A method for detecting the rear main contacts of indoor side-mounted suspended high-voltage high-current disconnectors

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Abstract

By configuring two coaxial stationary contacts, horizontal direct-plug switching with the moving contact conductive rod is realized. The two stationary contacts respectively provide connection positions for the high-potential busbar, causing the entire switch assembly—including the operating mechanism and busbar—to simultaneously reside at high potential within the power grid, thereby avoiding insulation breakdown between the operating mechanism and the main disconnector body due to high voltage. Employing remotely controlled pure compressed air to actuate the pull rod achieves electrical isolation between drive and control. The design exhibits strong immunity to electromagnetic interference, preventing maloperation caused by strong EMI; it operates safely and conveniently, reduces engineering costs, and can satisfy isolation requirements for frequent indoor high-voltage instantaneous large-current operations at various voltage levels up to and including 110 kV.

Full Text

Preamble

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An Indoor Side-Mounted Suspension-Type High-Voltage High-Current Disconnector

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Abstract

By employing two coaxial static contacts, this design achieves horizontal direct-plug switching with a movable contact conducting rod. The two static contacts provide connection points for high-potential busbars, placing the entire switch assembly—including the operating mechanism and busbars—at the same high potential within the power grid. This eliminates insulation breakdown problems between the operating mechanism and the disconnector body. Remote control using clean compressed air to drive the pull rod achieves electrical isolation between drive and control functions. The system offers strong resistance to electromagnetic interference, preventing maloperation caused by strong electromagnetic fields. Safe and convenient to operate, it reduces project costs and meets the isolation requirements for indoor high-voltage instantaneous high-current conditions with frequent operations at voltage levels up to 110 kV and below.

Keywords: Test room, indoor, high voltage and large current, disconnector

1 Introduction

High-voltage high-current testing is essential for verifying whether high-voltage electrical products meet national standard requirements. Large-capacity test laboratories must accommodate various test specimens with different parameters, requiring the construction of diverse test circuits for different test types. In power grids, disconnectors primarily provide safety isolation while being capable of withstanding short-circuit currents equivalent to those of circuit breakers, though they generally lack short-circuit current making capability. Test circuit construction in laboratories relies on hundreds of disconnectors, and the overall system layout depends heavily on the dimensions and structural configuration of these disconnectors.

As voltage levels increase, disconnector mechanical structures become more complex and occupy substantial floor space. When installed in specific wall-adjacent overhead line configurations, the limited space makes it difficult to meet design requirements. In indoor high-capacity test laboratories—whether for short-circuit breaking tests or full-current making tests—every standard type test requires support from the laboratory circuit. As a national certification and testing center, Xi’ an High Voltage Apparatus Research Institute conducts various electrical product tests daily. Laboratory design directly affects whether each capacity level test circuit can be constructed, and the performance of each device in the test circuit determines whether these circuits can operate effectively.

Due to different test specimens and varying circuit configurations, large-capacity test laboratories must switch different disconnectors to construct different short-circuit fault test circuits. This involves frequent operations and repeated exposure to short-circuit current impacts, posing significant challenges to disconnector performance. Traditional indoor disconnectors include rotary and insert types, as shown in [Figure 1: see original paper] and [Figure 2: see original paper]. The three-phase common-base structure of insert-type indoor disconnectors consists mainly of static contacts, a base, post insulators, pull-rod insulators, and movable contacts, installed in parallel with multi-point insert contact.

As voltage level and current-carrying capacity increase, the contact gap must meet standard requirements, necessitating expansion of the overall disconnector structure and increasing footprint and costs. When applied in large-capacity test circuits, arranging multiple high-voltage disconnectors presents a major challenge to overall circuit design. In wall-adjacent overhead line applications, available space is often insufficient to meet design requirements. Traditional disconnector operating mechanisms are insulated from the switch body to prevent high-potential intrusion, requiring timely and long-term maintenance. In indoor making, breaking, and switching test circuits, frequent operations subject disconnectors to repeated high-current impact voltages, cumulatively increasing electrodynamic forces on the mechanism and imposing greater demands on insulation withstand levels. Moreover, operating in high-voltage, high-current, strong electromagnetic field environments makes mechanisms susceptible to interference, increasing the probability of disconnector maloperation and failure, necessitating frequent maintenance [6-14].

Pneumatic control systems represent an important means of production automation. Due to advantages such as fire and explosion prevention, pollution-free operation, minimal electromagnetic influence, and high reliability, they have been widely applied in many industrial fields [1-5].

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2 Disconnector

2.1 Overall Technical Solution

Addressing existing disconnector technology limitations, wall-adjacent, overhead, high-voltage, high-current impact, and strong magnetic field environmental factors are all objective conditions that test laboratories must consider. Technical requirements such as normal current load and overload conditions, static and dynamic mechanical loads on terminals, conductors connected to disconnectors, required operating performance, and switching capabilities must be comprehensively designed based on actual needs.

The horizontal direct-plug disconnector described in this paper is side-mounted in suspension configuration on indoor wall-adjacent high-current overhead lines. The overall design features two sets of static contacts with a movable contact conducting rod that cooperates with them, along with several brackets with different installation positions in a hollowed-out configuration. To maintain a low probability of disruptive discharge across the isolation gap, the disconnector is installed parallel to busbars via side-mounted suspension insulators, with insulators vertically mounted on indoor walls adjacent to busbars. Both sets of static contacts include front and rear static contacts fixed on brackets, with coaxial design employed. Each phase' s front and rear static contacts connect to the corresponding front and rear sections of the main busbar in the power grid. A movable contact conducting rod fixed on a pull rod is positioned between each phase' s front and rear static contacts. The other end of the pull rod connects to an operating mechanism that provides driving force and is insulated from ground. The operating mechanism employs pneumatic drive, with the pneumatic piston pull rod made of steel. The three phases in the power grid are independently installed and can be operated independently (or simultaneously with a common mechanism) [15-21]. The overall assembly is shown in [Figure 3: see original paper].

2.2 Mechanism Scheme

Based on the overall disconnector mechanism, spring fingers are installed in both front and rear static contacts at positions cooperating with the movable contact conducting rod. According to the maximum system circuit current at the actual installation location in the test laboratory, elliptical spring fingers made of silver alloy are embedded in corresponding installation grooves within the static contacts. Since disconnectors lack standardized continuous overcurrent capability, selection should ensure rated current accommodates any possible load current during operation. Each static contact in the proposed device contains at least four spring finger coils, with the number of contact points per group determined based on maximum current flow. The contact finger design is shown in [Figure 5: see original paper].

A guide ring is installed at the contact position between the rear static contact and movable contact conducting rod, mounted in a corresponding installation groove. The ring surface is higher than the embedded groove surface, ensuring tight cooperation with the movable contact conducting rod. To maintain alignment of the movable contact conducting rod during switching and ensure complete, uniform, linear contact with spring fingers after closing—preventing spring finger burnout due to contact deviation during high current flow—the guide ring is made of self-lubricating polytetrafluoroethylene material. As shown in [Figure 4: see original paper], notched grooves are provided in both front and rear static contacts, containing spring fingers.

The movable contact conducting rod features mounting holes, connecting to the operating mechanism only through these contact mounting holes. As shown in [Figure 7: see original paper], to prevent contact deviation from its operating trajectory due to self-weight during switching, the movable contact employs hollow design with silver-plated surfaces. Both ends of the conducting rod feature guide tapers for easy entry into static contacts, reducing skin effect and power loss while ensuring capability to withstand rated terminal static and dynamic mechanical loads without compromising reliability and current-carrying capacity. This improves disconnector switching operation stability. To ensure tight contact between movable and static contacts, reduce contact resistance, and meet high-current conduction requirements, the design is as shown in [Figure 4: see original paper] and [Figure 5: see original paper].

Spacing between adjacent ports forms the contact gap distance. The static contacts' limiting function ensures horizontal movement of the movable contact conducting rod, with the contact gap meeting isolation requirements and preventing dangerous leakage current from flowing between terminals on either side. During disconnector switching, the movable contact conducting rod remains continuously connected to the rear static contact. Under cylinder piston action, the rod moves forward to horizontally insert into the front static contact, contacting spring fingers to achieve closing. Under cylinder piston action, the rod moves backward to disengage from the front static contact until reaching the front end of the rear static contact, achieving opening.

2.3 Control Scheme

Each phase' s front static contact connects to the corresponding busbar front section, while the rear static contact connects to the busbar rear section. The two static contacts provide connection positions for high-potential busbars, enabling horizontal direct-plug switching. During energized operation, the entire switch assembly—including the operating mechanism and busbars—remains at high potential in the power grid, avoiding high-voltage insulation breakdown between the operating mechanism and disconnector body. The mechanism preferably employs a pneumatic-electrically isolated horizontal operating mechanism, with pneumatic drive connected via pneumatic lines or optical cables to the secondary control system that operates the disconnector. The cylinder body features open/close signal indicator lights that feed back signals to the remote operation console, ensuring each movable contact' s position for isolation gaps is indicated by reliable, visible position indicators. The secondary control system is located in a control cabinet at a safe distance, with two air pipes extending from the cabinet to the drive cylinder, achieving pneumatic-electric isolation. During disconnector switching, the secondary control system directs air into and out of the pipes to drive the cylinder piston pull rod, thereby operating the disconnector. This provides advantages including fire and explosion prevention, pollution-free operation, minimal electromagnetic field influence, strong anti-interference capability, reliable operation, and convenient maintenance. The steel pneumatic piston pull rod can withstand repeated electrodynamic force impacts, preventing fracture during frequent operations.

Bracket configuration enables overhead installation, with contact gap distance adjustable according to required rated voltage to meet different insulation distance design requirements. The hollowed-out bracket design reduces structural dimensions, minimizes space occupation, and simplifies maintenance. The bracket design is shown in [Figure 8: see original paper].

Locating the secondary control system in a control cabinet at a safe distance—remote from the disconnector body and connected via air pipes—ensures control insulation through the ground-insulated operating mechanism, achieving electrical isolation between drive and control. The control cabinet itself is electromagnetically shielded, protecting the secondary control system from high-voltage invasion or maloperation due to strong electromagnetic interference during flashover events.

3 Technical Solution Analysis

The disconnector described in this paper operates under high-voltage high-current conditions, meeting various type test requirements for rated voltage 110 kV and rated short-circuit current effective value up to 80 kA. The field assembly is shown in [Figure 9: see original paper], and the equipment has been commissioned in test laboratories. Since the equipment operates in a capacity laboratory for short-circuit fault tests with very short current flow duration, instantaneous heat dissipation is sufficient, making standard temperature rise tests for disconnectors non-mandatory. Based on the equipment’ s location requirements in the test laboratory, it serves only for constructing test circuit isolation without small-current switching requirements.

Oscillograms of rated peak withstand current and rated short-time withstand current during conventional short-circuit tests and within rated short-circuit duration are shown in [Figure 10: see original paper] and [Figure 11: see original paper]. At parameters of 63 kA (rms, 3s) and 174 kA (peak), the disconnector in closed position shows no contact separation, no arcing, and no visible mechanical damage to any components, meeting standard requirements. Under gravity, vibration, and impact conditions, the disconnector and its operating mechanism do not disengage from their open or closed positions.

The mechanical structure is compact, with the cylinder, piston pull rod, movable contact, and static contacts all aligned on the same straight line. Indoor wall-adjacent overhead installation occupies minimal space with simple operation through pneumatic direct-plug switching. The design of movable/static contacts and contact fingers enhances system stability. The disconnector body maintains high-voltage equipotential with busbars, while the operating mechanism features pneumatic-electric isolation, making secondary control immune to high-potential strong magnetic field interference with strong anti-interference capability. Single-phase operation offers flexible application, simple maintenance, and cost savings.

4 Conclusion

The disconnector described in this paper features a direct-plug switching configuration with compact structure, suitable for indoor side-mounted suspension installation in cooperation with pneumatic operating mechanisms. Although employing single-phase disconnectors, the design is equally applicable to three-phase or multi-phase configurations. Front and rear static contact insulation spacing can be determined based on voltage level, with insulation distance extendable according to design requirements. Connecting movable and static contacts to corresponding phase busbars allows either individual operating mechanisms or a common mechanism. Replacing the operating pull rod with a conductive copper rod can further minimize equipment volume. While described as side-mounted suspension type, the design also accommodates flat installation or inverted suspension installation, providing more optimization options for laboratory construction based on different location requirements.

The equipment is significant for China' s high-voltage high-current engineering construction and safe operation. Combined with fast operating mechanisms, it can also make short-circuit current, offering strong plasticity. Operation is safe and simple, reducing indoor substation project costs, maintenance frequency, and resource expenses—particularly effective when used extensively indoors. It provides greater space for indoor test circuit design.

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