

Application of Intelligent High Voltage Switchgear



Qin Zou, Hao Lei, Xushu Ye, Xiting Dong, Kezhen Yang, and Jin Chen

Abstract In the background of modern distribution model, people put forward higher requirements for the power system, and the intelligent high-voltage switchgear in the modern distribution model of the intelligent distribution network link plays a crucial role. This paper focuses on the application of intelligent high voltage switchgear and compares the structure and function of traditional high voltage switchgear and intelligent high voltage switchgear. This paper briefly introduces the faults in the operation of the high voltage switchgear. In the design and application of monitoring system, mechanical characteristics detection system, video double confirmation system, electric grounding switch, electric chassis car were introduced and analyzed, and analyzed the advantages of intelligent high voltage switchgear in substation, operation and maintenance, safety and other fields of application, for reference.

Keywords High voltage switch complete equipment · Electrical design · Intelligent Chinese library classification number

1 Introduction

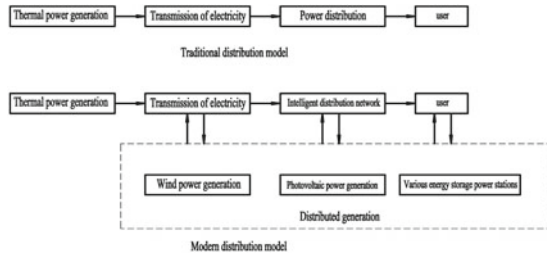
With the emergence of 5G, sensors, computers and other new technologies, as well as the development of alternative energy sources such as wind power generation, photovoltaic power generation and various energy storage stations (such as pumped energy storage, compressed air energy storage, flywheel energy storage, super capacitor, chemical battery energy storage, etc. [1]), energy can come from different places, and its coordination and control have become more advanced. Distribution models are also transitioning from traditional single-source to end-customer side distribution models to modern ones, as shown in Fig. 1.

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1269

Fig. 1 Traditional distribution model and modern distribution model diagram



The modern distribution model in Fig. 1 is compared with the traditional distribution model. The power generation mode has changed from the traditional thermal power generation to the multi- source form of thermal power generation plus distributed power generation. The distribution network has changed from the traditional distribution mode to the intelligent digital distribution network. The intelligent high-voltage switchgear plays a vital role in the intelligent distribution network.

Intelligent high voltage switchgear, it is based on the modern Internet technology under the condition of a new type of electrical products, through the introduction of computer technology to it as the core of detection, protection, and with circuit breakers, sensors, electric ground cutter and other components, so that the functions of protection, control, communication and recording can be reliably applied through intelligent technology. This is also in line with the requirements of distribution network automation.

2 Traditional High Voltage Switchgear and Intelligent High Voltage Switchgear

2.1 Traditional High Voltage Switchgear

The traditional high voltage switch cabinet is mainly composed of isolation switch, earthing knife-switch, current transformer, surge arrester, vacuum circuit breaker, interlocking mechanism, live display, ammeter, signal indicator light, transfer switch, electromagnetic lock and cabinet body. The protection level of cabinet body is IP2X. It plays the role of power distribution and control in the three-phase AC 50 Hz indoor system. As shown in Fig. 2.

This traditional switch cabinet needs to be equipped with various analog pointer instruments and relays. It is difficult to realize more complex control logic. The operation mode is mainly manual operation and it is more complex. There are also safety risks such as entering the equipment electrified interval by mistake, unlocking by mistake, and operating by mistake, which brings great inconvenience to production, monitoring, and operation and maintenance.

Fig. 2 Traditional high voltage switchgear diagram



2.2 Intelligent High-Voltage Switch Cabinet

The intelligent high-voltage [2] switch cabinet is divided into four independent compartments: bus room, instrument room, circuit breaker room and cable room. The protection grade of the cabinet is IP4X, as shown in Fig. 3.

The intelligent high-voltage switch cabinet includes vacuum circuit breaker, electric earthing switch, video double confirmation host, camera, electric chassis, intelligent terminal, sensor and other components. Its metering, protection, control, communication and recording functions are safely and reliably applied through intelligent technology, digital display technology and other technologies, which is also consistent with the requirements of distribution network automation. As shown in Fig. 4.

Compared with the traditional high-voltage switch cabinet, the system design of intelligent switch cabinet uses computer technology as the core technology of monitoring, metering and protection. Transform the complex, error-prone and manned traditional operation process into data visualization, simplified operation process and remote control. For some scenarios where it is difficult for personnel to reach in a harsh environment, it can effectively avoid various safety risks and effectively



Fig. 3 Intelligent high voltage switchgear diagram

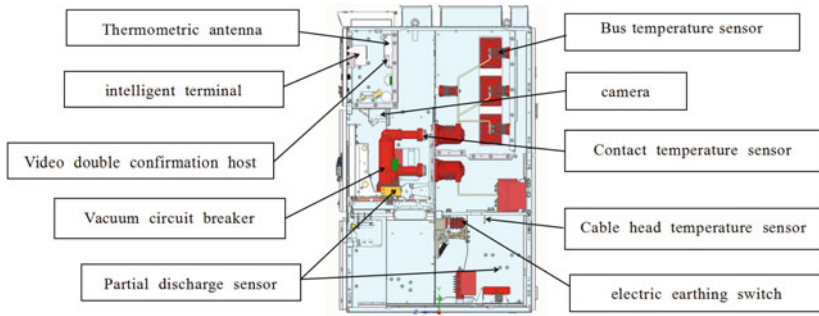
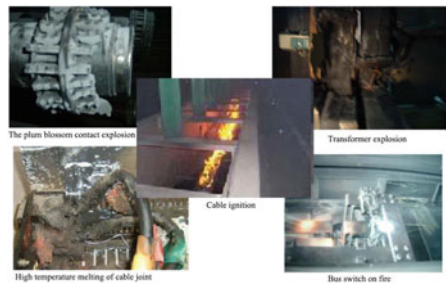


Fig. 4 Components of intelligent high voltage switchgear

Fig. 5 Accident diagram of high voltage switchgear



reduce equipment maintenance costs. So as to ensure the safe, intelligent, efficient and stable operation of the intelligent distribution network.

3 Failure in the Operation of High Voltage Switchgear

High-voltage switchgear will have insulation aging, mechanical failure, heating and other problems in long-term operation. If these faults are not repaired in time, they will often cause mis operation or refusal of operation of the switch, which will expand the fault. If the fault is serious, it will lead to a large area of power failure. When the heating fault accumulates the heat to a certain extent, it will cause the secondary side of the equipment or even the equipment itself to burn, and even the spread of the electrical fire to adjacent equipment leads to a large scale, causing great damage, as shown in Fig. 5.

Literature [3] lists the failure modes of high voltage switchgear, which mainly include rejection failure, mis operation failure, breaking and closing failure, insulation failure, external force and other failures. The key to solve the above problems lies in online state detection, timely discovery and timely treatment of faults. The intelligent high voltage switchgear can effectively discover and notify the operation and maintenance personnel to deal with the above faults in time.

4 Design and Application of Intelligent High Voltage Switchgear

Taking an intelligent high-voltage switchgear pilot project of Huayuan Electric as an example, this project adopts monitoring system, mechanical characteristics monitoring system, video double confirmation system, electric earth switch and electric chassis car, and its topological structure is shown in Fig. 6

4.1 Monitoring System

The monitoring content of the intelligent high-voltage switchgear includes partial discharge monitoring, ultrasonic wave, geoelectric wave and temperature sensor to collect corresponding data, and then transmit it to the intelligent data acquisition gateway through wired mode. The intelligent data acquisition gateway transmits the collected monitoring data to the monitoring center server through the optical network.

Contact Temperature Monitoring

Literature [4] has studied the temperature rise characteristics under typical contact faults, such as the fault at the junction of the incoming busbar of the switchgear, the plum contact fault and the circuit breaker contact fault, and has concluded that the overall temperature rise of the switchgear is increased and the temperature rise at the fault point is the highest when the contact fault occurs. These typical faults will cause overheating, which will accelerate insulation aging and lead to breakdown. It is the main failure mode of high-voltage switchgear.

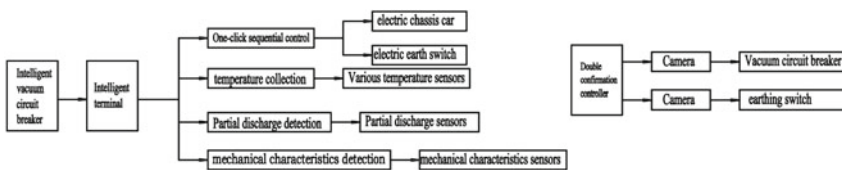
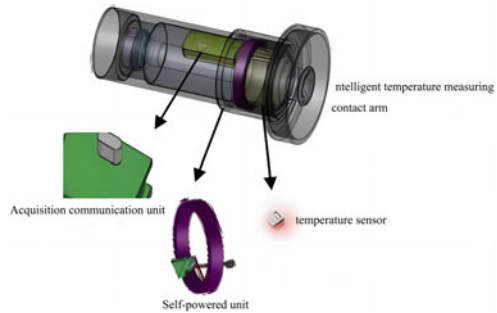


Fig. 6 Topological diagram of intelligent high voltage switchgear

Fig. 7 Structure diagram of the intelligent temperature measuring contact arm



The wireless temperature sensor of the intelligent high voltage switchgear is built into the vacuum circuit breaker to monitor the temperature change of the measuring point in real time to realize early fault prediction and alarm. When a fault occurs, it sends alarm information to quickly determine the location of the fault point and take safety measures according to the corresponding plan.

As shown in Fig. 7, the intelligent temperature measuring contact arm is composed of acquisition communication unit, self-powered unit and temperature sensor. The self-powered unit provides power for the acquisition communication unit and the temperature sensor. The acquisition and communication unit collects the temperature data generated by the temperature sensor in real time and sends the data wirelessly to the monitoring system. This sensor installation mode has the advantages of self-powered, maintenance-free, complete isolation of high and low potential, no electrical connection, flexible installation mode, etc. [5].

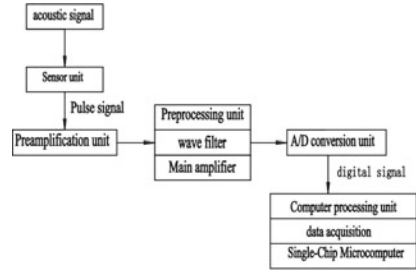
Partial Discharge Monitoring

The damage process of potential partial discharge is often slow and long-term. However, the characteristics of partial discharge can better confirm the insulation problem, so the insulation performance of the product can be objectively evaluated by comprehensive measurement of partial discharge characteristics.

For the intelligent high-voltage switchgear designed by our company, its partial discharge detection method adopts ultrasonic detection method. Ultrasonic method is a kind of mechanical vibration wave. From the perspective of energy, the process of partial discharge is the process of energy release, and electrical energy is released in the form of sound, light, heat and electromagnetic energy. The electrical breakdown occurs in the air gap. At this time, the discharge is completed in an instant and converted into heat energy. The air in the discharge center expands under the influence of heat energy, and its temperature is higher than the ambient temperature, and the sound wave is generated to spread outward; Because the area of partial discharge is relatively small, the local discharge sound source is the point sound source [6].

As shown in Fig. 8, when the sensor picks up the acoustic signal generated by partial discharge in the equipment, it converts the acoustic signal into electric pulse signal, which is amplified by the preamplifier unit and sent to the signal pre-processing unit. The signal preprocessing unit completes the filtering and further

Fig. 8 Schematic diagram of ultrasonic detection device



amplification of the electrical signal, and then converts the partial discharge acoustic analog signal into digital signal through the A/D conversion unit, It is transmitted to the computer and the digital signal is analyzed and processed by the processing software to determine the discharge mode and position [7].

4.2 Mechanical Characteristics Detection System

At present, when the circuit breaker on the high voltage switchgear is too fast, its action mechanism will bear greater mechanical stress and impact, resulting in the deformation of the mechanism parts and shortening the mechanical life of the circuit breaker; when the opening speed is too low, the arc extinguishing time will be increased, and the arc will cause metal melting on the surface of the contact, thus accelerating the electrical erosion of the circuit breaker contacts and reducing the service life of the circuit breaker [8] (Fig. 9).

The mechanical characteristic detection system sets standard mechanical characteristic parameters and corresponding mechanical characteristic error range parameters during installation. Compare the current mechanical characteristic parameters when the equipment is running. If the current mechanical characteristic parameters exceed the error range, it will be judged as abnormal. At the same time, when the circuit breaker acts, the system will generate a corresponding action report to display the parameters of the action, such as opening and closing time, speed, serial number, circuit breaker count, etc.

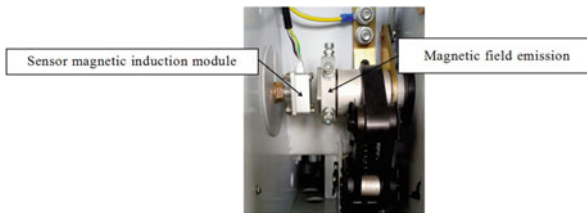
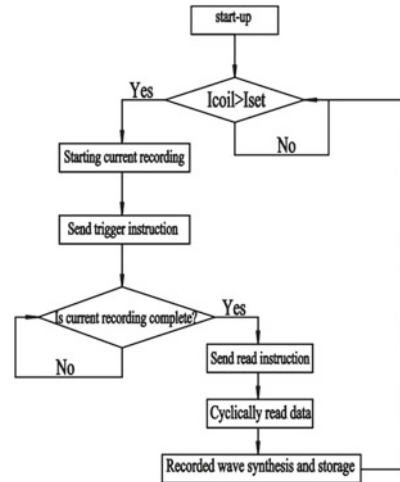


Fig. 9 Mechanical characteristics sensor installation diagram

Fig. 10 Flow chart of mechanical characteristics sensor



As shown in Fig. 10, the device can determine whether the circuit breaker acts by detecting whether there is current in the opening and closing coil current in real time. The current setting I_{set} can be set manually. After the opening and closing coil has current, the device sends the trigger command, the sensor starts to record the mechanical characteristic curve, and the device starts the current recording. After the current wave recording is completed, read the mechanical characteristic curve data for wave recording synthesis and storage [9].

4.3 Video Double Confirmation System

The video double confirmation system measures the displacement of the hand car through video, monitors the movement of the hand car throughout the whole process, intelligently analyzes the working position of the hand car, the test position, and the full stroke of the opening and closing of the hand car for video monitoring. According to the video status, it can be clearly seen the contact entering state when the hand car moves. During the inspection process, it can provide real-time video images of the intelligent high voltage switch cabinet (Fig. 11).

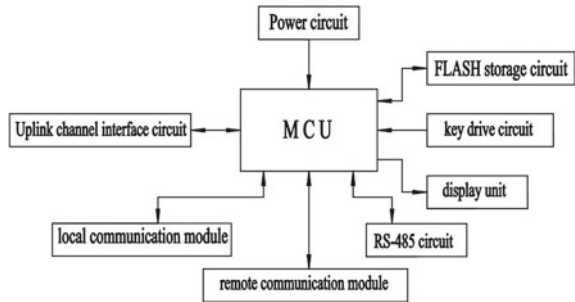
The double confirmation image processing host includes MCU module, power circuit, uplink channel interface circuit, FLASH storage circuit, key drive circuit, display unit, local communication module, remote communication module and RS-485 circuit.

As shown in Fig. 12, the MCU module is equipped with software to identify the algorithm of the corresponding color block within the range of HSV and the size range of the color block. The power circuit supplies power to the MCU module, the video signal output terminal of the MCU module is connected to the video signal input terminal of the display unit, and the key signal output terminal of the

Fig. 11 Actual position diagram of circuit breaker contact cabinet



Fig. 12 Schematic diagram of video double confirmation system



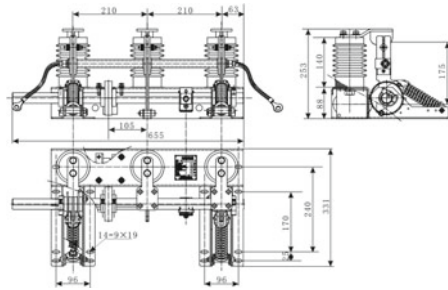
key drive circuit is connected to the key signal input terminal of the MCU module. The uplink channel interface circuit, FLASH storage circuit, local communication module, remote communication module and RS-485 circuit are connected to the communication port of MCU module. The double confirmation measurement camera is connected to the video signal of MCU module through 7RS-485 circuit. The upper computer is connected to MCU module through the remote communication module [10].

4.4 Electric Earth Switch

The electric earth switch does not change the opening and closing structure of the original earth switch body, but adds an electric operating device, which enables the switch to also conduct electric opening and closing operations, with local operation, remote operation and manual priority functions. Its structure is simple and its operation is safe and reliable.

The electric earth switch is composed of switch body, motor, clutch gear, transmission gear, valve electromagnet, energy storage spring, large shaft, etc. (Fig. 13).

Fig. 13 Structure diagram of electric earth switch



When closing is required, the positive transmission of the motor drives the clutch gear to rotate, thus driving the transmission gear and large shaft to rotate to the dead point of the energy storage spring, the position switch automatically switches the motor, and the earth switch quickly closes under the action of the energy storage spring.

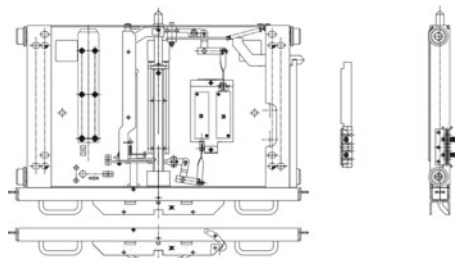
When opening is required, the motor reverses, drives the clutch gear, transmission gear and large shaft to move in reverse direction, the energy storage spring reaches the dead point, and the position switch switches again to realize opening operation [11].

4.5 Electric Earth Switch

The electric chassis car can not only operate the chassis car electrically, but also manually in the case of no power supply. It has local and remote operation functions. The electric chassis car is composed of chassis, lead screw, motor and other parts (Fig. 14).

When the motor is started, it drives the gear to rotate through the reducer, thus driving the screw to rotate. Under the action of the screw, the chassis car drives the circuit breaker to the working position until it reaches the working position. The normally closed contact of the auxiliary switch at the working position is switched

Fig. 14 Structure diagram of electric chassis car



to normally open contact, the motor is shut down, and the chassis car stops moving [12].

5 Conclusion

In recent years, as the demand for electricity has soared, the demand for power supply has become increasingly high. It is very important to ensure the security of intelligent distribution network, and the key node is prevention. High voltage switchgear as an important complete set of equipment in power system, ensure its stable and efficient operation, can have a direct and significant impact on the power supply quality of intelligent distribution. The following describes the advantages of intelligent high voltage switchgear in intelligent operation and maintenance.

5.1 *Advantages of Application in Intelligent Substation*

In the application environment of intelligent substation, the operation and maintenance of high-voltage switchgear has changed from manual patrol inspection to online monitoring, from fault repair to active repair, from post-repair to pre-warning, and from passive power failure to active operation and maintenance. The intelligent high-voltage switchgear has the functions of on-line real-time monitoring and remote control, which lays the technical foundation for intelligent substation to realize “feeder automation”, when the distribution network line fails, The distribution automation master station can conduct fault research and judgment by itself, perform fault isolation by fully automatic remote control, and quickly restore power supply to non-fault areas, thus reducing the time and scope of power failure, improving power supply reliability, and bringing social benefits.

5.2 *Advantages of Application in Equipment Operation and Maintenance*

The monitoring system, video double confirmation system and mechanical characteristic monitoring system configured for the intelligent high-voltage switchgear can provide a lot of convenience for the operation and maintenance management work, so that the operation and maintenance personnel can obtain extremely reliable auxiliary force in the equipment monitoring. Through real-time collection of uploaded video imaging and data, the alarm will be sent in time after the abnormal problem is detected, so as to ensure that the operation and maintenance personnel can find the abnormal information in time, According to the intelligent monitoring results, we

can quickly find the root cause of the problem, reduce its negative impact on power supply, improve the effectiveness of operation and maintenance management, and effectively reduce the occurrence rate of high-voltage switchgear failure.

5.3 Advantages of Application in Operation and Maintenance Security

Intelligent high-voltage switch cabinet is equipped with electric earth switch, electric chassis car, intelligent vacuum circuit breaker and other components. It is the basis for realizing the “remote control” function. It is precisely based on the realization of the “remote control” function that personnel can operate the high-voltage switchgear remotely, thus avoiding the impact of electric arc burns, electric current burns, skin metallization, explosion and other injuries caused by poor contact of the circuit breaker contacts during the opening and closing operation. The application of electric chassis vehicle can effectively prevent the operation and maintenance personnel from being hit and injured by objects caused by the overturning of handcart during the operation of handcart transfer and maintenance. Reduce the accident risk through remote operation and fully guarantee the personal safety of operation and maintenance personnel.

To sum up, the designers have continuously integrated new technologies and materials during the design and practice of high-voltage switchgear to accumulate technical experience. Constantly improve the operation efficiency and stability of the equipment, and lay a good foundation for the operation of the intelligent distribution network.

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