Commercialization of the 145kV Gas-Insulated Switchgear (V-GIS) for Overseas Market

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Keywords: High voltage, Large capacity, VCB, Switchgear, VI, Axial magnetic field electrode, Environmentally-friendly

Abstract

We have been working on product development for Vacuum Circuit-Breakers (VCBs). Since the VCB performs current interruption under a vacuum and it does not use any sulfur hexafluoride (SF_6), it offers outstanding features such as excellent environmental performance, easy maintenance and inspection, and a long operational life. Because of these attractive features, high-voltage and large-capacity versions are preferred. We developed 84kV VCBs in the 1970s and 145kV VCBs (single break) in 2010. This was the world's first achievement of its kind.

As a spring-board in the expanding application of high-voltage VCBs, we developed a Gas-Insulated Switchgear with a VCB (V-GIS). It has a VCB of 145kV rating. The first product was delivered in 2016 and the second product was delivered in 2017 to an ASEAN market. This V-GIS has attracted worldwide attention and been recognized as a 145kV GIS with the world's first single break VCBs. We expect more orders for this product in the future.

1 Preface

In the 1990s, we released the 145kV class Gas-Insulated Switchgear (GIS) where Gas Circuit-Breakers (GCBs) were incorporated. For twenty years, this product was shipped to both Japan and overseas markets during which, we have been working on the development of high-voltage Vacuum Circuit-Breakers (VCBs). As a result, we commercialized the 145kV class single break live tank type VCBs in 2010. In the VCB, current interruption is performed under a vacuum. Since no SF_6 gas is used in the current breaking chamber, there is no generation of decomposed gases. As such, the VCB offers an outstanding feature of excellent environmental performance in addition to other attractive advantages: easy maintenance and inspection and a long operational life. Due to these features, customers expect higher voltage and larger capacity models.

This paper introduces the GIS with VCB (V-GIS) which accommodates 145kV class single break VCBs. For the current breaking chamber of the VCB installed in this GIS, we changed the Vacuum Interrupter (VI) of a conventional insulation tube made of glass into a ceramic VI. This is for mass production, reduction of manufacturing processes, and better air-sealing reliability.

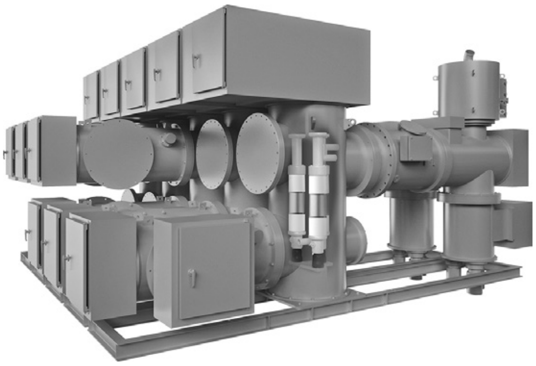
2 Ratings and Construction

Table 1 shows the ratings of a 145kV V-GIS. Fig. 1 shows an example of the external appearance and cross section of the V-GIS. Regarding the basic configuration, this GIS is composed of the VCB unit, the bus bar disconnecting switch/earthing

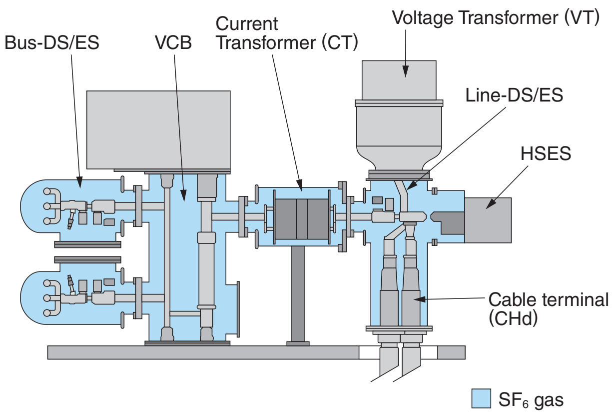
Table 1 Ratings of the 145kV V-GIS

Ratings of the 145kV V-GIS are shown.

Items		Ratings
Rated voltage		145kV
Rated current		2000A
Rated short-time withstand current		31.5kA-3s
Rated withstand voltage	Power frequency withstand voltage	275kV
	Lightning impulse withstand voltage	650kV
Rated SF_6 gas pressure (MPaG)	VCB Bus bar Disconnecting Switch (DS)	0.16
	Others	0.50
Applicable standard		IEC 62271-203 (2011)



(a) External appearance



(b) Cross section

Fig. 1 Example of External Appearance and Cross Section of V-GIS

An external appearance and a cross section are shown as a case of power reception from cable racks.

switch (Bus-DS/ES) unit, and the High Speed Earthing Switch (HSES) unit. This equipment is also applicable to overhead incoming lines.

3 Features

3.1 Reduction of SF_6 Gas Volume

Table 2 shows comparison of our conventional GCB and this specific VCB. By using three-dimensional electric field analysis, we designed the shape and allocation of electrode (conductor) inside the tank to produce an optimal insulation design. The rated gas pressure of the VCB and bus bar DS unit was 0.16MPaG. This is a change from the value of our conventional GCB rated gas pressure: 0.65MPaG. According to an individual unit comparison between the VCB unit and the GCB unit, the quantity of SF_6 gas used was decreased by approximately 50% and we developed new products with lower environmental impact.

Table 2 Comparison of our Conventional GCB and this VCB

A comparison table of our conventional GCB and this VCB is shown. This VCB shows the decreased use of SF_6 gas and the outstanding electrical endurance performance.

Items		This VCB	Our GCB
Rated gas pressure (MPaG)		0.16	0.65
Volume of gas used (%)		50	100
Current breaking section lifetime (times of operation)	Load current 2000A	10,000	2000
	Rated breaking current 31.5kA	30	10
Overhaul inspection for current breaking section		Not required	Every 2000 times of operation
SF_6 decomposed gases		None	Generation

Here it must be noted that the GCB makes current interruption inside the SF_6 gas environment while the VCB makes it under vacuum inside the vessel (inside the VI). In the latter case, there is no generation of any decomposed gases or impurities at the time of current interruption. At the time of equipment demobilization or inspection, the internal SF_6 gas can be re-used after being collected from the V-GIS for removal or inspection.

3.2 Electrical Endurance Performance

Compared with the GCB, the VCB generates less arc energy at the time of current interruption. This results in less erosion of contacts. The VI electrodes can be classified into spiral electrodes and axial magnetic field electrodes. Compared with the spiral electrode, the axial magnetic field electrodes feature less contact erosion based on the principle of arc extinction (current interruption theorem). Accordingly, the axial magnetic field electrode offers an advantage that it is outstanding in electrical endurance performance. For the VI accommodated in this VCB, the aforementioned axial magnetic field electrodes are adopted. Compared with our former GCBs, the rated number of current breaking times is 30 and the number of load current switching times is 10,000, implying an outstanding mechanical endurance performance. After every 2000 to 5000 switching times, general GCBs are required to open the tank interior and inspect current breaking sections, and replace abraded parts. Internal inspection for our VCB's current breaking sections are not required until 10,000 operation switches. This means labor saving for maintenance and inspection.

3.3 Single Break Ceramic VI

For VIs to be accommodated in the V-GIS, we newly developed a 145kV ceramic VI. In the past, we demonstrated the superb characteristics for 72kV class version ceramic VI. The purpose of this development is to realize mass production and provide better reliability of the hermetically sealed sections. As a result of changing the glass VI into the ceramic VI, all hermetically sealed sections can be processed by vacuum brazing and the conventionally unavoidable welding processes became unnecessary. Compared with our already released 145kV live tank type VCBs, this VCB put its VIs inside the tank (at the ground layer) as such a component layout affects insulation performance in the VI due to the effects of being on the ground layer. For this reason, further improvement of withstand voltage performance is required for the VI. Fig. 2 shows a comparison of results from electric field analysis in the VI interior. For the improvement of withstand voltage performance, there are effective approaches such as modification of contact shape and material and conditioning on the contact surface. Regarding the method of contact surface conditioning, a current below the rated breaking current is purposely interrupted to cause fusion on the contact surface so that a dispersion layer of fine copper and chromium particles is established for the resulting improvement of contact surface conditions. This method is called current conditioning. There is another method called voltage conditioning, where fine protrusions and foreign substances are removed through the application of a high voltage resulting in the making of a smooth contact surface. For this VI product, an optimal combined condition of current conditioning and voltage conditioning has been defined through investigation and verification.

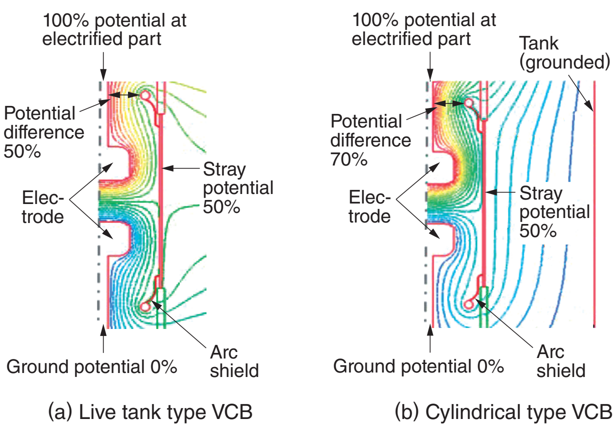


Fig. 2 Comparison of Results from Electric Field Analysis in the VI Interior

The result of electric field analysis in the VI interior is shown. In the case of a cylindrical type VCB where its periphery is grounded, the potential difference is increased and it is, therefore, necessary to improve withstand voltage performance characteristics.

4 Verification Test

Table 3 shows major items of the verification test carried out for the verification of characteristics of the 145kV V-GIS (GIS・VCB・DS/ES・HSES). The GIS conforming to IEC 62271-203, the VCB to IEC 62271-100, and the DS/ES and HSES to IEC 62271-102 have respectively undergone a series of relevant type tests. Still more, a margin test and practical performance test have been carried out for these products with positive results. Major test results are described below.

4.1 Withstand Voltage Test

The power frequency withstand voltage test on the main circuit was carried out at a test voltage of 275kV that is stipulated for equipment of 145kV rating. The version under test was proven to withstand the test voltage. In the lightning impulse voltage test, performance of 145kV rating was proven to withstand the application of 650kV. Fig. 3 shows a situation of a withstand voltage test.

Table 3 Items of Verification Test

Major items of verification test for the V-GIS is shown.

Contents of verification	Test items	Type test	Reference test
Insulation performance	Power frequency withstand voltage test	○	—
	Lightning impulse withstand voltage test	○	—
	Partial discharge test	○	—
Current carrying performance	Temperature rise test	○	—
	Short-time withstand current test	○	—
Practical performance	Transportation test	—	○
	Water injection test	—	○
Current breaking/ switching performance	VCB short-circuit breaking test	○	—
	DS switching test of bus-charging currents	○	—
	HSES induced current switching test	○	—
	HSES short-circuit making current test	○	—
Mechanical and environmental performance	High/low temperature test	—	○
	Extended mechanical endurance tests	—	○

Fig. 3 Situation of Withstand Voltage Test

A situation of withstand voltage test performed under the general conditions is shown.

4.2 Short-Time Withstand Current Test

Under the overall conditions, testing was carried out at 82kA and a peak current of 31.5kA for 3 seconds. Around the contact and connector parts, there was no occurrence of arcing and welding. In addition, there was no change in the main-circuit resistance values before and after the testing. It was verified that the developed version has enough durability against the carried currents.

4.3 Short-Circuit Making Current Test

An adequate contact closing speed and arcing shape were chosen from the result of electric field analysis. The short-circuit making current test of Class E1 (closure: twice) was carried out with favorable results.

5 Postscript

This paper introduced the construction and features of the 145kV GIS with VCB (V-GIS). This incorporates a single break VCB and is the world's first of its 145kV class versions. Currently, the 145kV GCBs are mostly used for the said voltage class whereas this V-GIS, realized outstanding features of maintenance labor saving and long operational life using VCBs. In addition, ceramic VIs are adopted for VCB mass production and better reliability.

The first product of the V-GIS was delivered in 2016 and the second product was shipped in 2017. We anticipate receiving more orders mainly from the ASEAN countries. Going forward, we will work on more product lineups to meet the large capacity and comply with relevant Japanese industrial standards.