FEATURES OF CUBICLE TYPE VACUUM-INSULATED SWITCHGEAR (C-VIS)

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ABSTRACT

A 24kV cubicle type vacuum-insulated switchgear (C-VIS) has been developed to satisfy a wide variety of requirements for electric power supply systems. The C-VIS has achieved a SF_6-gas-free system by mixed insulation technology with vacuum, solid and air for both environmental friendliness and ease of maintenance. The vacuum switches for circuit breaker, disconnector and earthing switch are integrated as one switch unit in order to reduce the size and the weight of the equipment. The switch unit is insulated with molded epoxy resin against the earth fault. No high-voltage part is exposed in the C-VIS for safety improvement. Moreover, the molded epoxy resin ensures the long-term reliability of the switches. Each phase is separated completely to prevent inter-phase short circuit. The double-break three-position vacuum switch improves the reliability of the current breaking performance. The electro-magnetic driving mechanism with greaseless linkages makes periodical lubrication unnecessary and saves the driving energy.

INTRODUCTION

A switchgear protecting and monitoring power system is a key-component for stable electric power supply, and can be applied to various fields such as buildings, industrial plants, and substation facilities. Currently cubicle type SF_6 gas insulated switchgears (C-GIS) occupy the majority position all over the world in 24/36 kV class switchgears. However SF_6 gas was designated as an emission regulation gas in the Kyoto protocols because its global warming potential is 23,900 times that of CO_2 gas. Therefore, reducing SF_6 gas will be significantly effective for preventing global warming.

From the viewpoint of global environment conservation, the cubicle type vacuum-insulated switchgear (C-VIS) without using SF_6 gas has been developed. The various technologies applied to the C-VIS are presented in this paper.

CONCEPT AND SPECIFICATIONS OF C-VIS

Table 1 shows the C-VIS concepts. The C-VIS has been developed on the basis of environmental friendliness, safety, ease of maintenance, and reductions in size and weight.

There is no possibility that the C-VIS will emit greenhouse gas into the atmosphere. The switching devices were downsized by using vacuum insulation that has dielectric strength three times that of SF_6 gas with atmosphere pressure. With regard to the C-VIS, the weight was decreased to 40%, and the volume was reduced to 70% of our products C-GIS. Accordingly, it is unnecessary to keep gas pressure or to maintain gaskets and absorbent materials.

The overall configuration of 24kV class C-VIS is shown in Fig. 1. The C-VIS mainly consists of vacuum switches and a greaseless electromagnetic driving mechanism, and is equipped with voltage transformer, current transformer, protection relay, voltage detector and vacuum leakage monitor. The representative ratings and the applicable standards are listed in Tables 2 and 3, respectively. Three types of the C-VIS panel (Fig. 2) have been made ready as standard specifications, and can constitute C-VIS unit (Fig. 3) adequate for various power supply systems. Many C-VIS units have already been delivered worldwide.

Table 1. C-VIS development concepts

Terms	Contents
Environment friendliness	SF_6 gas free.
Safety	Mixed insulation system with vacuum, epoxy resin and air.
	The phase electrically-isolated structure for protection from inter-phase short circuit .
	Vacuum leakage monitoring system for proactive measure.
	No exposed high-voltage part for preventing electric shock accident.
Maintainability	Vacuum switches by using molded epoxy resin with earthed surface for high reliability.
	Greaseless operation system eliminating lubrication maintenance.
Reduction in size and weight	Compact switch unit integrating vacuum switch, disconnector, and earthing switch.

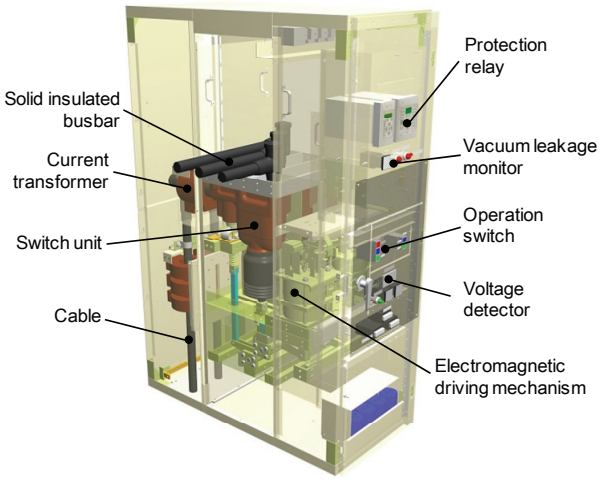


Fig. 1 Overall configuration of C-VIS

Table 2. Ratings of the C-VIS

Rated voltage	24	kV
Rated frequency	50/60	Hz
Rated short-duration power-frequency withstand voltage	50	kV
Rated lightning impulse withstand voltage	125	kV
Rated short time withstand current	25 (3 sec)	kA
Rated short circuit breaking current	25	kA
Rated normal current / Feeder panel	630/800/1,250	A
Rated normal current / Bus section panel	1,250	A
Width × Depth × Height	600×1,300×2,000	mm

Table 3. Applicable standards

International standards	IEC62271-1 (2011) IEC62271-100 (2012) IEC62271-200 (2011)

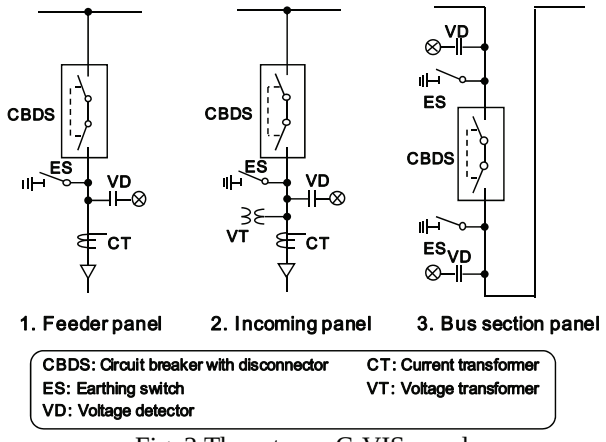


Fig. 2 Three types C-VIS panel

Fig. 3 C-VIS unit

HIGH-PERFORMANCE TECHNOLOGIES APPLIED TO C-VIS

Switch Unit

Figure 4 shows the configuration of the switch unit that integrates the vacuum switch (double-break three-position switch), the earthing switch, the cable bushings, the busbar bushings and the voltage detector in each phase. The earthing switch is also a vacuum insulated type with short-circuit making capability, so it is secure even if the earthing switch is closed accidentally. The size of the insulation part in the switch unit was able to be reduced by 10% compared with the corresponding part of SF_6 gas insulated C-GIS by utilizing composite insulation of vacuum, air, and molded epoxy resin[1]. Each switch unit is segregated in phase by the earthed layer so as to restrain an inter-phase short circuit.

This switch unit does not need any pressure release devices because hazardous pressure increase is not caused in the case of internal arc faults. The vacuum brazing technologies long proven in VCB assembly technology can ensure reliability of the seal for the vacuum switch housing.

The vacuum switches and bushings are covered with the molded epoxy resin to avoid a ground-fault accident even when a vacuum leakage occurs. The outer surface of the epoxy resin is coated with an earthed conductive layer for contact safety. The surface of the epoxy resin does not need to be cleaned because dust pollution cannot decrease the dielectric strength due to the earthed conductive layer. The vacuum switches inside the epoxy resin have long-term reliability because they are not affected by dewfall, salt adhesion or corrosive gases.

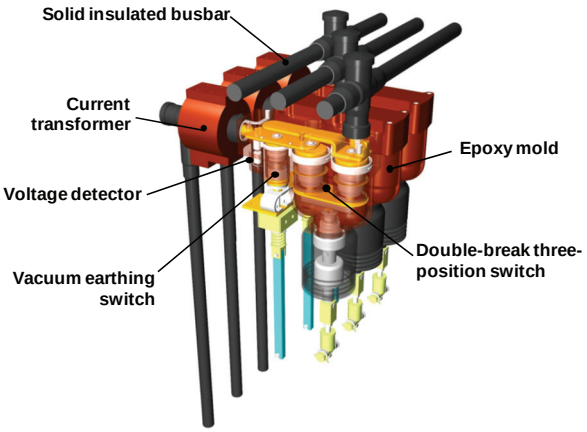


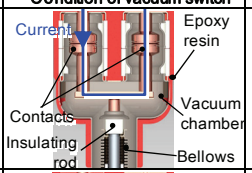
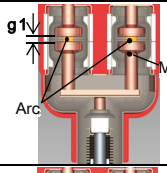
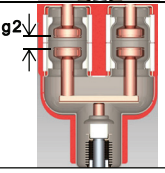
Fig. 4 C-VIS switch unit

Double-Break Three-Position Vacuum Switch

The vacuum switch with double-breaking contacts can take three switching positions. This switch has a disconnect position in addition to close and open positions. In other words, this vacuum switch serves both as the circuit breaker and disconnector. Consequently, the equipment size and weight are reduced. Table 4 shows the cross-sectional view and the operation of the double-break three-position vacuum switch. The vacuum chamber contains the fixed contact and the movable contact connected to the driving mechanism through the insulating rod. The reliability of the insulating rod can be kept by the metal bellows preventing it from being exposed to air.

The double-breaking contact increases the reliability of the circuit breaker and disconnector. Each contact has a capability of 24 kV - 25 kA breaking and insulating. The double-breaking contact can withstand higher voltage because transient recovery voltage is divided by two contacts. The results of short-circuit test confirmed that the breaking current of the double-breaking contact was 1.3 times that of a single breaking contact.

Table 4 Three position vacuum switch motion

Status	Condition of vacuum switch	Desctription
Close		Switch is insulated by vacuum, epoxy resin, and insulation rod. Outer surface of the epoxy resin is coated with a conductive layer earthed for touch safety.
Open		Current is interrupted by two contacts. Dividing the recovery voltage to each contact improves the interrupt performance. Each breaking gap "g1" withstands a LIWL of 125kV. *LIWL: Lightning Impulse Withstand Level
Disconnect		Disconnecting gap "g2" is set twice that of gap "g1" to confirm the dielectric strength of disconnector. Each disconnecting gap "g2" withstands a LIWL of 145kV.

Greaseless Linkages

A solid lubricant is used instead of grease for mechanical linkages, which helps to eliminate periodical lubricating maintenance. The stainless steel (SUS) pin is used as the shaft. The bearing consists of a lubricating layer and sintered bronze on the surface of a steel base, as shown in Fig. 5. The SUS pin side of the lubricating layer is PTFE-coated and consequently the friction coefficient of the linkage was able to be hold down to from 0.04 to 0.1.

This technology has been applied to many fields, such as transportation fields like automotives, aircrafts, rail systems and in industrial fields like multi-function lathe machine. More than 10,000 operations of the solid lubricant applied to the C-VIS have already been verified in the opening and closing tests.

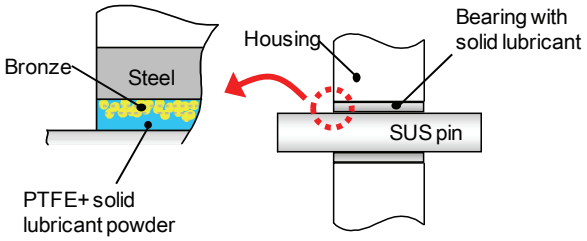


Fig. 5 Linkage structure using a solid lubricant

Vacuum leakage monitoring

The electrode to detect vacuum leakage is located on the outside surface of the molded epoxy resin as shown in Fig. 6. The vacuum chamber consists of a metallic case and ceramic insulators. The metallic case insulated with the epoxy resin is electrically floating. If a vacuum leakage occurs, the metallic case potential increases due to a flashover from the movable contact, as shown in Fig. 7. The vacuum leakage can be monitored by measuring the potential of the electrode located outside the surface of the epoxy resin capacitively coupled with the metallic case.

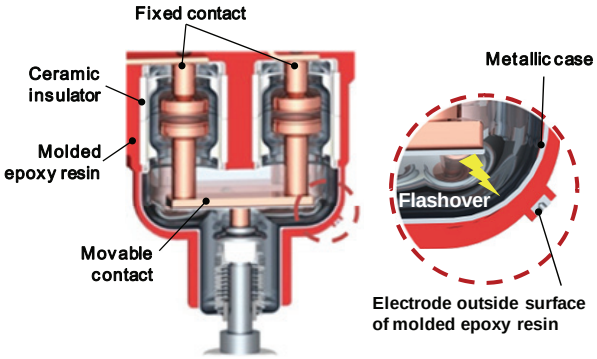


Fig. 6 Electrode for monitoring potential of metallic case

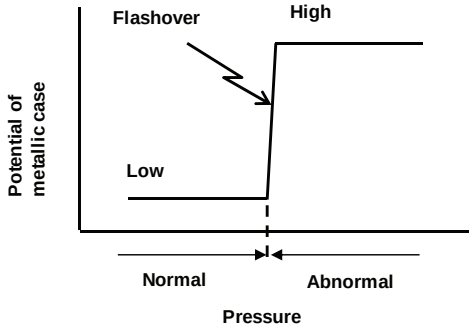


Fig. 7 Potential of metallic case

Electromagnetic Driving Mechanism

The driving mechanism with the hybrid type electro-magnet has been developed for vacuum switches and earthing switches[2]. The simple construction of the driving mechanism with high reliability and low maintenance can decrease number of components to 15% compared with our conventional electric motor spring driving mechanism.

Fig. 8 schematically shows the view and the operation of the hybrid type electromagnet. This electromagnet has the advantages of both the plunger type and the plate armature type electromagnets. The plunger type electromagnet can generate comparatively constant attraction force during a long stroke because of its small magnetic resistance. On the other hand, the plate armature type electromagnet has a large attraction force right before the contacts close. The operational mechanism of the hybrid type electromagnet is mentioned bellow.

1) Close operation

First, the solenoid coil is exited in order to generate magnetic flux Φ_c. The plate armature is attracted by magnetic attraction force F_p deriving from the magnetic flux Φ_c. Next, the magnetic flux Φ_m generated by the permanent magnet overlaps Φ_c through the plate armature particularly just prior to close state, which suites the VCB's characteristic of the load force being drastically increased by the wipe spring when the movable contact touches the fixed one.

2) Latching close operation

The solenoid coil current is shut down after close operation is completed, and then the close state can be latched only by the attraction force of the permanent magnet. Complex equipments for latching is not required in the hybrid type electromagnet. Furthermore, energy can be saved because the solenoid coil current is not necessary.

3) Open operation

The magnetic flux Φ_m is lowered inside the plunger by the solenoid coil exited in the reverse direction. As a result, the magnetic attraction force F_p is cancelled, and the open operation can be done by the spring force F_s, which is charged during close operation.

The simple structured hybrid type electromagnet has high reliability against various environments. The soundness of the operating characteristics has been verified by a high and low temperature test (-20 to 60˚C), a corrosion test with 5% salt solution splay (left it as for a month after splaying), and a dust-proof test under the condition that iron dust scattered to the entire surface of the hybrid type electromagnet.

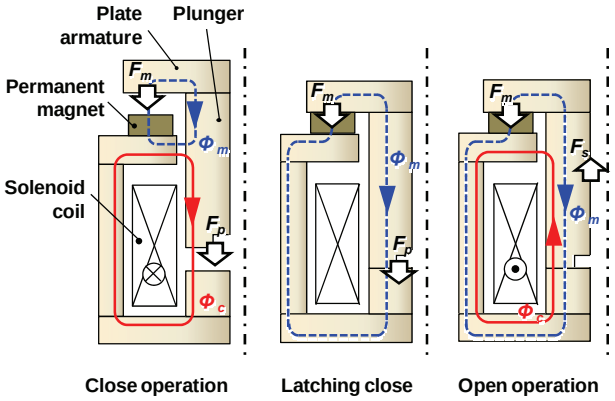


Fig. 8 Hybrid type electromagnet

SUMMARY

This paper introduced the technologies applied to the developed C-VIS. A composite insulation of vacuum, air and molded epoxy resin is applied to the switch unit integrating circuit-breaker, disconnector, and earthing switch, so as to realize both compact equipment size and long-term reliability. The double-breaking three-position switch can serve both as a circuit-breaker and a diconnector, and improves the current breaking performance. The electromagnetic driving mechanism with greaseless linkages requires little maintenance and saves operation energy. The C-VIS can satisfy various needs for electric power systems such as environmental friendliness, safety and ease of maintenance.

REFERENCES

[1] Katsuaki Sato, et. al., 2009, "Development of 24-kV Cubicle Type Vacuum-insulated Switchgear (C-VIS) for Overseas Markets", *Hitachi Review*, vol.58, No.5, 203-207

[2] Ayumu Morita, et. al., 2004, "Vacuum Circuit Breaker with a New Electromagnetic Actuator", *ICEE 2004 conference proceedings*, 264-269