Development of Vacuum Circuit-Breaker (VCB) for 12kV Air Insulated Switchgear (AIS) for Overseas Markets

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Abstract

The many of our supplied units for ASEAN nations are mostly model of 12kV switchgear with Vacuum Circuit-Breaker (VCB). These customers call for more compact design VCB with a lighter weight, improved reliability, more labor-saving maintenance, and a lower Life Cycle Cost (LCC).

As a result, we have developed a VCB for the Air Insulated Switchgear (AIS). This VCB realized high performance, high reliability, and low LCC. This VCB passed a series of type tests at Korea Electrotechnology Research Institute (KERI), a third-party type-testing and certification institution in Korea. The VCBs went through a series of short-circuit tests, withstand voltage test, temperature rise tests, and mechanical tests. It has since acquired the VCB class certification on E2, C2 and M2 stipulated by the IEC International Standard. The certified VCB assures high performance and high reliability.

1 Preface

Since 1986, we have shipped 12kV Air Insulated Switchgears (AISs) called HICLAD-10J for overseas markets. More than 25,000 units have been delivered to the Southeast Asian and Middle Eastern markets. Most of these 12kV VCBs were the track type where the VCB main body can directly be drawn out of the switchgear. In the case of recent AISs, however, due to the market needs for a more compact design, higher reliability, and higher performance, the market trend shows the migration from the conventional track type to a cassette type as a major type. Against such background, we have developed a cassette type VCB that features a more compact design and labor saving maintenance by using solid mold insulation. It is designed conforming to the latest IEC 62271-100 Standard and demonstrates outstanding electrical and mechanical durability. This paper introduces the features of the VCB (model name: VZA-12) for the new 12kV AIS.

2 Ratings and Construction

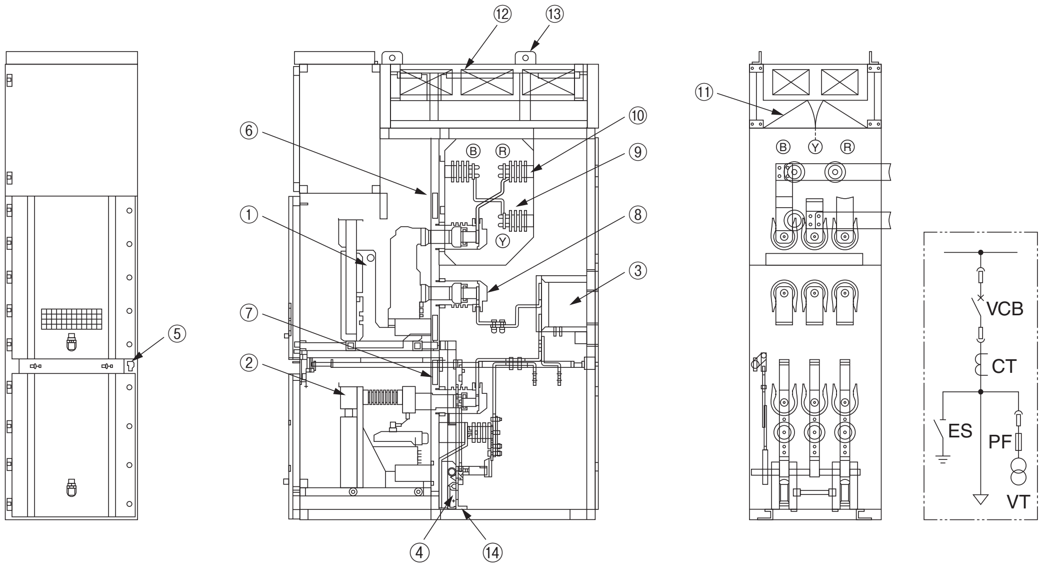
Table 1 shows the VCB ratings. Fig. 1 shows the outline drawing of a switchgear. Fig. 2 shows the external appearance of the VCB. Fig. 3 shows the structural drawing.

Table 1 VCB Ratings

Ratings of the VCB are shown.

Item	Ratings
Rated voltage	12kV
Rated current	630/1250/2000A
Rated lightning impulse withstand voltage	75kV
Rated breaking current	25kA
Rated short-time withstand current	25kA-3s
Rated closing current	65kA
IEC reliability class	E2/C2/M2
Applicable standard	IEC 62271-100 (2012)

This VCB comes in a series of versions for 630A, 1250A, and 2000A. Since the cassette type is adopted for the VCB, the switchgear can accommodate VCBs in two-tier stacks. As for individual off-power operation of a conventional VCB for maintenance and inspection, the manual mechanical operation of individual VCB is made after withdrawing it from the switchgear by opening the



Incoming panel (W: 650mm)

No.	Name	No.	Name
①	Vacuum Circuit-Breaker (VCB)	⑧	Bushing
②	Voltage Transformer (VT) with current limiting fuses	⑨	Main circuit bus
③	Current Transformer (CT)	⑩	Support insulator
④	Earthing Switch (ES)	⑪	Relief device
⑤	Earthing switch operating device	⑫	Arc bumper
⑥	VCB disconnecting part shutter	⑬	Lifting lug
⑦	VT disconnecting part shutter	⑭	Earthing bus

Fig. 1 **Outline Drawing of Switchgear**

Outline drawing and equipment configuration of the cassette type switchgear are shown.

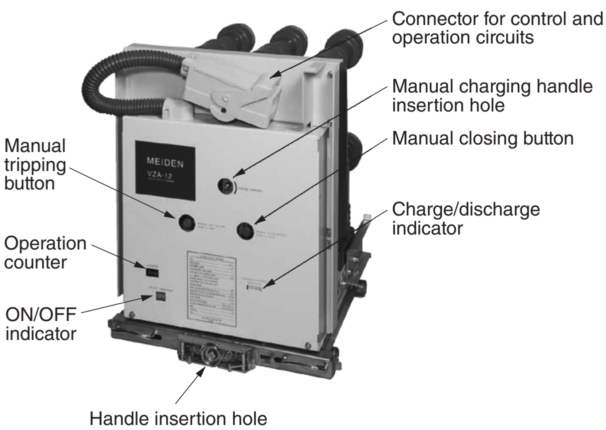


Fig. 2 **New Type of VCB for 12kV AIS for Overseas Market**

The external appearance of the new type VCB is shown.

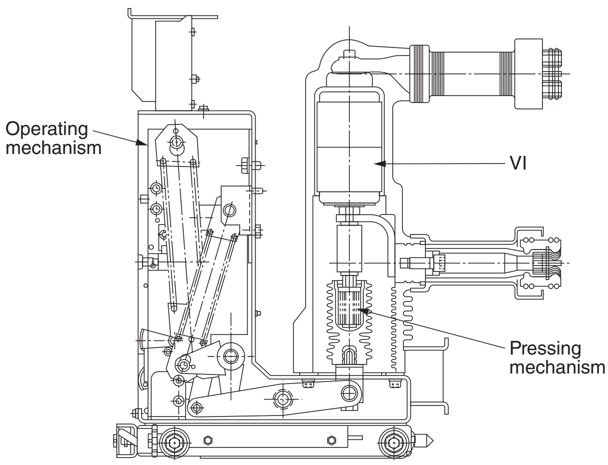


Fig. 3 **Structural Drawing of the New VCB**

By putting the VI, insulation rod, and the contact pressing mechanism into an mold case, the operating mechanism became a compact design.

switchgear door. The new type of VCB is designed according to the latest IEC Standard, as the operator can manually perform Vacuum Interrupter (VI)-level connection and disconnection of the off-power VCB and make a switching operation of VCB without opening the switchgear door.

3 Features

3.1 Realizing Compact Design and High Reliability

Compared with the former type of VCB, the

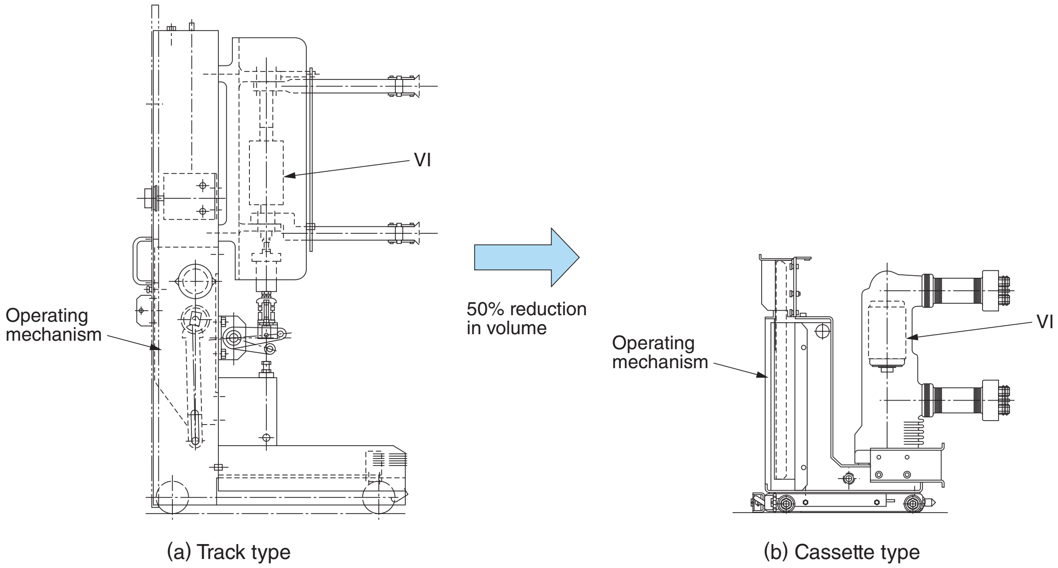


Fig. 4 Comparison of VCB Types

Comparison of structures is shown between conventional track type VCB and new cassette type VCB. The new type of VCB realized 50% reduction in volume from the track type.

optimal design of the closing cam shape for this VCB allows a reduction of 30% for the closing spring force of the operating mechanism. Further, the tripping spring force is decreased by 50% in order to reduce the operating force by inserting a two-stage lever arrangement between the operating mechanism and the VI. As a result, compared with the conventional products, the overall size of the operating mechanism is reduced by 20%. This VCB offers more features such as a smaller footprint due to the adoption of centralized layout of fitting electrical parts and printed circuit boards. It also offers a reduction of the number of cables used, and wiring routes.

The live-part VI and the conductor, the insulation rod, and the pressing mechanism are integrated in a case mold body. As a result, the insulation distance is reduced, and high safety is secured. As shown in Fig. 4, the volumetric reduction by 50% has been achieved, compared with our track type model. As a result of such an integrated construction, the maintenance of the VI and insulation rod section can be omitted, although this maintenance has been indispensable in the case of conventional constructions.

The electrical and mechanical durability shown below refers to the class stipulation by IEC 62271-100 according to the applications. This VCB has passed the type test for the highest IEC classification. The fact shows we realized a high reliability and low Life Cycle Cost (LCC) of the product.

Table 2 Class Classification on Reliability Evaluation According to IEC 62271-100

According to the IEC Standard, the VCB is classified into each class and Class 2 means a higher performance.

Classification	Class and its contents
Electrical endurance	E1: Circuit-breaker with basic electrical endurance E2: Circuit-breaker designed so as not to require maintenance of the interrupting parts of the main circuit during its expected operating life, and only minimal maintenance of its other parts.
Cable-charging current switching performance	C1: Circuit-breaker with low probability of restrike during capacitive current breaking as demonstrated by specific type tests. C2: Circuit-breaker with very low probability of restrike during capacitive current breaking as demonstrated by specific type tests.
Mechanical durability	M1: Circuit-breaker with normal mechanical endurance as demonstrated by 2000 times operating sequence. M2: Circuit-breaker for special service requirements and designed so as to require only limited maintenance as demonstrated by 10,000 times operating sequence.

Source: Established in reference to “IEC62271-100 3.4.112”

3.2 Realizing High Performance

As shown in Table 2, performance characteristics, maintainability, and mechanical durability of circuit-breakers are classified by the latest IEC Standard. This VCB is evaluated to belong to the highest class through testing according to the latest IEC Standard. It has acquired the certification of E2, C2 and M2 from Korea Electrotechnology Research Institute (KERI) which is a third-party type-testing and certification institution in Korea. Fig. 5 shows our testing situation at the KERI.

Fig. 5 Testing Situation at the KERI

It shows our current interruption test at the KERI.

3.2.1 Electrical Durability Class E2

Spiral contacts are used in the VI. Arcs are driven by an electromagnetic force that is created by the contact shape and current path consisting of arcs. In this system, arc extinction capability is increased by driving arcs. The force used to drive and rotate arcs, is called the Lorentz force. The stronger the force, the faster the rotation. When arcs are rotated faster, the local concentration of arcs can be avoided. We conducted magnetic field analysis of arcs generated by a breaking current of 25kA in order to optimize the shapes of the VI contact gap and tip. As a result, the Lorentz force was increased approximately by 8% compared with our conventional contact shapes. The contact erosion caused by arcs was suppressed. **Fig. 6** shows the electromagnetic field analysis of arcs generated around the VI contacts and **Table 3** shows the duties of current interruption test for electrical durability Class E2 According to IEC 62271-100.

3.2.2 Cable-Charging Current Switching Performance Class C2

The cable-charging current test is based on duties for charging current interruption in cable connections. After current interruption, a maximum of twice the source voltage is applied to a gap between VI contacts. This test is intended to pursue the insulation durability with a high insulation recovery capability to be required after the lapse of 8.3ms (for testing at 60Hz) after current interruption. **Table 4** shows the duties of a current breaking test for cable-charging current switching performance Class C2 according to IEC 62271-100. For this VI, current breaking performance has been improved through the optimization of switching speed and current interruption performance to clear the requirements of classes E2 and C2.

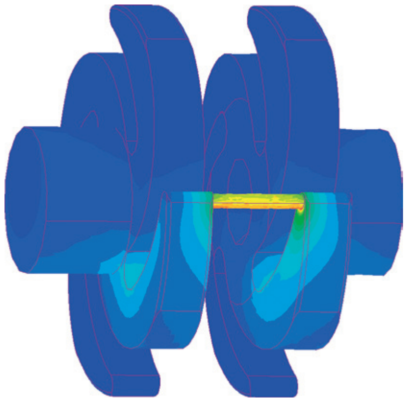


Fig. 6 Electromagnetic Field Analysis of Arcs Generated around the VI Contacts

An example of analysis is shown. The part at the contact point in yellow indicates an arc column.

Table 3 Duties of Current Interruption Test for Electrical Durability Class E2 According to IEC 62271-100

For all duty cycle tests, we obtained favorable results. Character “O” for the current breaking operation duty denotes a tripping operation and “CO” denotes a tripping operation to be performed soon after the closing operation (after the lapse of tens of milliseconds).

Rating of test current vs. rated breaking current	Current breaking operation duty	No. of current breaking tests (list3)	Test result
10%	O-0.3s-CO-t-CO	1	Pass
30%	O-0.3s-CO-t-CO	1	Pass
60%	O	15	Pass
	O-0.3s-CO-t-CO	15	Pass
100% (Symmetrical component current)	O-0.3s-CO-t-CO	2	Pass

3.2.3 Mechanical Durability Class M2

For this VCB’s pressing mechanism, we studied the structure by taking into account the impacting force to be applied to such parts as the pressing mechanism and operational mechanism, etc. Consequently, the VCB passed the testing of 10,000 switching operations conforming to the continuous switching duties of Class M2 stipulated by IEC 62271-100. **Table 5** shows the testing duties for mechanical durability Class M2 according to IEC 62271-100.

Table 4	Duties of Current Breaking Test for Cable-Charging Current Switching Performance Class C2 According to IEC 62271-100

For all duty cycle or duty tests, we obtained positive results. The test program is conducted-starting with the upper box of the table. This test is carried out to define the flashover probability.

Testing duty	Test current	Current interruption duty	Breaking test cycle	Result
T60	15kA	For VCB of Class C2, this test is carried out before the cable-charging current switching test in order to assume the amount of contact erosion at the time of current interruption.	1 (O-CO-CO)	Pass
CC1	2.5~ 10A	Cable-charging current breaking test to be repeated 24 times	24	Pass
CC2	25A	Cable-charging current breaking test to be repeated 24 times	24	Pass

Table 5	Testing Duties for Mechanical Durability Class M2 According to IEC 62271-100

For all duty cycle tests, we obtained beneficial results. Repeated impacts are generated by each switching operation. The VCB, however, has ample durability which we confirmed based on the result of our study of its allowable stresses.

Operational duty	Control voltage	No. of tests	Result
C-t-O-t	Minimum	2500 times	Pass
	Rated	2500 times	Pass
	Maximum	2500 times	Pass
O-0.3s-CO-t-C-t	Rated	1250 times (a total of 2500 switching operations)	Pass

4 Dealing with Another Arrangement Request

While the cassette type VCBs are mainly requested in the markets, there are still requests for the track type VCBs because of its feature of integral structure on an easily movable compact rack.

As described in Section **3.1**, we realized a design VCB. Although the cassette type VCB is the standard application, we attempted to deal with the conversion to the truck type VCB. For this conversion, we put a new design on the switchgear frame design by putting an underframe to allow the truck to come inside. **Fig. 7** shows the track type VCB and switchgear.

5 Dealing with Multiple Switching Performance Requirements

As a performance item for a circuit-breaker, European VCB suppliers often cite their VCB's capability on the duties for 100 times of switching. The test duties are more rigorous than the Class E2 test stipulated by the IEC Standard 62271-100. This test is composed of 50 times of closure and 50 times of breaking. For our new VCB, the switching speed is improved, and VI contact erosion is reduced through the improvement of the efficient operating mechanism and optimization of the VI contact shape. This improved the current breaking performance and the number of permissible current breaking times. As a result, we realized the application to the duties for 100 times of switching.

Fig. 7 Track Type VCB and Switchgear

This shows that a track type VCB is being withdrawn from the switchgear.

6 Postscript

We recently developed the VCB for AIS. This VCB conforms to the latest IEC 62271-100 Standard. This VCB secures high current breaking performance and mechanical performance characteristics, and it is a cassette type VCB featuring the labor-saving maintenance by adopting a solid mold insulation design. It has acquired the certification of IEC Classes (E2, C2 and M2) from the KERI – a third-party type-testing and certification institution in Korea. This IEC certification means high performance and high reliability of our VCB; the first product of its kind shipped in 2016. Going forward, we will expand our markets in the Southeast Asia and Middle East.