Chapter 8
Research on Fault Detection Technology of Primary and Secondary Circuit of Switchgear

Xuesong Lin, Yu Xu, Changsong Ni, Jingwen Cai, Chunqing Lin, Lei Zhang, and Di Yu

Abstract At present, the primary and secondary equipment integration has been realized in 10 kV switching station and ring main unit, and the functions of telesignalling, telemetering and telecontrol have been realized by assembling Data Transfer Unit (DTU). However, in actual operation and maintenance, if an equipment fault occurs, it is necessary to first determine whether it is a primary or secondary equipment failure, and then send corresponding maintenance personnel to the site. In addition, this maintenance mode also needs to be powered off. The existing primary equipment does not have a circuit breaker test position. If the test is required, the whole section of bus must be powered off. Due to the important user and reliability requirements, the power off is almost difficult to implement. If the fault identification cannot be solved at one time, the power off times need to be increased, which affects the reliability of power supply. The primary equipment is electrified, and the secondary equipment has few test methods, low safety factor and more equipment operation with faults, which is not conducive to the healthy development of distribution network (M. Adams, Effectiveness of different design solutions to control internal faults in MV switchgear, IEE Colloquium on Risk Reduction: Internal Faults in T&D Switchgear (Digest No: 1997/295), pp. 5/1–5/6, 1997). In order to solve the above problems, this paper proposes a ring network unit fault detection device that can distinguish between primary and secondary circuit failures without power failure. On the basis of the traditional fault diagnosis method, a low-voltage live detection method with high safety and easy operation is added.

8.1 Introduction

With the development of the power industry, the power distribution switchgear has evolved into a complete set of automation equipment with primary and secondary integration. Dispatch remote operation and automatic fault isolation have been widely

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used in daily operation, and it has also brought great technical challenges to the operation and maintenance of power distribution.

When the switchgear refuses to operate or exits from the operation mode, it is necessary to accurately determine whether it is a primary equipment failure or a secondary circuit failure. According to different fault types of high-voltage switchgear, fault detection methods using mechanical properties, electrical properties, temperature and other parameters have been proposed at home and abroad. Various monitoring methods can be used to easily obtain the state parameters of the high-voltage switchgear and the waveforms of related signals. However, because the high-voltage switchgear is a combination of multiple electrical equipment, it involves various physical phenomena such as electricity, magnetism, and temperature, and the manifestations and mechanisms of faults are very different. It not only affects the reliability of power supply, but also causes a great waste of manpower and financial resources. Therefore, it is necessary and imminent to study the detection technology of the primary and secondary circuit failures of the distribution automation ring mains.

This paper proposes the isolation and detection of the primary and secondary circuits in the ring network unit system. It is proposed to conduct online live diagnosis for most primary and secondary circuit faults without power failure. On the basis of the traditional fault diagnosis method, a low-voltage live detection method is added, which provides high safety and easy operation.

8.2 Research on Switchgear Fault

8.2.1 Primary Faults

Investigation statistics show that the primary faults of high-voltage switchgear mainly fall into the following categories:

(1) Fault of refusing action and misoperation: This kind of fault is the main fault of high-voltage switchgear, and its causes can be divided into two categories: one is caused by mechanical faults of operating mechanism and transmission system. The other is caused by electrical control and auxiliary circuits.

(2) Insulation fault: It is manifested as external insulation to ground flashover breakdown, internal insulation to ground flashover breakdown, phase-to-phase insulation flashover breakdown, lightning overvoltage flashover breakdown, porcelain bushing, porcelain bottle fracture, etc. [3].

(3) Current-carrying fault: The main cause of current-carrying fault at voltage levels of 7.2 to 12 kV is the poor contact of the switchgear isolation plug, which causes the contacts to melt [4].

(4) External forces and other faults: including foreign body impact, natural disasters, short circuiting of small animals, etc.

8.2.2 Secondary Faults

The secondary faults of the switchgear generally fall into the following categories:

(1) Power source: AC and DC circuits; current and voltage circuits.

(2) Purpose: signal circuit, protection circuit, automatic device circuit, control circuit and measurement circuit.

(3) Equipment: transformer secondary circuits, switch secondary circuits, capacitor secondary circuits, etc.

8.3 Design of Detection System Structure

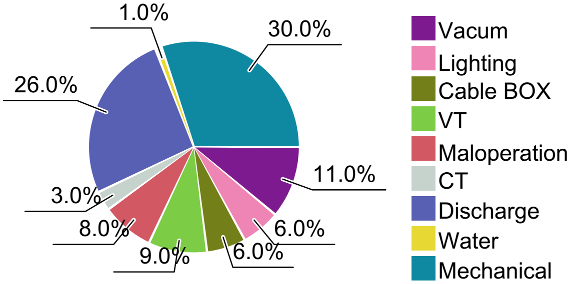
When the switchgear is put into operation, after pulling out the working plug, the detection system enters the test state. At this time, the telecontrol closing signal is given in the background, the test power indicator is on, the closing relay is pulled in, and the test closing indicator is on and maintained, which proves that the closing circuit works normally, and the test of switch-off circuit is the same (Fig. 8.1).

As shown in Fig. 8.2, there are 11 terminals in the test terminal block on the door of the ring switch cabinet, and each terminal consists of an upper end and a lower end which can be communicated or isolated. In the daily operation state, the working plug is inserted into the test terminal block of the cabinet door, so that the upper and lower ends of the terminals of the terminal block are in a communication state.

The lower ends of terminals 1, 2, 3 and 4, terminals 5 and 6, terminals 7 and 8 and terminals 9 and 10 of the cabinet door test terminal block are all equipped with a shorting ring (Table 8.1).

As shown in Fig. 8.3, the terminal of the cabinet test terminal base is composed of upper and lower parts, and the lower end of the terminal is provided with a short circuit ring. The upper and lower ends of the terminal are normally open. During daily operation, the working plug is inserted into the cabinet door test terminal block, the upper and lower ends of the terminal are connected, the short circuit ring at the lower end of the terminal is invalid, KA1, KA2 relays, HR1, HR2 and Hg indicator lights do not work, and the test circuit is separated from the control circuit.

Fig. 8.1 Different kinds of faults in switchgears



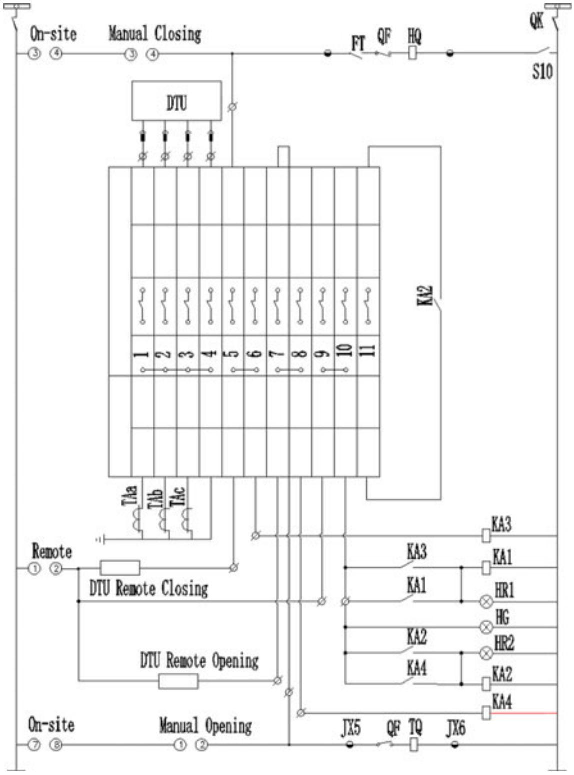


Fig. 8.2 Terminal on the door of ring switch cabinet

Figure 8.4 shows, when faults need to be detected, pull out the working plug of the cabinet test terminal block and insert the test plug. At this time, the upper and lower terminals of the cabinet test terminal block are disconnected, and the short ring at the lower end of the terminal is invalid. The short-circuited ring at the lower end of the test plug is effective, so that the lower end of terminals 1, 2, 3 and 4 is short circuited and the protection current circuit is sealed. Add an overcurrent signal to DTU at the upper end of the test plug; the lower end of terminal 7 and 8 of the test plug is short circuited, and the telecontrol trip circuit is switched from the circuit breaker trip coil to KA2 coil. Receive overcurrent signal in DTU, send overcurrent remote control trip signal, intermediate relay KA2 operation; the passive open point of intermediate relay KA2 is closed, and the closure of intermediate relay KA2 can be measured by the upper and lower conduction of terminal 11 of the plug through the test.

After the test is completed, the work switch is reset to the local position, and then the trip time can be tested again when it is turned remotely. Pull out the test plug and insert the work plug to release the self-locking and experimental circuit and return to normal working state.

Table 8.1 Terminals of ring switch cabinet

Terminal	Bottom	Top	Function
1, 2, 3, 4	Secondary winding of CT	DTU	Conduct, provide interface for external detection equipment
5	DTU output port	Circuit breaker closing circuit	Conduction and isolation
6	K1 relay	empty	Test the conduction of DTU telecontrol closing circuit
7	DTU export	Circuit breaker opening circuit	Conduction and isolation of telecontrol opening circuit
8	K1 relay	empty	Test the conduction of DTU telecontrol closing circuit
9	DTU export	empty	Detect the conduction of DTU remote switching-off circuit
10	Auxiliary contacts of KA1 and KA2 relays	empty	Detect the conduction of DTU telecontrol closing circuit and opening circuit with terminals 8 and 9
11	Auxiliary contact of KA2 relay	Auxiliary contact of KA2 relay	Backup protection tripping standby time detection point

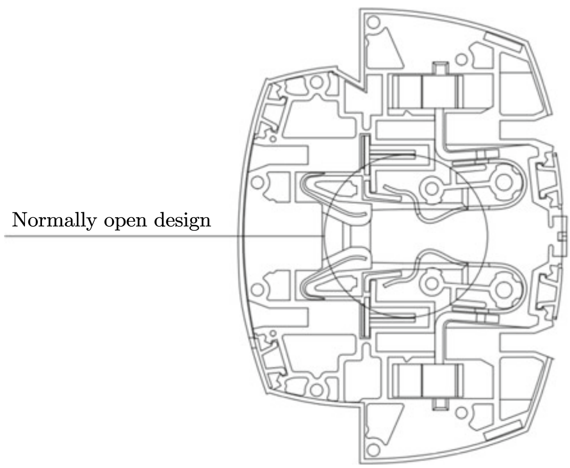


Fig. 8.3 Cabinet test terminal block

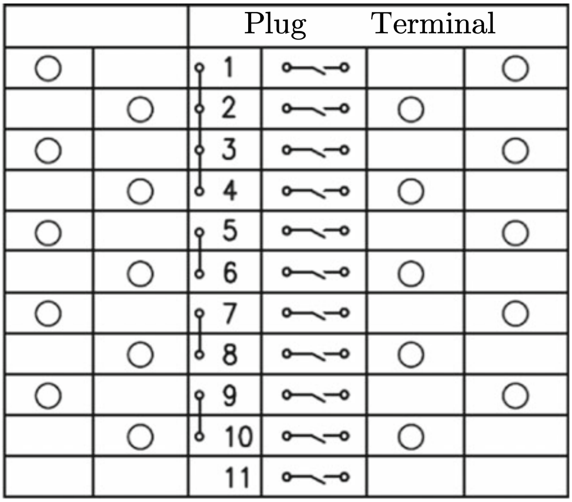


Fig. 8.4 Plugs and terminals for testing

When the system is running normally, the background will monitor the current value of the current system in real time. When the three-phase current value of the power grid is found to be unbalanced, it may be the primary equipment (such as current transformer), or the secondary ammeter or detection system. At this time, the working plug of the cabinet test terminal block can be pulled out, and the short-circuit ring at the lower end of the terminal takes effect to short circuit the secondary current circuit, so as to prevent overvoltage caused by the open circuit of the secondary circuit of the current transformer. Then, the plug inserts the test plug into the cabinet test terminal block. At this time, the test terminal block at the lower end of the short ring invalid, instead of the test plug on the short ring in effect, replace the test terminal block on the function of the short ring. At the same time, the upper and lower terminals of the cabinet test terminal block are disconnected to realize separation from the measuring device of the system. The testing device is connected to the binding post of the test plug, and then the short-circuit ring on the test plug is removed to realize the role of detecting the current value of the system. If the three-phase current is balanced and the value meets the standard, it is proved that the primary equipment has no problem, and the problem lies in the secondary measuring equipment on the system.

8.4 Research on Detection Technology

At present, the primary and secondary circuit fault detection method of the switchgear mainly includes three main points: fault detection of the secondary circuit, protection setting mechanism, and the prevention of the secondary circuit CT open circuit and PT short circuit.

8.4.1 Fault Detection of the Secondary Circuit

When the equipment fails and the switch refuses to operate or the remote control fails, the current practice requires the entire section of the bus to be powered off before troubleshooting. Moreover, it is more dangerous to short circuit the CT in the current secondary circuit live test, and it is easy to misoperate and cause the switch to trip. In addition, it is necessary to remove the equipment trip connection to prevent the equipment protection from malfunctioning, which may cause the risk of malfunction [5].

By on-line monitoring and testing of relevant functions of secondary equipment, the successfully developed secondary circuit monitoring component can distinguish the specific fault section of primary and secondary equipment. When the failure reason cannot be directly determined by reading the DTU message and fault information, it can be inserted through the test terminal to enter the test state, dispatch the telecontrol command, and indicate the telecontrol state through the indicator light on site, so as to quickly distinguish the fault reason of primary and secondary equipment. In case of secondary equipment failure, troubleshooting and protection of transmission can be carried out when the primary equipment is live, which will not cause risks such as tripping at the outlet of the primary equipment and has high safety.

8.4.2 Protection Setting Mechanism

It is difficult to implement the protection setting when the relay protection is running on line, and the safety risk is high. The switch trip and personal accident caused by the disconnection error and CT short-circuit error occurs. There is an urgent need for a simple, plug-and-play test method to reduce personnel safety risks and operational difficulties.

Therefore, the protection setting mechanism of distribution automation switch under the condition of live operation is studied, and the switch action display under the test state is realized through the equipment. The protection test, set value setting, protection transmission and other functions of the electrified secondary circuit of the primary equipment are realized, and the protection set value is realized on the premise of ensuring the safety of the human body and equipment.

8.4.3 Prevent CT Open Circuit and PT Short Circuit

The equipment can automatically short circuit the CT circuit and disconnect the PT circuit, and automatically connect to the test section sub-circuit. The operator directly connects the test wiring to the test section, which is convenient and practical, and prevents personnel safety risks caused by the opening of CT and PT short circuit during the test.

8.5 Conclusion

By studying the fault monitoring method and monitoring components of secondary circuit based on primary and secondary fusion switchgear, the specific fault segments of primary and secondary equipment are distinguished, and the related functions of secondary equipment are tested through online monitoring. At the same time, it can realize the protection setting mechanism under the energized operation of the distribution automation switch, and realize the protection test, setting value setting, protection transmission and other functions of the primary equipment on the secondary circuit through the equipment. The automatic CT circuit and PT circuit can also be automatically short circuited and opened through the equipment, so as to avoid switch tripping and personal accidents caused by disconnection errors and CT short-circuit errors. Main technical advantages:

(1) During the fault detection, it can realize the isolation of the primary and secondary circuits and detect the operating state without power failure, and identify the location and section of the fault on the spot.

(2) Strong versatility, suitable for all the ring network elements of the first and second fusion system.

(3) Simple operation, easy to use, to solve the existing equipment test difficult problem, to solve the problem of live adjustment protection value, reduce the difficulty and safety risk of the primary equipment running secondary equipment live test.

References

1. M. Adams, Effectiveness of different design solutions to control internal faults in MV switchgear, IEE Colloquium on Risk Reduction: Internal Faults in T&D Switchgear (Digest No: 1997/295) (1997), pp. 5/1–5/6. https://doi.org/10.1049/ic:19970977
2. Q. Hu, M. Sahni, C. Gibune, S. Liang, W. Lee, Development of an online real time web accessible low-voltage switchgear arcing fault early warning system, in *2007 39th North American Power Symposium* (2007), pp. 20–24. https://doi.org/10.1109/NAPS.2007.4402280
3. D.W. Klaus, Internal faults in distribution switchgear-risk reduction and design considerations, IEE Colloquium on Risk Reduction: Internal Faults in T&D Switchgear (Digest No: 1997/295) (1997), pp. 2/1–2/4. https://doi.org/10.1049/ic:19970974
4. G.A. Hussain, M. Shafiq, M. Lehtonen, Predicting arc faults in distribution switchgears, in *2016 17th International Scientific Conference on Electric Power Engineering (EPE)* (2016), pp. 1–6. https://doi.org/10.1109/EPE.2016.7521722
5. Z. Hailong, J. Song, Z. Dongchen, L. Zhirui, L. Chengpu, W. Hejian, Research on detection system for 10kV distribution switcher of both Primary and secondary technology. Int. Conf. Power Syst. Technol. (POWERCON) **2018**, 3929–3935 (2018). https://doi.org/10.1109/POWERCON.2018.8601599