204kV Gas-Insulated Switchgear (GIS)

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Abstract

Using the technologies of a 168/204kV dead-tank type double-break Vacuum Circuit-Breaker (VCB), we newly developed a 204kV Gas-Insulated Switchgear (GIS). The installation space of a GIS can be remarkably reduced, compared to the open-structure method. In addition, compared with a conventional GIS with Gas Circuit-Breaker (GCB), we can reduce the used volume of SF_6 gas (a greenhouse gas). The vacuum interrupter, adopting an axial magnetic field electrodes structure, can reduce the consumption rate of electrodes. This is due to arcs that are dispersed at the time of a breaking current. The load current switching capability is 10,000 operations. This is much more than the case of the GCB. As such, the lifecycle cost of the VCB is much lower than that of the GCB. Using this 204kV GIS, we will market it to projects involving the replacement of existing facilities or new GIS projects.

1 Preface

We have core competence on Vacuum Circuit-Breakers (VCBs). We have been working on the R&D for the application of VCB into a higher voltage range which is commonly used by Gas Circuit-Breakers (GCBs). In 2013, we developed VCBs for higher voltages and large capacities. We commercialized the 120kV single-break and 168/204kV double-break dead -tank type VCBs. Further, we developed the 145kV class Gas-Insulated Switchgear (GIS) incorporating a VCB called "V-GIS." This is a 145 kV model for overseas markets. This V-GIS is the world's first top voltage rating as a GIS with VCB, which uses our expertise on high-voltage single-break VCB. The first product was shipped in February 2016(2).

About 30 years ago, we delivered our GISs, the "V-Sub140G," for Japan markets. These supplied models are now facing time for renovation. As such, we developed a 204kV GIS model. This GIS model has been made based on the expertise of the already developed 204kV double-break dead-tank type VCB mentioned above. Compared with conventional open-structure method where individual power products are installed, the GIS is a package design and it can realize a substantial space-saving. This paper introduces the structure and features of the 204kV GIS.

2 Ratings and Construction

Table 1 shows the ratings of the 204kV GIS. Fig. 1 shows an external appearance, Fig. 2 shows the GIS circuit configuration, and Fig. 3 shows the cross section of the GIS. The rated voltage of the 204kV GIS is 204kV, rated current is 1200A, breaking current is 31.5kA, and its circuit configuration is Two Incomings and Two Transformers. The leftmost section in Fig. 3 is an operator box where the VCB operating mechanisms are accommodated. The cylindrical tank on its right side contains two Vacuum Interrupters (VIs) of the VCB, allocated vertically. Three cylindrical tanks are aligned in the depth direction. From the top and bottom of each tank, large horizontally arranged cylindrical tanks for one phase are extruded toward the right side. These horizontal tanks are allocated for three phases. In these tanks, 3-phase Disconnecting Switches (DSs) and maintenance Earthing Switches (ESs) are accommodated for the three phases. Conductors from round open sections of the DS section are connected to busbars.

Fig. 4 shows a diagram of a "Two Incomings and Two Transformers" single-line connection configuration and Fig. 5 shows an outline drawing of

Table 1 Ratings of the 204kV GIS

Ratings of the 204kV GIS are shown.

Model	Item	Specifications	
Conduit type GIS	Rated voltage	204kV	
	Rated current	1200A	
	Rated frequency	50/60Hz	
	Rated breaking current	31.5kA	
	Rated short-time withstand current	31.5kA-2s	
	Insulating medium	SF_6 gas insulation	
	Rated gas pressure (at 20℃)	VCB	0.16MPa·G
		Busbar DS + ES	0.16MPa·G
		Others	0.5MPa·G
	Applicable standards	JEC 2350 (2005)・JRCS302	
	Installation place	Indoors	
	Ambient temperature	−20〜40℃	
	Altitude	1000m or below	
VCB	Rated voltage	204kV	
	Rated current	1200A	
	Rated breaking current	31.5kA	
	Rated short-time withstand current	31.5kA-3s	
	Standard operating duty	0-0.3s-CO-3min-CO	
	Rated breaking time (cycles)	3 cycles	
	Operating mechanism	Closing: Motor charged spring, Opening: Spring	
	Applicable standards	JEC 2300 (2010)・JRCS302	
DS	Rated voltage	204kV	
	Rated current	1200A	
	Rated short-time withstand current	31.5kA-2s	
	Operating mechanism	Manual/Motor-drive	
	Applicable standards	JEC 2310 (2014)・JRCS302	
ES	Rated voltage	204kV	
	Rated short-time withstand current	31.5kA-2s	
	Operating mechanism	Manual	
	Applicable standards	JEC 2310 (2014)・JRCS302	
Earth switch (Line HSES)	Rated voltage	204kV	
	Rated short-time withstand current	31.5kA-2s	
	Operating mechanism	Manual/Motor charged spring	
	Applicable standards	JEC 2310 (2014)・JRCS302	

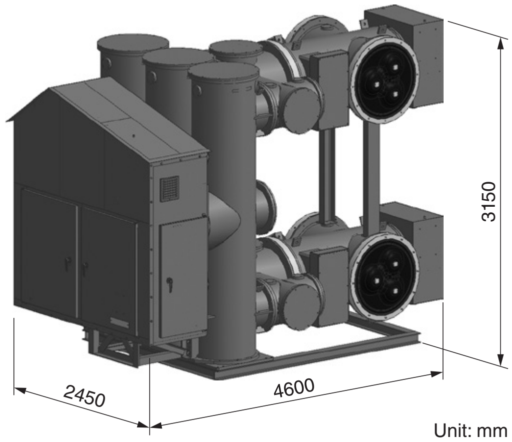

Fig. 1 204kV GIS

An external appearance of the 204kV GIS unit is shown.

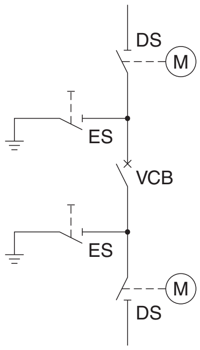

Fig. 2 Circuit Configuration of the 204kV GIS

The circuit configuration of the 204kV GIS is shown.

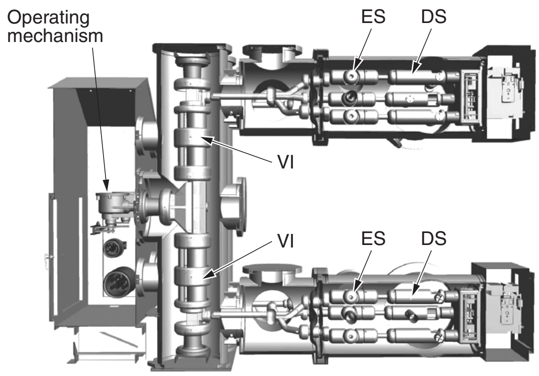

Fig. 3 Cross Section of the 204kV GIS

A cross-sectional appearance of the 204kV GIS is shown. Equipment allocation composing the interior is also shown.

the 204kV GIS configuration in a bird's-eye-view mode. This is an example of a power receiving cable connection. It is based on the assumption that a main power transformer is directly connected with the GIS. (The main power transformer is not shown. Connections with the main circuit only are indicated.)

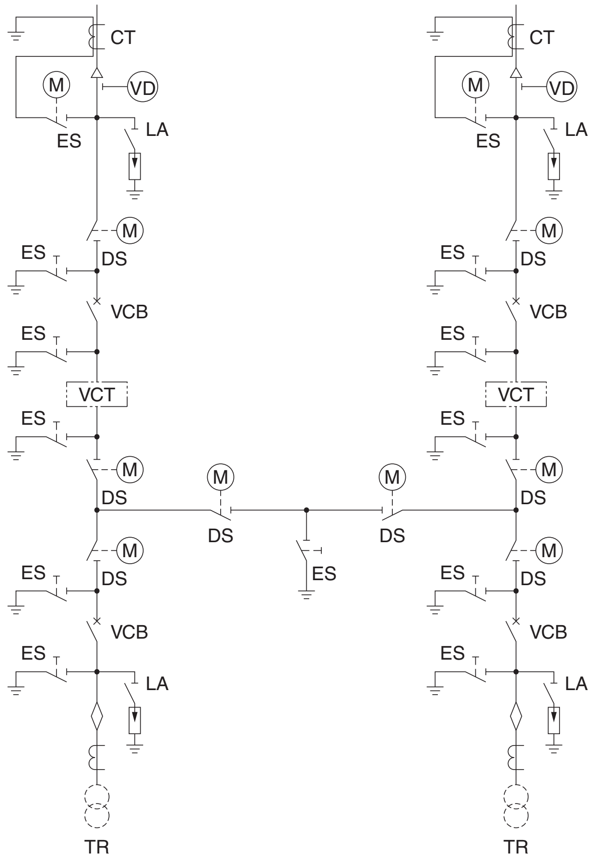

Fig. 4 Example of "Two Incomings and Two Transformers" Single-Line Connection Diagram Configuration

An example of single-line connection diagram is shown for "Two Incomings and Two Transformers" equipment layout.

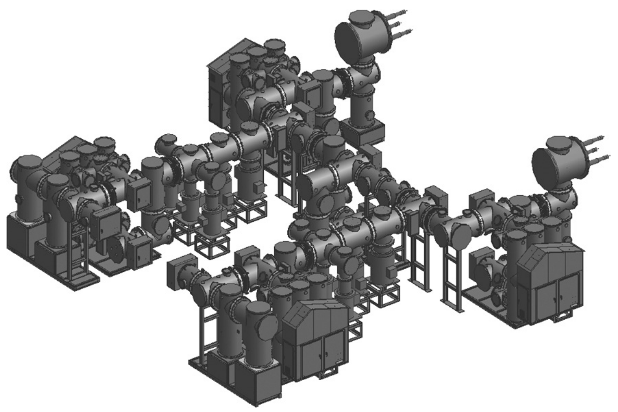

Fig. 5 Outline Drawing of the 204kV GIS Configuration

A bird-eye view drawing of the 204kV GIS is shown for the equipment layout of single-line connection shown in Fig. 4.

3 Features

3.1 Space-Saving

The big feature of the 204kV GIS is an installation space-saving design. Fig. 6 shows a comparison of installation space between a GIS and a conventional open-structure method substation. The latter connects individual power products by overhead power lines. Fig. 7 shows an example of One Incoming and One Transformer single-line connection diagram. The conventional open-structure method substation has an advantage of easy maintenance for individual units. It has, however, a disadvantage of taking up a large space for installation. For this reason, in the case of a conventional open-structure method substation, when equipment is installed in a

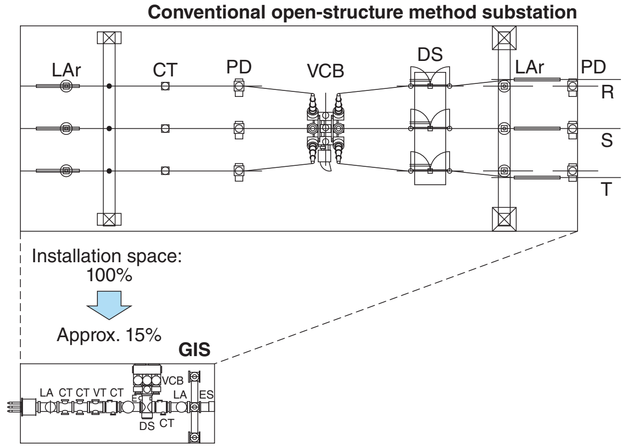

Fig. 6 Comparison of Installation Space between GIS and Conventional Open-Structure Method Substation

Assuming the required installation space for a conventional open-structure method substation shown in the single line diagram in Fig. 7 as 100%, the space for the GIS is about 15%. (Note: A transformer is excluded from this comparison in regard to the installation space.)

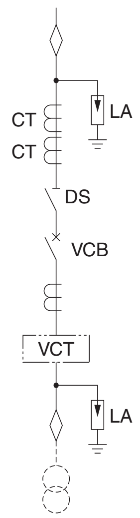

Fig. 7 Example of One Incoming and One Transformer Single-Line Connection Diagram

An example of single-line connection diagram is shown for One Incoming and One Transformer.

building or underground, or in the case of facility renovation, it is always a challenge to secure sufficient installation space. According to an example in Fig. 7, assuming the installation space for the conventional open-structure method design takes 100%, space for the GIS takes only about 15%.

Since the installation space required for the GIS is smaller as described above, it is easy to design an installation layout even in the case of a small location, like a hilly area or a narrow space underground. For the renewal of existing facilities, the installation space is generally limited, but the GIS has a space advantage.

3.2 Environmental Load

For 204kV class substations, in many cases, the GCB is adopted. In a current breaking chamber of a GCB, sulfur hexafluoride (SF_6) gas is generally used. The SF_6 gas is a greenhouse gas. Regarding climate change, assume that carbon dioxide (CO_2), which is also a greenhouse gas, is 1, then SF_6 is 22,800 (3). Accordingly, even though the amount of SF_6 is small, it is a large negative influence. For this reason, the amount of SF_6 gas use must be reduced and it is necessary to restrict the emission into the atmosphere.

Our GIS employs the VCB and the current breaking chamber accommodates VI. No SF_6 gas is used as a current breaking medium. In order to maintain insulation, however, SF_6 gas is used as an insulation gas. Compared with the GCB, however, the gas pressure can be kept lower. (Compared with our GCB products, gas pressure is 5.0Atm for GCB and 1.6Atm for VCB.) As a result, the amount of gas used is reduced to about half. Since SF_6 is not decomposed at the time of current breaking, it can be recycled.

3.3 Reduction of Life Cycle Cost (LCC)

Advantages from the adoption of VCBs are not limited to environmental load reduction. For the GCB, currents are interrupted in the atmosphere of SF_6 gas and, therefore, deterioration of the gas will occur due to the effect of the arcs. For this reason, it is generally necessary for the GCB to overhaul and check the interior and replace parts as required by opening the tank at the intervals of 2000 switching operations. For the VCB, however, currents are interrupted inside the VI and deterioration of SF_6 gas due to arcs does not occur. Since electrode erosion is minimal, the VI interior need not be inspected up to 10,000 switching operations that are generally considered to be the limit of switching life.

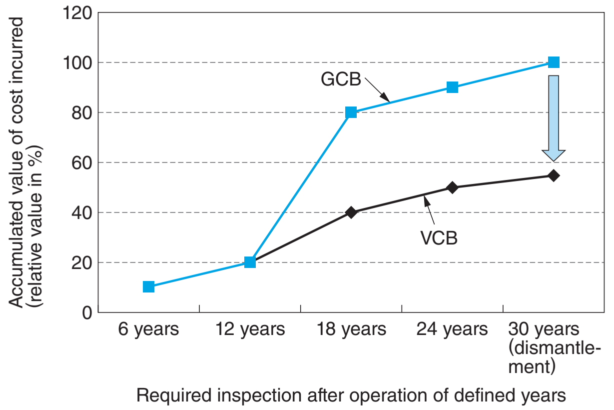

Fig. 8 **Transition of Maintenance and Inspection Cost for GCB and VCB**

Maintenance and inspection costs needed for every six years of operation is calculated for the comparison between GCB and VCB. There is no much difference in cost until the 12 years of operation. There is, however, a difference in cost for the GCB after 18 years of operation because replacement of parts is required by opening the GIS.

Fig. 8 shows the transition of maintenance and inspection cost for GCB and VCB. It is assumed that the GCB will receive inspection and some parts replacement by opening the tank after 18 years of operation. This causes a difference in costs incurred between the GCB and the VCB after 18 years of operation. After 30 years of operation, such a cost difference increases to approximately 40%. In case of a busy switching traction substation, switching is carried out about once a day. Compared with the GCB, the VCB has a longer switching life. As such, the maintenance cost can be reduced.

3.4 Adoption of the Latest Axial Magnetic Field Electrode VI

The VI electrodes used in this VCB are made of a copper-chromium alloy that has high withstand voltage and high welding resistance characteristics. Since the electrode structure employs axial magnetic field electrodes (see Fig. 9.), it can secure good current interruption performance. Unless a magnetic field is exerted, arcs may be concentrated in one point at the time of current interruption and this can be a cause of electrode erosion. For this product, however, an axial magnetic field is generated around the electrode and arcs can be uniformly distributed at the electrode. Since arcs are dispersed, electrode erosion volume becomes

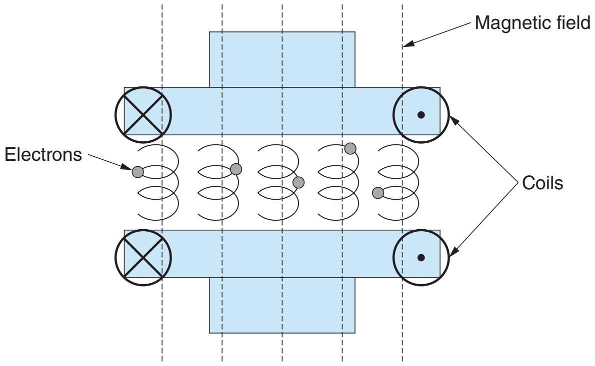

Fig. 9 Construction of Axial Magnetic Field Electrodes

When the axial magnetic field is generated by electrode coils, electrons coming out at the time of current breaking in the VI are dispersed by the effect of the axial magnetic field. These electrons move among electrodes and move in an arc.

small and we could realize high current interruption performance and high reliability.

4 Postscript

We have core competence in VCB technology and we have developed VCB technologies even further. We challenge ourselves to attain higher voltage VCBs in the domain of "world's first" range. For electric rail sector, our VCBs have an advantage over the conventional GCB in terms of a longer switching capability. If VCBs can replace GCBs at higher voltage substations, it will help to alleviate the issue of impact on Climate Change. Even though the initial cost of VCBs should be higher compared with GCBs, the price of VCBs will be equivalent to that of the GCBs, or less expensive if various other factors like LCC are taken into account. We will continue to market and promote our VCBs to let our customers understand the advantages and potential of the VCB.

・All product and company names mentioned in this paper are the trademarks and/or service marks of their respective owners.

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