Operation Mode of DC Traction Power Supply System and its Feeder Protection

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Abstract: At this stage, DC traction power supply systems are widely used in the development of China's rail transit. In order to ensure the safety of rail transit, we need to strengthen the research work of DC traction power supply system. We can study and explore from the operation mode of the power supply system and feeder protection measures. Among them, we must pay special attention to feeder protection measures, as far as possible to ensure the safe operation of the DC traction power supply system, so as to ensure the stable operation of rail transit.

1. Introduction
With the rapid development of rail transit in this country, people have more diversified travel modes, and people are increasingly dependent on rail transit. In the process of urban rail transit construction, we must improve the relevant configuration of rail transit vehicles to ensure the safe and normal operation of rail transit and prevent safety accidents during the operation of rail transit vehicles. The DC traction power supply system can provide effective power for the operation of rail vehicles and ensure the stability and reliability of the power supply system during the operation of the rail. Therefore, we need to increase the importance of DC traction power supply system operation mode and feeder protection, by improving the application effect of DC traction power supply system feeder protection measures. In this way, the possibility of failure of rail vehicles during operation can be reduced and people can travel safely.

2. Significance of Feeder Protection in DC Traction Power Supply System
With the rapid development of modern society and economy, the pressure on urban traffic is increasing. In order to alleviate the pressure on urban traffic, the scale of rail transit is also increasing. The carrying capacity of urban rail transit is relatively large, the noise pollution generated by it is relatively small, and the operation speed is relatively fast. Therefore, the rapid development of urban rail transit has become an important measure for building a modern city.

In the development of urban rail transit, feeder protection must be considered. For urban rail vehicles using DC traction power supply system, we must pay attention to the necessity of DC traction system feeder protection. Normally, the DC power supply system mainly includes control system, protection system, DC switch cabinet, DC cable contact rail and other parts. The main function of the control system and protection system is to ensure the safe operation of rail transit. These two systems can not only provide reliable and safe power supply for rail operation, reduce the possibility of rail transit failures during operation, but also can selectively remove faults when the DC traction power
supply system fails to ensure that the shortest Overhaul and eliminate the fault within time to ensure the safety of trains, equipment and personnel. In addition, during the operation of the DC power supply protection system, if a sudden failure occurs, the control system and the protection system can quickly and accurately cut off the faulty line. In order to ensure the safe and normal operation of trains, we also need to analyze and deal with the misadjustment caused by changes in electrical parameters [1].

3. Overview of DC Traction Power Supply System

The urban rail DC traction power supply system can transmit electric energy from the traction substation to the electric train through the feeder line and the contact rail. Afterwards, the electric train flows back to the traction substation through the track return line. Traction network is generally composed of contact rails, feeders, running rails and return lines. The traction network is an important part of the DC traction power supply system, and the traction substation is an indispensable power supply link in the operation of urban rail transit. In general, rectifier units, DC switch cabinets, negative cabinets, potential limiting devices, etc. can form a traction substation. The contact rail is mainly a conductive rail that directly supplies electric energy to the electric train through the power receiver of the electric train. The feeder line is the wire used by the substation to transmit traction power to the contact rail. The function of the return line is to return the traction current to the traction substation.

In order to be able to effectively overhaul the DC traction power supply system and troubleshoot hidden faults and safety hazards, we need to minimize the scope of the accident when the fault occurs. We can divide the contact rail into multiple stages, which can be called contact rail power supply sections. If you want to use straddle monorail trains, we only need to lay a separate return line along the track to achieve the purpose of traction current back to the substation. In the process of carrying out division operations, the most important thing is to strengthen the detailed division of traction substations. We need to consider the capacity and distance. If any traction substation fails, the adjacent substation needs to overload the traction load in this area. In consequence, when dividing traction substations, we generally adopt the cross-region power supply method. At the same time, we also need to scientifically design the load carried by the substation. Under normal circumstances, the actual load of the traction substation will be higher than the maximum load during the peak period.

4. Operation Mode of DC Traction Power Supply System

Generally, the power supply modes of traction substations are unilateral power supply, bilateral power supply and cross-region power supply. During the operation of urban rail transit, it is necessary to pass through the contact rail and use the electric segment to complete the electrical isolation work, and divide the original single power supply area into two power supply partitions. In this way, the towed train only obtains electric energy from one substation on a single power supply arm, which is the unilateral power supply mode. If electric energy is obtained from two adjacent traction substations, it is a bilateral power supply mode. If the adjacent traction substation fails to supply power to the train, the traction section between the two failed substations will be paralyzed, causing the entire line to stop running. In this case, we can use the cross-region power supply method to solve the problem.

During the normal operation of the train, the two traction rectifier units of the traction substation are in operation, and can complete operations such as the incoming switch, the feeder switch, the electric disconnect switch and the load disconnect switch, etc., so as to ensure the positive contact rail and the negative rail is live. Two adjacent traction substations can form a bilateral power supply mode, and the units on the depot operate in a unilateral mode, which is the main power supply mode for rail transit during operation. In the case that rail transit cannot operate normally, if maintenance and troubleshooting are required, one of the two units will stop operating. However, in order to ensure the reliability of power supply, the other set will be in overload operation. In this case, if the unit that maintains the power supply fails, it will have an impact on the normal rail transit operation, and we need to start the cross-zone power supply method. Emergency operation mode and cross-zone power
supply mode mainly refer to the inability to supply power to the track when two adjacent traction substations have serious failures. In this way, the traction section between the faulty substations will lose power supply, which will greatly affect the operation of the entire line. At this time, we can use the cross-zone power supply method to transmit the power supply of the adjacent contact rails to the non-electric traction zone [2].

5. Feeder Protection Method for DC Traction Power System

5.1 Switch Current Quick Break Protection
The current quick-break protection of the switch is an important feeder protection measure. The shunt can collect and analyze the current transmitted to the protection device of the feeder circuit breaker, so that we can use the protection device to accurately judge whether to perform the protection action. The current action value of the current quick-break protection is smaller than or equal to the high-current trip action value of the feeder switch. The current quick-break protection device can not only protect the metallic short-circuit faults in the near end and the middle distance of the section, but also protect the measured current. If the measured current is greater than the set value, start timing. If the time exceeds the set value, a trip command will appear. The characteristic curve of protection trip is shown in Figure 1.

![Figure 1 Switch Current Quick-break Protection Characteristic Curve](image)

5.2 DDL Protection
DDL protection is the main measure of feeder protection in DC traction power supply system. This protection measure can overcome the misoperation of separate di/dt protection due to interference, and can also make up for the shortcomings of the protection action. DDL protection mainly includes DDL+ΔI protection and DDL+ΔT protection. The activation of these two protection measures requires a predetermined current rise rate. After starting the feeder protection, the two types of protection will enter their own delay stage and are mutually independent. When any protection reaches the protection action condition first, protection can be started. In the DDL+ΔI protection process, the protection device measures and analyzes the change of the current rise. When the change is higher than the maximum value set by the parameter, the event T is higher than the maximum value and a trip signal will appear. If the current change rate is lower than the return value of the current rise rate before the protection outlet is activated, the overall protection is resetting. When DDL+ΔT protection is running, the measured value of ΔT is higher than the highest parameter value, and the trip signal is activated when the DDL+ΔT protection action starts. If the current change rate is detected before the protection outlet action, the current change rate is lower than F, the entire protection will return [3].

5.3 Line Test Protection
When testing the circuit, we need to test before closing the circuit breaker, so as to prevent the circuit breaker from closing on the faulty circuit. The specific circuit test diagram is shown in Figure 2. In the whole test process, the test circuit includes fixed resistance, fuse, contactor, transmission, protection device, etc. Adding the bus voltage to the feeder circuit using the test circuit can accurately judge whether it can be closed. In the process of applying line test protection, the number of tests, the
interval between two tests and the time of each test can be effectively adjusted according to specific protection requirements. During the operation of the protection device, the measurement bus voltage $U_B$, the feeder power supply $U_R$ and the feeder current $I$ are mainly used to calculate the residual resistance $R_r$. If the remaining resistance $R_r$ is greater than the specified value of the minimum resistance allowed to close, it can be judged to allow closing.

![Figure 2 Circuit Test Diagram](image)

5.4 Line Reclosing Protection
After the line fails and trips, we can use the automatic reclosing function to quickly restore power to the line. The line reclosing protection needs to be reasonably selected according to the fault type. First, if it is a transient fault, it will automatically overlap to ensure that the system can resume normal power supply. Second, if it is a permanent fault, it will be directly locked and closed until it is manually repaired. In order to prevent the fault line from being reclosed, we need to carry out a line test before closing to effectively check whether the line is faulty. If the line test is passed, reclosing can be performed, otherwise we need to lock the switch [4].

5.5 Two-sided Joint Jump Protection
In the process of feeder protection of DC traction power supply system, bilateral joint trip protection is mainly carried out by interlocking the power supply circuit breakers of the same power supply section to ensure the safety and reliability of the fault line. In the process of feeder protection, the signal connection is hard-wired. Hard wiring can send out pulse signals according to the working mode of the protection device. The signal completes the signal sending and receiving work through the sending end module of the joint jumper installed in the interface cabinet of each station and the corresponding receiving end module. When the system is operating normally, two adjacent traction substations can simultaneously provide bilateral power supply to the same power supply zone in the traction network. In this way, once a loop or fault occurs, the high-current trip protection or DDL protection of a feeder switch in the traction substation closer to the fault point will act first, and will send a trip signal to the joint trip device of the station. Meanwhile, the joint jumper cable can be used to send a feeder switch trip signal to the joint trip device of another traction substation.

5.6 Other Protection Methods
In addition to the above feeder protection, there are other protections in the DC traction system, which mainly include the following aspects. First, countercurrent protection. Reverse current protection is also reverse current protection. If the power cable between the rectifier unit and the switch cabinet fails, in order to prevent external interference from returning fault current to the faulty part, we need to
set up reverse current protection. The main feature of reverse current protection is that it needs to measure the magnitude and direction of the current, and send the signal to the protection device after completing the collection work. The protection device can use the set reverse current value and time to determine whether there is reverse current protection, thereby tripping the switch. Second, frame protection. This feeder protection is relatively special. It is a unique protection method in the subway DC traction power supply system. It generally includes frame current protection and frame voltage protection. Frame current protection mainly achieves the purpose of protection by preventing leakage current between grounding and DC switch insulation frames. In the protection process, we need to use shunts and transmitters to measure the current value between the ground and the frame. In addition, we also need to send the collected current value to the protection device. If the collected current value is greater than the protection value set by the protection device, it can be determined that frame current protection has occurred. The main function of frame voltage protection is to prevent the potential difference of the equipment shell from being larger than the safe allowable potential difference, and to provide reliable protection for personal safety. Frame voltage protection is mainly to measure the potential difference between the negative return bus and the housing of the DC switchgear, and send the measured potential difference to the protection device. If the measured potential difference is greater than the protection setting set by the protection device, the frame voltage protection can be determined. The operation of the framework protection will cause a large-scale blackout of subway equipment. This kind of protection has high contingency and relatively high sensitivity [5].

6. Conclusion

All in all, in order to ensure the safe and stable operation of rail transit, we need to strengthen the research on feeder protection of DC traction power supply system. In the research process, we need to accurately understand and analyze the specific application of many protection measures based on the specific operation mode of the DC traction power supply system. Only in this way can we take scientific and reasonable feeder protection measures according to the rail transit power supply mode to ensure the safety and reliability of the urban rail transit power supply system, thereby improving the operational safety of rail transit.

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