteristic. Each startup element must operate the exit, start, and protect elements at the same time after the computation begins, so that dual-channel sampling data can meet the operational requirements. Otherwise, drag and drop cannot be performed.

(2) Differential protection starting element

The starting element of differential protection is protected by over-current relay reflecting the variation of power frequency between stages, supplemented by zero-sequence over-current relay reflecting full current, open differential protection.

(3) Setting of differential dynamic fixed value

PCS-9613D is the threshold value of associative brake and differential action current, and Iblzd is the lowest value of differential protection. For the maximum range value of the protection device, a comprehensive calculation can be made according to the requirements of the manufacturer to obtain: $I_{blzd} = K_{bph} IL / nTA = 0.2 \times 1650 / 300 = 1.1$. In the formula for the calculation, $K_{bph}$ is the imbalance coefficient, which is usually less than 20 percent. After that, the minimum range value of the protection device is $I_{blzd} = K_{rel} IL / nTA = 1.2 \times 800 / 300 = 3.2(A)$ to minimize the error caused by the problems in the data transmission process. In the calculation formula, $K_{rel}$ stands for the reliability coefficient, but in the calculation process, it is necessary to further consider the impact and changes that may be brought by the operation, so the reliability coefficient here is 1.2. In the process of practical application, the setting of differential protection device will far exceed the calculated range value, because the current is less than the set range in the actual operation process. In this way, the protection device can be started in the first time in case of circuit problems.

(4) Test and debugging

The above calculation must not only meet the requirements of relay protection specifications, but also be combined with field practice and the characteristics of the PPC-9613D protection equipment. The computational setup process must be standardized and reasonable. After the update, in the experiment of the unit's full-screen mode, the values of the vertical direction code and the opposite vertical direction code are set to the same value, the abnormal channel light is not lit, the input corresponding to the differential setting control word is lit, and the soft press plate and the hard press plate enter according to the opposite point. Variable starting current. When the change of phase current is greater than the set value, the starting element will play a role. Start the phase current. When the current is greater than the set value, relay operation, trigger lamp, relay display ratio I, ratio II action. In order to meet the requirements, the PCS-9613D protection device is accurate, reliable and highly sensitive, which can eliminate the full-length fault of transmission line in a short time without affecting other factors, thus improving the speed and selectivity of relay protection transmitted. In the protection starting link test using high speed disconnecting device, the action speed is fast, high speed disconnecting device can meet the requirement of high speed switching without interference.

4. Conclusion

Optical fiber differential protection device uses optical fiber communication technology, and it can participate in the working process of line differential protection relay, which brings the development opportunity for line current differential protection. Today, our country technology constantly push forward and the undisturbed switching become the focus on the current, but also a difficult point for people to study. Fast cutting device, by introducing the differential protection for its open protected mode, not only can avoid the failure of the line, but also greatly shorten the malfunction, line short circuit time, makes the basic grid quality is not affected by the interference of external factors, so as to ensure the normal of the grid work, also can carry out immediate standby power switch, then ensure the normal power supply, as well as the durability and reliability of power supply mode.
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