Production of 36-84kV Eco-Tank Type Vacuum Circuit-Breakers (VCBs)

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Abstract

In response to the need to mitigate global warming, we have promoted the commercialization of a dry-air-insulated tank type of Vacuum Circuit-Breaker (VCB) which does not use greenhouse effect gases, such as SF_6 gas. Recently, in particular, there has been a growing need to reduce lifecycle cost and improve environmental impacts. As such, we have developed the eco-tank type of VCBs with the rated voltages of 36kV and 72/84kV focusing on compact design with a lightweight and economics. It also addresses five items of environmentally conscious actions of the '3Rs and a Long use and Separable "LS".' Since the first commercial operation in 2007, we have shipped this type of VCB to various customers, 300 units to North America and Australia, and 400 units to Japanese users (as of March 2014). Amid the rising global concern on climate change, we believe that our VCB products will contribute in mitigating global warming and reducing environmental load.

1 Preface

Since 1980, we manufactured a 36kV to 84kV SF_6 gas-insulated tank type of Vacuum Circuit-Breakers (VCBs) and shipped about 3700 units. The SF_6 insulation gas used for this type of VCB, however, has a high global warming potential of 23,900 times that of carbon dioxide (CO_2). As such, SF_6 gas was specified as a greenhouse effect gas and it became a restricted gas at the COP3 (The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change) held in Kyoto in 1997. To compensate for such restrictions, the SF_6 gas-insulated switchgear has been rigorously controlled for its use and the collection of such gas has been positively promoted. Against such background, we have promptly embarked on the R&D programs to develop SF_6 gas-free VCBs. In 2003, we manufactured a worlds first dry-air-insulated tank type of VCB of a 72/84kV class[(1)].

We have developed an eco-tank type of VCB featuring improved environmental performance and good economics such as reduced Life Cycle Cost (LCC). This paper shows the general outline.

Table 1 Ratings of the Eco-Tank Type VCB

Ratings of 36kV and 72/84kV VCBs are shown.

Rated voltage	36kV	72/84kV
Rated current	1200A/2000A	1200A/2000A, 3000A
Rated short-circuit breaking current	31.5kA	31.5, 40kA
Insulation medium	Dry air	Dry air
Rated pneumatic pressure	0.5MPa・G	0.5MPa・G
Operation system	Motor-charged spring-stored energy system	Motor-charged spring-stored energy system
Applicable standards	JEC2300 IEC62271-100	JEC2300 IEC62271-100 ANSI-C37.06

2 Ratings and Construction

Table 1 shows the ratings of the eco-tank type of VCB and Fig. 1 shows an external view of the 72/84kV eco-tank type of VCB. Fig. 2 shows its internal construction.

3 Features

3.1 Adoption of an Aluminum Tank

Conventional SF_6 gas-insulated tank type of VCBs adopted tanks made of steel materials fabricated into a welded construction. For eco-tank type of VCBs, an integrated construction made of aluminum alloy has been adopted. Because of excellent characteristics of aluminum materials, it is possible

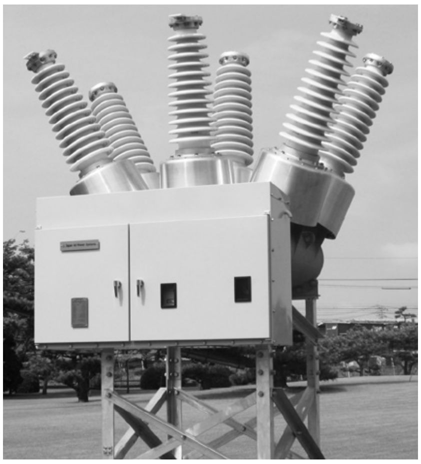
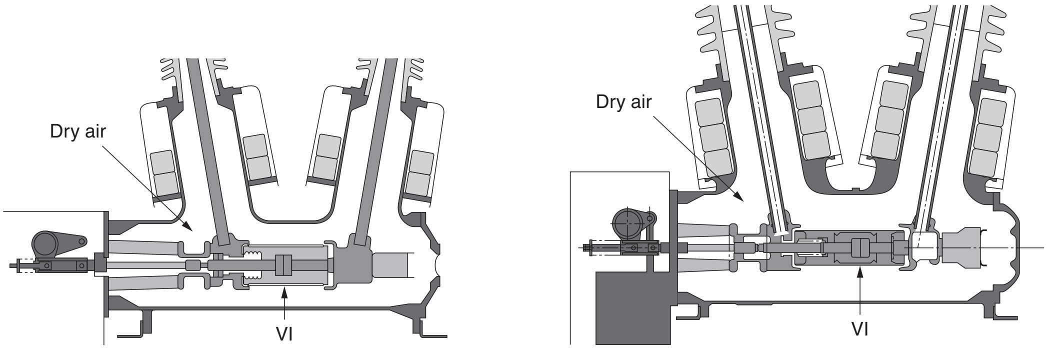


Fig. 1 72/84kV Eco-Tank Type VCB

to reduce mass, improve rustproof performance, and lower eddy current losses resulting by using non-ferrous material. As a result, it became possible to reduce the cost for transportation, installation, foundation work, maintenance, and inspection. In addition, the loss factor caused by power transmission and distribution can be lowered during operation.

3.2 Adoption of a Vacuum Interrupter (VI) in Self-Closing Force Reduced Construction

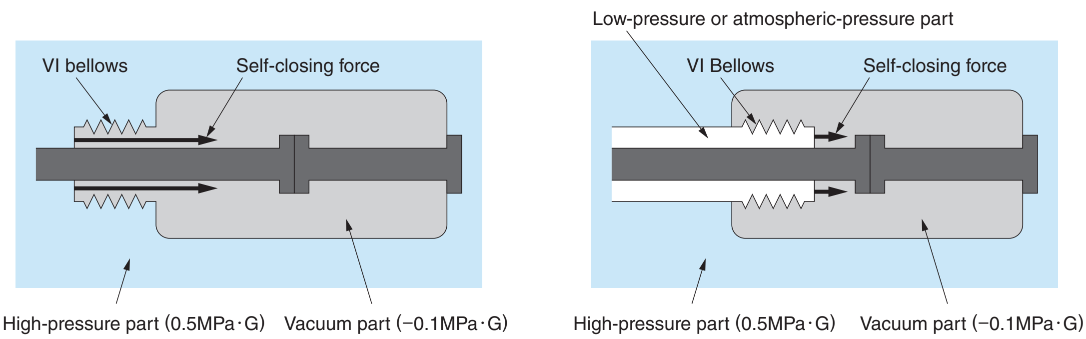
The gas pressure of a conventional SF_6 gas-insulated tank type of VCB was maintained at 0.15MPa·G. For an eco-tank type of VCB, the dielectric strength of dry air used for insulation is about 1/3 that of SF_6 gas. It is, therefore, necessary to raise the insulating dry air pressure as high as 0.5MPa·G. In the VI, its self-closing force is increased if the pressure of the bellows is raised. For this reason, it is necessary to increase the operating energy required for current interruption.



(a) 36kV rating (b) 72/84kV rating

Fig. 2 Internal Construction of Eco-Tank Type of VCB

Internal construction of the eco-tank type of VCB is shown for the rated voltages of 36kV and 72/84kV.



(a) Conventional design (b) Eco-tank type of VCB

Fig. 3 Conceptual Diagram of the VI Bellows and VI Self-Closing Force

Conceptual diagram of the VI bellows and VI self-closing force is shown. According to conventional designing approach, the differential pressure upon the bellows is increased and the self-closing force becomes large as well. For the eco-tank type of VCB, the differential pressure is made small and the self-closing force is also reduced.

In addition, it is necessary to use a special external-pressure type of bellows to withstand the specified high pressure. In order to solve these two problems, the eco-tank type of VCB has been designed so that the pressure to be exerted on the VI bellows is kept at a low atmospheric pressure and a high pressure of 0.5MPa・G is applied to other insulation areas. Fig. 3 shows the conceptual diagrams of the VI Bellows used in an eco-tank type of VCB and VI self-closing force.

3.3 Compact Design for Tanks

In the case of an SF_6 gas-insulated tank type of VCB, the fixed-side and movable-side VI conductors and their surrounding electrical-field relieving shields are respectively separated and independently installed. For an eco-tank type of VCB, however, conductors and shields are put into an integrated configuration by optimizing the electrical field. This approach is effective in reducing the tank diameter. Fig. 4 shows the construction of the electrical-field relieving shields (fixed side) for the VI.

The movable-side support insulator interior and the insulated operation rod maintained at a low pressure (a low dielectric strength) are designed to reduce dimensions of the tank in axial direction through the optimization of electrical field for the inserted metal fittings located inside the movable-side support insulator. As a result, the eco-tank type of VCB became compact: dimensions almost equal to those of the SF_6 gas-insulated tank type of VCB. Fig. 5 shows the result of electrical field analysis for a 36kV eco-tank type of VCB conduct around the movable-side and fixed-side support insulators. The three-dimensional electrical field strength analysis realized detailed analysis into the distribution of electrical field strength around inserts and conductors. This approach contributes greatly to highly accurate designing.

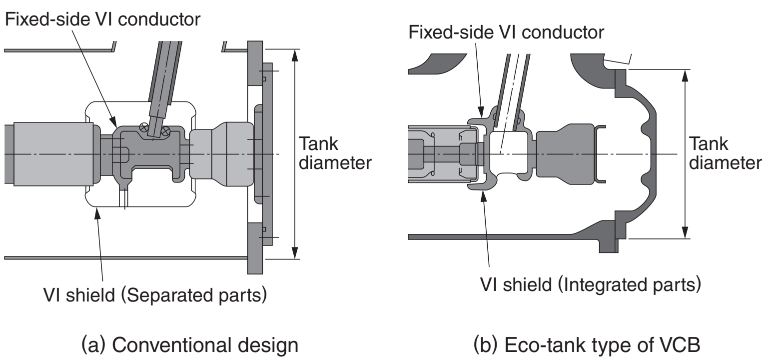


Fig. 4 Construction of VI Electrical Field Relieving Shield (Fixed Side)

With conventional design, the fixed-side and movable-side of VI conductors and their surrounding electrical field-relieving shields are respectively separated and independently installed. For the eco-tank type of VCB, conductors and shields can be put into an integrated configuration. As a result, the tank diameter can be reduced.

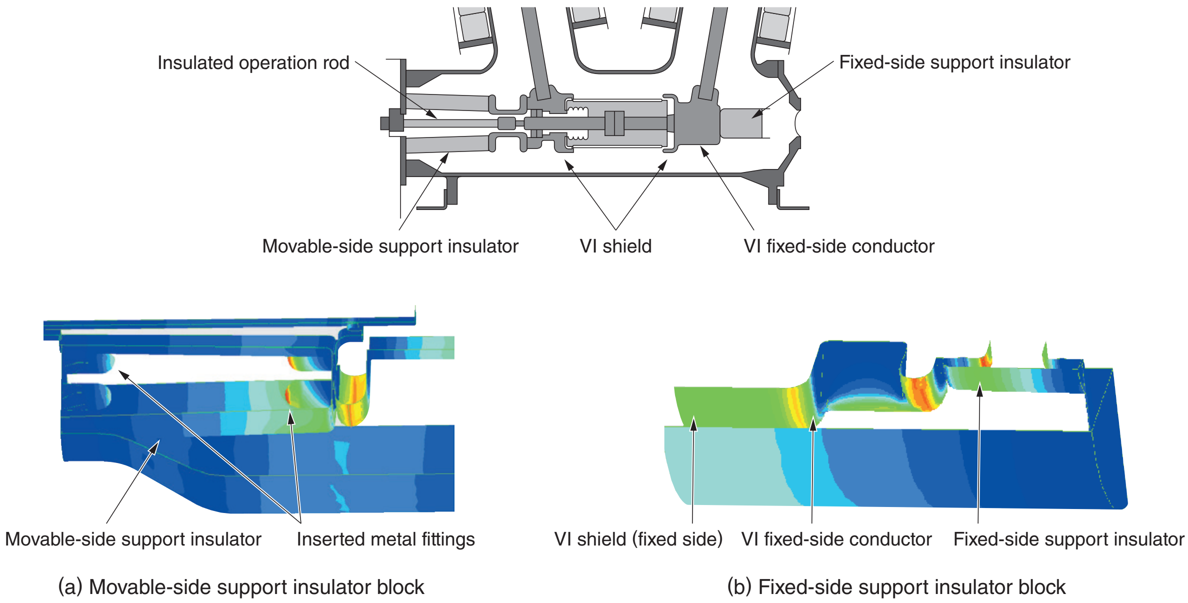


Fig. 5 Result of Electrical Field Analysis (36kV Eco-Tank Type VCB)

As an example of the result of the three-dimensional electrical field analysis for the 36kV eco-tank type of VCB, the movable-side and fixed-side support insulators are shown.

Table 2	**Undertakings for Eco-Friendly Considerations (3Rs and LS)※1**

Our actions for the items of eco-friendly considerations (3Rs and LS) are shown.

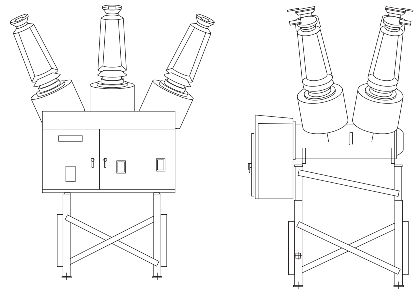
3Rs · LS	Concept	Items of actions taken for eco-tank type of VCBs
Reduce	Resources saving and energy saving	· Reduce mass by using aluminum materials · Reduce eddy current losses with aluminum tanks · Operating equipment going compact by reduction of operating force
	Reduce or abolish hazardous substances	· Use dry air insulation instead of SF_6 gas · Reduce coating with the use of aluminum materials
Reuse	Reuse raw materials and parts	· Reuse parts free from rust generation or corrosion (under research) · Reuse non-deterioration parts (under research)
Recycle	Use recyclable parts	· Recycling of metallic parts · Reuse of epoxy materials (under research)
Long use	Operation assured for a long duration of time	· Extension of life of interrupting part with the use of a VCB · Extension of life of contact points by using axil magnet field electrodes
Separable	Easy servicing for repair and replacement of parts Easy disassembly and classification	· No need for tank-opening inspection with the use of a VCB · No need for any SF_6 gas collection unit · Can dispose dry air by opening the valve

Note: ※1. 3Rs and LS: Five items of environmentally conscious action items in order to realize a recycling society for climate control

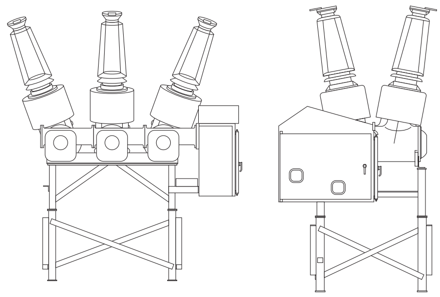
3.4 Expansion of Capacities (Realizing Rated Current 3000A)

The VI interior remains under the vacuum where high adiabatic performance is secured around conductors. This means that heat conduction and radiation are the only means for heat dissipation and no effect of heat dissipation by convection is available. In addition, the heat transfer coefficient of dry air that is an insulation medium for the eco-tank type of VCB is about 1/4 that of SF_6 gas at the same pressure. Since the heat dissipation capability of dry air including the effect of convection is inferior, it became less advantageous for dry air to expand current capacities, compared with SF_6 gas-insulated equipment.

In order to realize 3000A for 72/84kV eco-tank type of VCBs, key components for the main circuit were greatly modified from 2000A models: from aluminum materials to copper materials having a lower electrical resistance. Contact points were modified to the contact resistance reduced type. As a result, main circuit resistance in overall equipment was reduced by 45%, thus reducing heat generation around the current carrying parts of the main circuit remarkably. By thermal analysis, contacts and relating parts were optimized so that temperature distribution can be uniform in equipment as a whole.



(a) Type Ⅰ (Operator box installed in a short-sided direction)



(b) Type Ⅱ (Operator box installed in a lengthwise direction)

Fig. 6 **Arrangement of Operator Box for Eco-Tank Type of VCB**

There are two kinds of variations in the arrangement of the operator box for eco-tank type of VCBs. The operator box can be installed lengthwise or in a short-sided direction.

3.5 Five Items of Eco-Friendly Considerations (3Rs and Long Use and Separable "LS")

For the eco-tank type of VCB, no greenhouse effect gas is used and we factored various environmental considerations. It is a leading eco-friendly type of VCB. Table 2 shows our activities for 3Rs and LS.

3.6 Variation in Products

For the eco-tank type of VCB, the installation position for the operator box can be arbitrarily selected according to the substation layout such as the inspection path in a substation, positioning relationship with neighboring equipment, and acquisition of maintenance area. Fig. 6 shows variation of operator box allocation for the eco-tank type of VCB.

4 Postscript

This paper introduced the construction and features of the eco-tank type greenhouse gas-free

VCB. We factored low LCC and took measures against the 3Rs and LS.

Since the start of the operation of the first model in 2007, 350 units of eco-tank type of VCBs were delivered to North America and Australia, and 400 units to users in Japan (as of March 2014). They earned positive reviews by power companies, general industries, and railroad companies. In particular, this equipment does not require any later collection work of greenhouse gases. It, therefore, accommodates for use on islands, isolated locations, and mobile switchgear vehicles. Compared with SF_6 gas that is a conventional insulation medium, dry air has a higher saturated vapor pressure, and therefore has a characteristic hard to liquefy. As such, it is suitable for use in frigid zones. Amid rising world environmental concerns, we will continue to supply our eco-tank type of VCBs and contribute in mitigating global warming and reducing environmental load.

《**Reference**》

(1) Kiyohito Katsumata, Hitoshi Saito, Kozo Morita: "Trends toward SF_6 Gasless Technologies for Special High-Voltage VCBs." Meiden Jiho Vol.304, 2005/No.5, pp.5-8 (in Japanese)