Production of 120-204kV Tank Type Vacuum Circuit-Breakers (VCBs)

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Abstract

We worked on the Research and Development (R&D) program to realize higher voltages for Vacuum Circuit-Breakers (VCBs). In the 1970s, we developed and commercialized 84kV single-break and 168kV double-break tank type VCBs. Recently, we have developed 120kV to 204kV tank type VCBs to realize compact design, high performance, and lower lifecycle cost. These VCBs are made on the basic design of our 72/84kV tank type VCBs with rich supply records. These VCBs use the latest vacuum interrupters with the latest axial magnetic field electrodes. As a high-voltage class tank type VCB, we were the first company ever commercialized these products. Using VCBs for higher voltages and larger capacities applications is a worldwide trend and our models are getting increased recognition.

1 Preface

In the 1970s, we developed and commercialized 120kV to 168kV double-break porcelain type Vacuum Circuit-Breakers (VCBs) as a result of achieving higher voltages[(1)]. Compared with the tank type Gas-insulated Circuit-Breakers (GCBs) with the same ratings, such VCB's center of gravity used high and anti-seismic performance being inferior to the other. There was, therefore, room for more improvements in terms of size, mass, and anti-seismic performance.

Against this background, we have developed 120kV single-break and 168/204kV double-break tank type VCBs. These VCBs employ the latest Vacuum Interrupters (VIs) with axial magnetic field electrodes; in fact, these VCBs are realized for compact design, high performance, and economics by lower Life Cycle Cost (LCC). For the tank type VCBs of these high-voltage classes, these models are the world's-first commercialized products. This paper introduces the structure and features of the 120kV to 204kV tank type VCBs.

2 Ratings and Construction

Table 1 shows the ratings of the 120kV and 168/204kV Tank Type VCBs. Fig. 1 shows the external views and Fig. 2 shows the respective internal constructions.

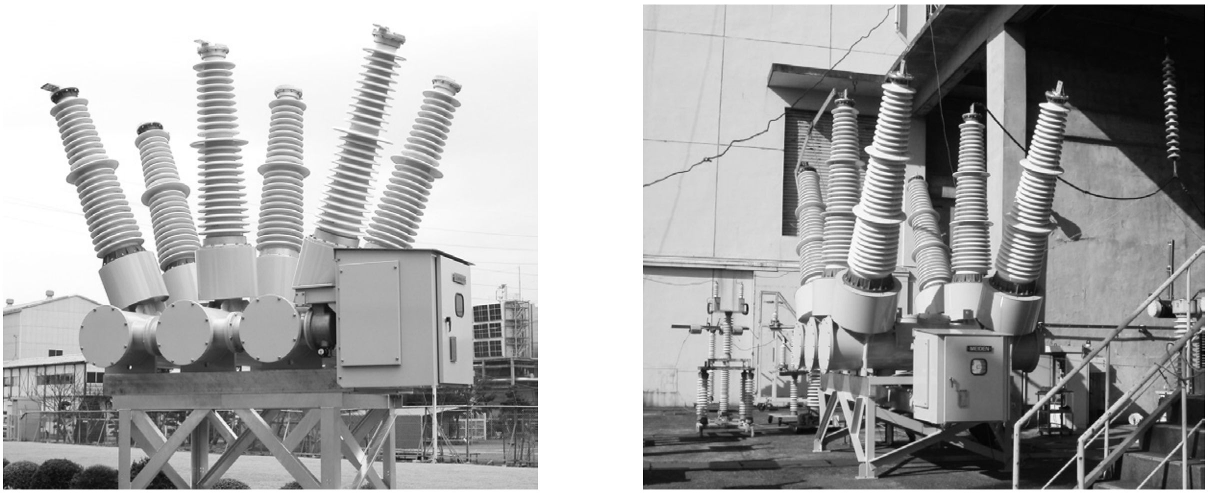
Table 1 Ratings of the 120kV and 168/204kV Tank Type VCBs

The ratings of the 120kV single-break and 168/204kV double-break tank type VCBs are shown.

Rated voltage (kV)	120	168/204
Rated current (A)	1200/2000	1200/2000
Rated breaking current (kA)	25/31.5	31.5/40
Rated breaking time (cycles)	3	3
No. of breaking points	1	2
Rated gas pressure (MPa · G)	0.15	0.15
Insulation medium	SF_6 gas (Breaking point by VI)	SF_6 gas (Breaking point by VI)
Operating system	Motor-charged spring-stored energy system	Motor-charged spring-stored energy system
Applicable standards	JEC-2300	JEC-2300

For the 120kV tank type VCB, the rated current is 31.5kA. It can perform 3-cycle breaking and has current carrying capacity of 2000A. The construction design of this type of VCB is based on that of the 72/84kV tank type VCB with rich supply records. It was designed to use common operating mechanism parts.

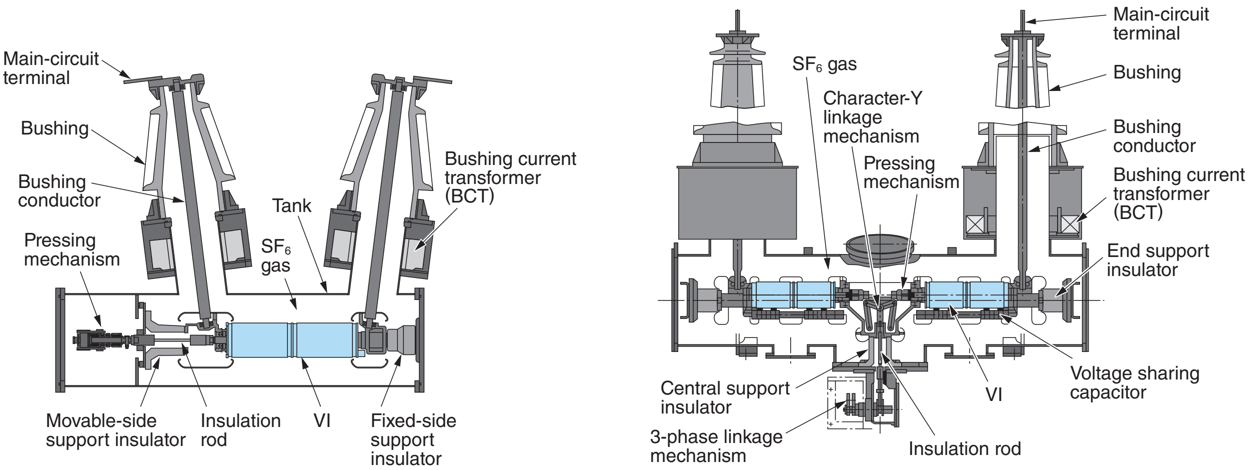
For the 168/204kV tank type VCBs, the rated current is 40kA. It can perform 3-cycle breaking and has current carrying capacity of 2000A. In regard to



(a) 120kV single-break tank type VCB　　(b) 168/204kV double-break tank type VCB

Fig. 1 **120kV and 168/204kV Tank Type VCBs**

External appearances of the 120kV single-break and 168/204kV double-break tank type VCBs are shown.



(a) 120kV single-break tank type VCB　　(b) 168/204kV double-break tank type VCB

Fig. 2 **Internal Constructions**

Internal Constructions of the 120kV single-break and 168/204kV double-break tank type VCBs are shown.

the construction of these VCBs, two VI units are connected in a series within the tank and are connected to the operating mechanism part through the character-Y and 3-phase linkage mechanisms. Regarding the method of connection between the VI and the voltage sharing capacitors, the optimization of current breaking parts has been devised to realize a compact design and high performance. In addition, necessary operating energy has been reduced by 40% compared with conventional porcelain type VCBs[(2)]. As a result, we can use common operating mechanism parts.

3 Features

3.1 Anti-Seismic Performance

In Japan where earthquakes frequently occur, it is very important to think of anti-seismic performance for substation equipment. Strength against earthquakes is examined by an analytical approach or actual acceleration test.

Fig. 3 shows the result of anti-seismic analysis performed on a 120kV tank type VCB. Similarly as for the actual acceleration test, anti-seismic analysis is carried out in the process such that the natural frequency is determined first and then a response from three-wave resonance sinusoidal acceleration

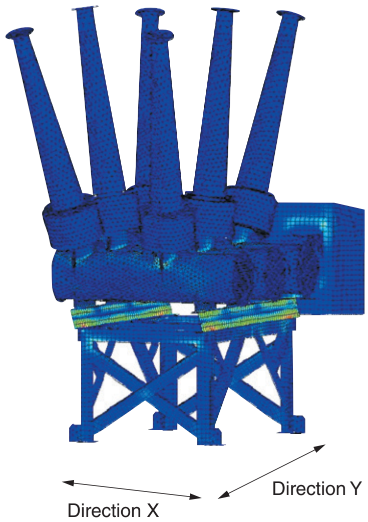


Fig. 3 **Result of Anti-Seismic Analysis (120kV Single-Break Tank Type VCB)**

The result of anti-seismic analysis performed on a 120kV single-break tank type VCB is shown. The result of this analysis is based on stress analysis under acceleration in Direction X.

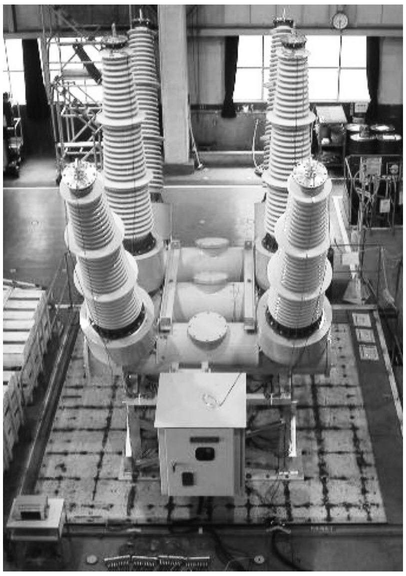


Fig. 4 **Scene of Anti-Seismic Performance Test (168/204kV Double-Break Tank Type VCB)**

A view of anti-seismic performance test is shown for the 168/204kV double-break tank type VCB.

at 3.0m/s^2 is analyzed in conjunction with the determined natural frequency. This figure shows the result of stress analysis performed at the time of acceleration in Direction X. In the case of this VCB, we confirmed that the safety factor for the maximum stress generation is more than 2 based on the permissible stress level under the conditions for Direction X and Direction Y, respectively.

Fig. 4 shows the actual acceleration test performed on a 168/204kV tank type VCB. As a result of this testing, we have confirmed that the respective parts of this VCB have enough strength against two types of seismic waves: a three-wave resonance sinusoidal acceleration at 3.0m/s^2 and actual seismic waves of Miyagiken-Oki Earthquake in May, 2003. Based on the measurement results during acceleration, it was confirmed that the safety factor is more than 2 in regard to the strength of each part. During the test, the specimen was found to be free from unwanted operation and gas leakage. At the time of the condition confirmation test performed after the completion of the above testing, we confirmed that there was no abnormality in equipment under test.

3.2 Reduction of LCC

The VCB is protective equipment for power systems and actual switching by this equipment is rare under ordinary operating conditions. In the case of a phase modifying operation or use in railroad systems, switching operation by a VCB is performed approximately once a day. In such a case of multi-frequency switching with a GCB, the tank interior is generally opened at the intervals of 2000 switching operations and the current interrupting parts are inspected and replaced if necessary. In the case of a VCB, the amount of electrode contact erosion is minimal and internal inspection is therefore, unnecessary until the expiration of the switching life of 10,000 switching operations.

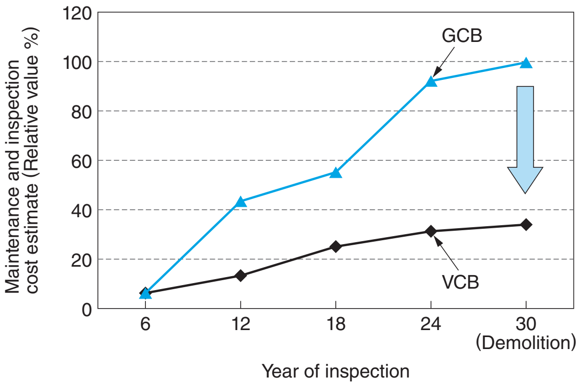


Fig. 5 **General Estimate Comparison of Maintenance and Inspection Cost between 168/204kV Tank Type VCB and Tank Type GCB**

General estimate of maintenance and inspection cost is expressed in relative values. Compared with GCB, the VCB cost can be reduced approximately to one third.

Fig. 5 shows a general estimate comparison of the costs of maintenance and inspection between the 168/204kV tank type VCB and the tank type GCB of the same class intended for frequent switching for 30 years. The GCB requires ordinary inspection services to be done every 6 years, and inspection of current interrupting parts and replacement of parts if needed at the time after 2000 switching operations (after 12 years and 24 years). The VCB, however, does not require any internal inspection. When both machines are assumed to operate for 30 years, the expenses needed for maintenance and inspection of VCB are about one third of GCB cost.

4 Postscript

Using VIs which incorporate the newest axial magnetic field electrodes, the 120kV single-break tank type VCBs have been developed. In addition, because 84kV VIs with axial magnetic field electrodes can be connected in a series to set up a double-break mechanism, the 168/204kV double-break tank type VCBs were commercialized as the first in the world. These tank type VCBs are not only realized of higher voltages and larger capacities, but also aim to secure high reliability and reduced LCC because inspection of the tank interior by overhaul is not required and treatment of decomposed gases is unnecessary at the time of equipment removal.

Since 2006 the 120kV tank type VCBs have been mainly delivered to power companies. Since 2007, the 168/204kV double-break tank type VCBs have been delivered to railroad companies for frequent switching applications. Still now, their supply records are increasing well. Where the application of VCBs to higher voltages and larger capacities is promoted worldwide, we will make every effort to actively increase product lineups of high-voltage VCBs.

《References》

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