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Research and Design of High Voltage Intelligent Switch Technology Based on Primary and Secondary Fusion

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Abstract. At present, the intelligence of high-voltage switch is mainly embodied in the application of intelligent components such as intelligent terminals. A large number of discrete components and cables are still used in the switch body and secondary circuit. It brings many difficulties to installation, debugging, operation and maintenance. In order to adapt to the development direction of digital, integrated and standardized of primary equipment, this paper proposes a high-voltage intelligent switch scheme, which is fully integrated primary and secondary. This scheme will build multi source intelligent sensors, such as position sensor, SF6 gas sensor, current sensor, and configure intelligent control module in mechanism box and control box. The intelligent sensor realizes self-perception of equipment state, and the intelligent control module integrated with the switch mechanism body completes the local intelligent signal acquisition and control, it realizes the secondary circuit composed of optical fiber instead of cable and intelligent operation circuit instead of traditional discrete components, which greatly simplifies the traditional secondary circuit of switch, improves operation and maintenance efficiency.

1. Introduction

High-voltage switch is one of the core equipment in substations. At present, the intelligent of high-volt age switch in intelligent substations is mainly embodied in the application of intelligent components su ch as intelligent terminals. By installing the intelligent terminals in the control cabinet, the signal trans mitted by traditional cables is converted into optical fibre signals to interact with secondary devices su ch as protection, measurement and control. The problems related to cables and cables between the cont rol cabinet and the protective measuring and controlling equipment are discussed. However, a large nu mber of cables are still used as the carrier of signal transmission between the switch body and the cont rol cabinet, and discrete relays are still used in the control cabinet to realize the control circuit of the s witch. As far as the switch body is concerned, its intelligence level needs to be further improved in ord er to enhance its intelligence, intelligent measurement and intelligent control ability. At present, the sw itch mainly has the following problems to be solved, such as it often appears components and cable da mage, insulation abnormalities and other defects because of a large number of discrete components an d cables in outdoor operation environment. It brings adverse effects to design, construction, commissio ning,operation and maintenance because of a large number of cable connections. The switch monitorin g are limited, and the online monitoring has not been widely promoted and applied, so it is impossible to effectively monitor the operating conditions of the switches [1-3].

With the development of microelectronics, computer technology,intelligent sensor and primary-secondary deep integration technology, it provides technical support for the development of primary equipment to intelligent equipment, and makes it possible for the development of intelligent equipment to be digital,integrated,standardized,and modular[4]. This paper proposes a high-voltage intelligent switch scheme, which is fully integrated primary and secondary. This scheme will build multi source intelligent sensors, such as position sensor, SF6 gas sensor, current sensor, and configure intelligent control module in mechanism box and control box. The built-in intelligent sensor realizes self-perception of equipment state. The intelligent control module integrated with the switch mechanism body completes the local intelligent signal acquisition and control, it realizes the secondary circuit composed of optical fiber instead of cable and intelligent operation circuit instead of traditional discrete components, which greatly simplifies the traditional secondary circuit of switch, effectively reduces operation risk, improves operation and maintenance efficiency, and fundamentally improves the intelligence level of switch equipment.

2. The architecture and the operation status of the current switch

2.1. The architecture of the current intelligent switch

At present, the intelligence of the switch is mainly embodied in the application of the intelligent components such as intelligent terminals and on-line monitoring[5-9]. The specific architecture is shown in Figure 1.

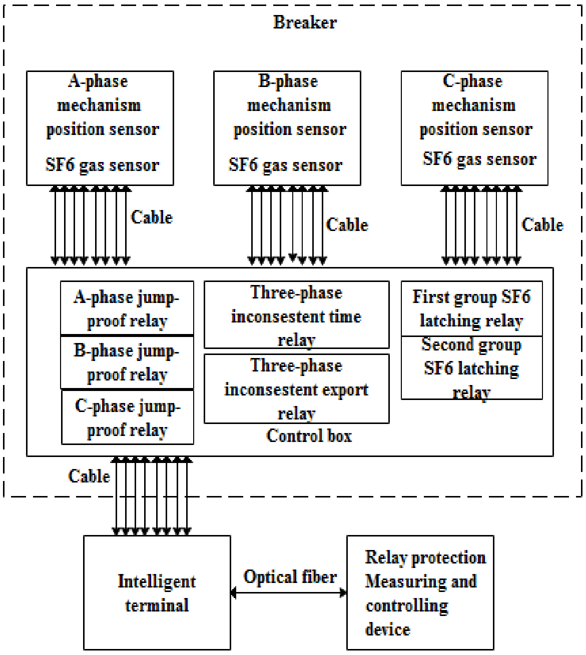

Figure 1. Structural Diagram of Switches in Existing Primary Intelligent Stations

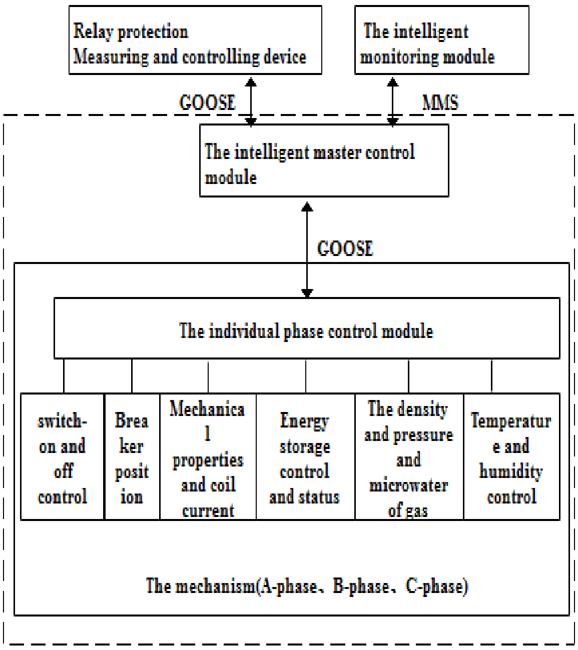

Figure 2. The Overall Architecture of and Secondary Fusion Intelligent Switch

From Figure 1, it can be seen that the existing intelligent station switch mainly installs local intelligent components in the control cabinet next to the switch, it converts the signal transmitted by the traditional cable into the optical fiber signal to interact with the secondary equipment such as protection, measurement and control, it eliminates the cable and cable-related problems between the control cabinet and the spacer equipment, and achieves the signal transmission optical fiber with the spacer equipment. In addition, on-line monitoring sensors, such as displacement sensors and SF6 gas sensors, are added to realize real-time monitoring of various state parameters of switch.

2.2. Analysis of Operation and Maintenance Status

Take Guangxi as an example to illustrate the current situation of switch operation and maintenance. There are 390 circuit breakers with defects of 110 kV and above in the whole network. The typical defects of circuit breakers are mainly SF6 gas leakage and secondary component damage.

The main defects of the switch are SF6 gas leakage and secondary circuit component failure. Aiming at the leakage defect of switch, the main cause of leakage is the quality of equipment. The main reason for the damage of secondary circuit components is the poor quality of components, such as auxiliary switches and energy storage contact, trip switches and time relays, outlet relays, open faults, etc. Apart from the poor quality of products, there is also a high failure rate of some components due to insufficient product design parameters.

Based on the analysis of the current switch structure and operation and maintenance status, the control circuit of switch is complex. The control circuit consists of multiple relays and many secondary cables, which brings adverse effects on design, construction, debugging and operation and maintenance.

3. Overall Architecture of Primary and Secondary Fusion Intelligent Switches

In order to improve the operation and maintenance level of switch and solve the problems mentioned above, such as a large number of cable connections, a large number of discrete components and complex control loops, this paper proposes a high-voltage intelligent switch scheme based on distributed control idea. The overall structure is shown in Figure 2. The first and second fully integrated high-voltage intelligent switch schemes are divided into the following functional modules.

1) The intelligent sensor module

The Intelligent sensor module mainly includes high reliability intelligent sensor in switching mechanism, including gas sensor, position sensor, current sensor, energy storage state sensor, etc. It realizes real-time monitoring of switching status, such as SF6 pressure, micro-water monitoring, switching stroke monitoring, current monitoring of switching coil, etc. It realizes self-sensing of equipment status through built-in multi source intelligent sensor. The off-state assessment provides reliable data support.

2) The individual phase control module

The individual phase control module is mainly based on distributed control idea, which delegates some functions of secondary equipment, it mainly realizes signal acquisition and control functions. On the one hand, it can collect the signals of intelligent sensors (gas sensor, position sensor, current sensor, energy storage state sensor) locally and transmit them to intelligent master control module through optical fiber (GOOSE signal) after processing, on the other hand, it can receive the control command of the intelligent master control module by GOOSE transmission mode and realize the control of switch-on, energy storage, temperature and humidity.

3) The intelligent master control module

The intelligent master control module mainly uses the controller to replace the traditional control loop composed of a large number of secondary cables and discrete components, such as the three-phase inconsistent loop of the main body. GOOSE transmission is used to realize the communication with the spacer protection measurement and control equipment, and individual phase control module of each body, so as to realize the function of signal acquisition and intelligent control.

4) The intelligent monitoring module

The intelligent monitoring module mainly realizes the collection and processing of multi source sensing information of switch, and realizes the comprehensive monitoring, condition assessment, intelligent diagnosis and operation trend analysis of switch.

Comparing with the existing switch architecture of intelligent station in Figure1, the intelligent switch in Figure 2 has the following advantages.1) Abolish a large number of cables from the mechanism box to the control box, and use optical fibers to transmit commands such as control.2) A large number of relays, such as three-phase inconsistent relays, have been canceled in the control box, and the traditional complex control circuit has been realized with the intelligent control module.3)

Built-in multi source sensor improves the self-perception ability of switch and operating environment, and provides reliable data source for state evaluation and intelligent diagnosis.

4. Key Module Design

From the foregoing, it can be seen that the overall architecture of the primary and secondary fusion intelligent switch is mainly composed of four parts. Analyzing its characteristics, each functional module can be divided into three parts, realizing ontology intelligence (intelligent sensing), secondary circuit intelligence(intelligent control module), and advanced application (intelligent monitoring module). The following will focus on these three aspects.

4.1. Ontology Intelligence

In order to improve the self-sensing ability of the switch and its intelligence level, the intelligent switch described in this paper mainly includes gas sensor, position sensor, current sensor and energy storage state sensor. In order to ensure the reliability of the sensor data and meet the plug and play requirements, the above sensors adopt redundant design schemes, which are realized from source to data acquisition and data processing. Dual configuration and mutual verification of data can effectively improve the reliability of sensor itself and data transmission. The following is illustrated with SF6 intelligent sensor as an example.

SF6 intelligent sensor mainly realizes gas temperature, pressure and micro-water monitoring function. In order to ensure data reliability, redundancy design and dual configuration (including sensor head, acquisition unit and processing unit) are adopted. The structure is shown in Figure 3.

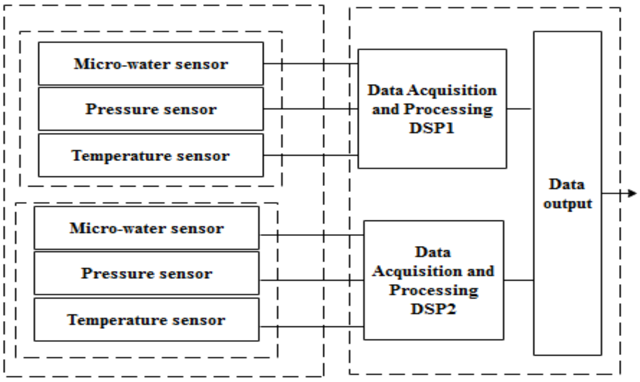

Figure 3. The Gas Sensor Architecture Scheme

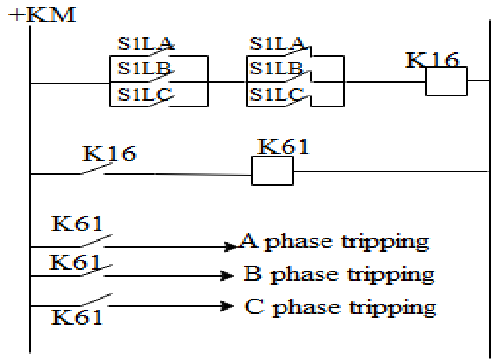

Figure 4. The Traditional Control Loop

4.2. Intelligent Secondary Circuit

The traditional control circuit is mainly composed of a large number of cables and various relays. The three-phase non-inductive circuit of the main body is illustrated as an example. Typical circuit of traditional ontology inconsistency protection is shown in Figure 4. A group of three-phase normally open contacts are connected in parallel and another group of three-phase normally closed contacts are connected in parallel. After the two are connected in series, a relay K16 with delay is started to determine whether there is three-phase inconsistency. When the three-phase of the circuit breaker is inconsistent, the two auxiliary contacts are always connected, and the K16 relay acts. When the setting delay is reached, the contacts are connected, the outlet relay K61 operates, and the tripping circuit of K61 is connected to the tripping circuit to trip the three-phase circuit breaker.

At present, the three-phase inconsistent protection configuration of circuit breaker body has high operational risk, which is mainly reflected in the relay design and selection problems, such as the relay contact closure caused by resonance may be inadequate anti-vibration ability, and the time delay of time relay has a certain discreteness; the aging problem of secondary components, relays, cables and so on in outdoor poor operating conditions. In the long-term operation, the performance gradually decreases.

Based on this, this paper puts forward the optimization scheme of secondary circuit. The controller replaces the traditional control circuit composed of a large number of secondary cables and discrete components. The three-phase inconsistent loop of the main body is described in detail below. The specific implementation method is shown in Figure. 5. Compared with Figure4, the Figure 5 replaces the original time relay and outlet relay with soft logic when realizing the three-phase inconsistent protection function of the main body. By installing local acquisition devices in the mechanism boxes, the cables from the mechanism boxes to the sink control boxes are canceled, which can effectively avoid the misoperation rejection caused by the above mentioned unreliable relays and abnormal cable insulation.

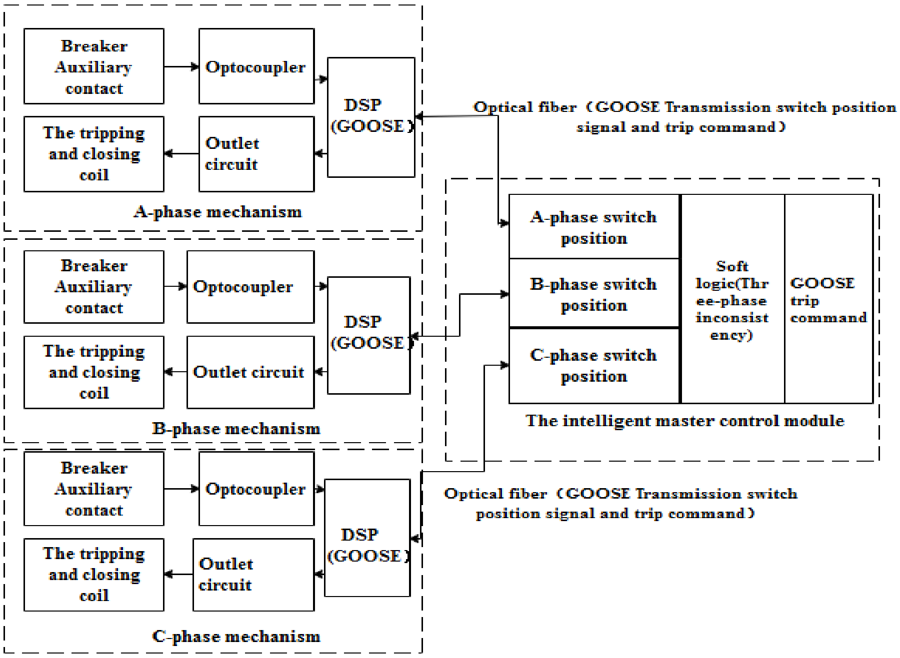

Fig. 5 The Intelligent secondary circuit

By installing intelligent control units in each mechanism box and control box, the traditional secondary circuit electromagnetic relay and a large number of control cables are replaced by software algorithm, and the intelligent secondary circuit of the switch is realized. This paper focuses on the implementation of the program in detail, the specific hardware and software algorithms are not described, but the design should focus on the operation environment and protection, data transmission reliability and so on.

4.3. Advanced Applications

It can be seen from the foregoing that the application of a large number of built-in intelligent sensors has realized the on-line monitoring of multi source information. It also provides a basis for multi source large data fusion analysis, state evaluation, intelligent diagnosis, etc. It enables to achieve higher intelligent operation and maintenance, and provides intelligent decision-making for operation and maintenance personnel.

The advanced applications described in this paper are mainly based on a comprehensive analysis platform with powerful data processing capabilities.It can realize the graphical display of intelligent sensing information of switch, such as current curve of switching coil, switching stroke, SF6 gas pressure, micro-water value, spring pressure value of circuit breaker, etc.It is equipped with state evaluation function based on multi parameters and intelligent diagnosis function based on autonomous learning technology for switch abnormal state. It realizes centralized management, multi point monitoring, state assessment, life prediction and intelligent diagnosis of switch operation status data.

5. Conclusion

In this paper, the current switch architecture and operation and maintenance are analyzed, and many existing problems are put forward. In order to solve such problems as multiple cables, poor reliability of relays and poor practicability of intelligent operation and maintenance, a fully integrated high-voltage intelligent switch scheme is proposed. The scheme is mainly based on digitization, integration, standardization, modularization, built-in position sensing and SF6. Gas sensor, current sensor and other multi source intelligent sensors. And the intelligent control module is installed in mechanism box and control box. The built-in intelligent sensor realizes self-perception of equipment state, provides data support for switch state assessment, and makes it possible for switch to change from patrol inspection and regular maintenance to condition-based maintenance. The intelligent signal acquisition and control are accomplished by intelligent control module integrated with switch mechanism. The secondary circuit composed of optical fiber instead of cable and intelligent operation circuit instead of traditional discrete components is realized, which greatly simplifies the traditional secondary circuit of switch, effectively reduces operation risk, improves operation and maintenance efficiency, and fundamentally improves the intelligence level of switch equipment.

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