Development of Next-generation Switchgear Targeting High Reliability and Maintenance Savings

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OVERVIEW: Ensuring a reliable supply of electricity to commerce, public institutions, and industrial equipment has become even more essential in recent years due to circumstances such as the increasing sophistication of the information society and the construction of high-efficiency production equipment. Switchgear are key components in electricity distribution systems, and in addition to the requirement for high reliability they are also subject to a diverse range of other requirements associated with advances in technology including safety, ease of inspection and maintenance, and consideration for the environment. Hitachi has developed switchgear with solid-insulated bus bars to meet diverse needs by utilizing various technologies including a vacuum disconnecting switch, improved safety through the use of solid-insulated bus bars, and maintenance savings made possible by integrating the main circuit elements into a single unit.

INTRODUCTION

THREE keywords have come to have a high importance in the modern world.

The first is "safety and reliability." Industries of all types give top priority to safety and reliability in their product development and the high-voltage electricity distribution equipment industry is no exception. Air-insulated switchgear have exposed live components and serious electric shocks can occur if human error or similar results in a person getting too close to these high-voltage parts. Similarly there is a risk of earth faults occurring due to foreign material getting into

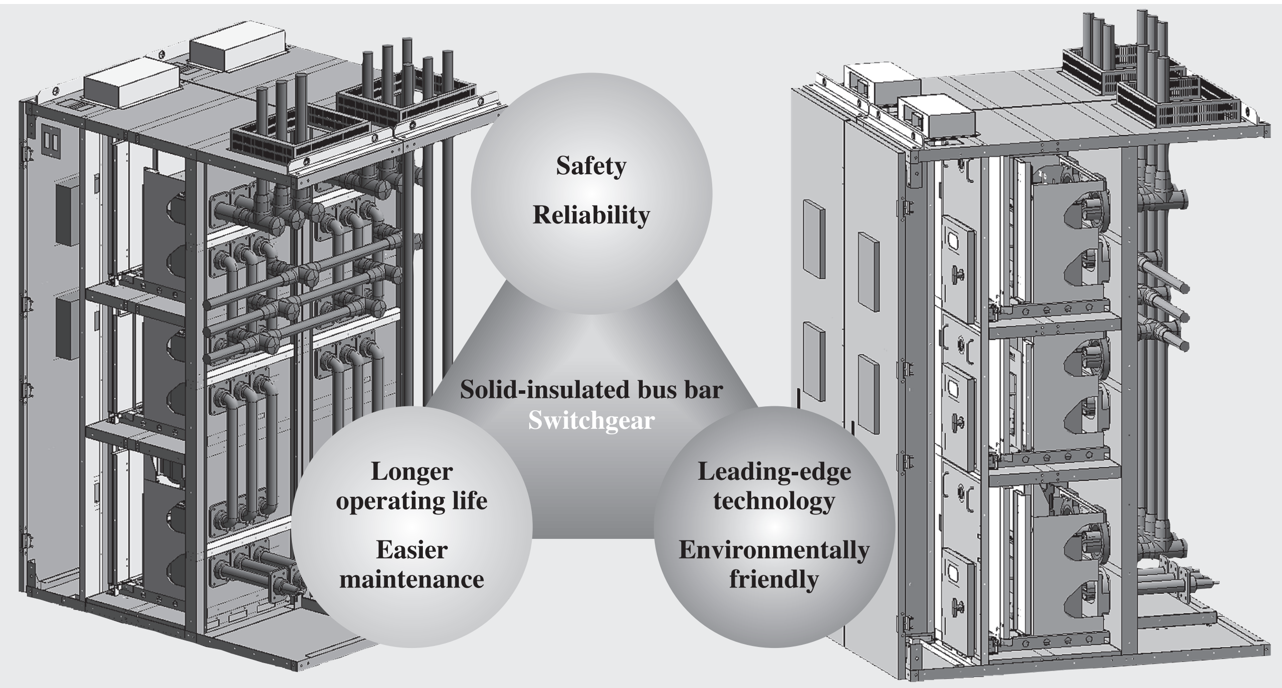

Fig. 1—Concepts Behind Switchgear with Solid-insulated Bus Bars.
The concepts behind Hitachi's environmentally friendly switchgear with solid-insulated bus bars which incorporate the company's leading-edge technologies to meet customer demands for safety, reliability, longer operating life, and easier maintenance are shown.

the switch or the buildup of dust after the unit has been in use for a long period of time. Development of the new switchgear aimed to produce a safe and reliable product that could eliminate these risks.

The second is “maintenance savings.” The requirement is for products with lower life cycle costs that are designed to make maintenance easier, such as allowing longer inspection cycles or not having to be cleaned inside the panel. Accordingly, Hitachi considered ease-of-maintenance and how to make maintenance savings when developing the switchgear.

The third is “consideration for the environment.” The term “eco-product” is also used to refer to this idea. In Japan where land is expensive and scarce, the requirement in the past has been to try to make electricity distribution equipment as small as possible. This resulted in the use of SF_6 (sulfur hexafluoride) gas as an insulator to allow the production of distribution panels with a small installation footprint. However, because SF_6 gas has a very high global warming coefficient, and because it is not easy to handle and needs to be managed, Hitachi undertook research and development to create more environmentally friendly electricity distribution equipment that does not use SF_6 gas.

The product developed based on these three keywords was the switchgear with solid-insulated bus bars.

This article describes the features and example applications of the switchgear with solid-insulated bus bars developed by Hitachi (see Fig. 1).

DEVELOPMENT OF SWITCHGEAR WITH SOLID-INSULATED BUS BARS

Switchgear Structure and Overview

Fig. 2 shows an overview of the switchgear with solid-insulated bus bars and its internal structure. The main features of the switchgear are as follows.

(1) Two different types of solid-insulated bus bars (epoxy and silicon rubber) are used in the bus bar chamber at the rear of the panel. The surface of each bus bar is earthed for safety to prevent electric shock if someone touches the bus bar.

(2) AIO (all-in-one) units that combine a VCB (vacuum circuit breaker), CT (current transformer), ZCT (zero-phase current transformer), and VT (voltage transformer) in a single unit are used in the top and middle chambers of the panel to make the internal components easier to maintain.

(3) The circuit breaker chambers have a sealed structure with dustproof covers on the front side of each chamber to protect the air-insulated parts from dust.

(4) A newly developed VDS (vacuum disconnecting switch) is used in place of the air-insulated disconnecting switches used in the past. Like the VCB, the VDS is also integrated into an AIO unit to make the internal components easier to maintain.

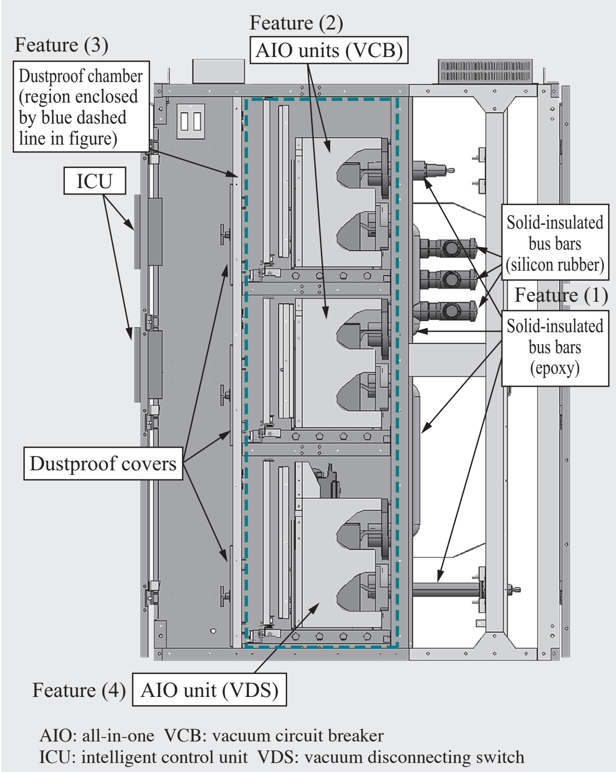

Fig. 2—Structure and Features of Switchgear with Solid-insulated Bus Bars.
The four key features of the switchgear are safe design with no risk of electric shock if components are touched by mistake (1), easy maintenance due to use of AIO units (VCB) (2), dustproofing (3), and easy maintenance due to use of AIO units (VDS) (4).

Product Concept

Safety and reliability

The switchgear uses two different types of solid-insulated bus bars. One type is coated in silicon rubber and used for the main bus bars that connect between panels. The other is coated in epoxy resin and is used for the conductors that connect between different circuits. As the surface of the solid-insulated bus bars made of silicon rubber are coated with electrically conductive rubber and the surface of the epoxy resin is painted with electrically conductive paint, the surface of the insulators can be earthed to eliminate any exposed live components inside the panel. This improves safety by preventing the risk of electric shock if someone touches or gets too close to a bus bar. Reliability is also improved by covering the surfaces of the insulation between the bus bars with an earthed coating which makes the risk of inter-phase short circuits or similar accidents extremely low (see Fig. 3).

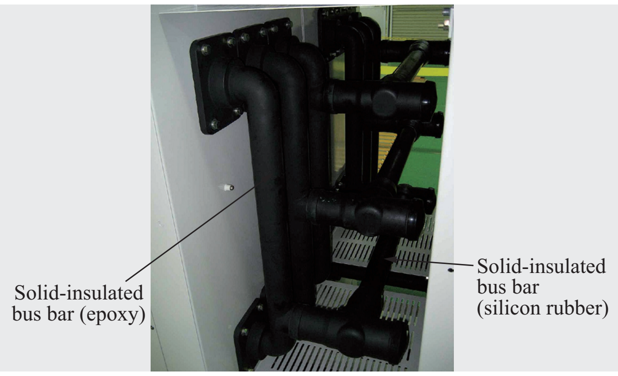

Fig. 3—View of Solid-insulated Bus Bars.
The solid-insulated bus bars are shown. The surfaces appear black because they are coated in conductive rubber or conductive paint.

Maintenance savings

Potential ways of saving on maintenance include making maintenance work more efficient (by shortening the time required), reducing the need for cleaning inspections (simplification), and by allowing longer inspection cycles.

(1) Shortening maintenance work

Inspection work was made difficult in the past by having components such as the CT and ZCT attached inside the switchgear panel as this meant a technician needed to get inside the panel to perform the inspection. Hitachi has shortened the time required for inspection and simplified the inspection procedure by combining the VCB, ZCT, CT, and VT in the single pull-out unit shown in Fig. 4 that can be pulled out of the panel for inspection.

The requirement to check the tightness of the bolt contacts required on previous air-insulated switchgear has been minimized by adopting solid-insulated bus bars. The number has been reduced by two-thirds from 18 locations per panel down to six.

Air-insulated disconnecting switches were also attached to the inside of the switchgear panel in the past which meant that inspections had to be performed in the minimal space available. In response, Hitachi developed a new VDS by enhancing a VCB with an electromagnetic actuator that has been used successfully in the past so as to allow inspection to be performed from outside the panel by integrating the disconnecting switch into a pull-out unit like the VCB. On the VDS, the withstand voltage standard required for use as a disconnecting switch was satisfied by enlarging the gap between the contacts inside the vacuum valve used in the VCB. Because the VDS unit has the same structure as the VCB, it can be used in an AIO unit consisting of a VDS and VT.

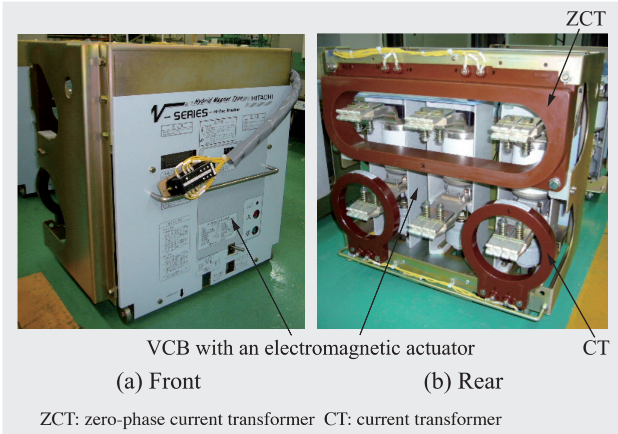

Fig. 4—AIO Unit.
The front and rear views of an AIO unit containing a VCB, ZCT, and CT are shown.

(2) Fewer cleaning inspections

Because the circuit breaker chamber which houses the main circuit components is the part most likely to suffer from degraded performance caused by the accumulation of dust, a dustproof design was adopted.

The dustproof chamber is designed to allow the circuit breaker to be inserted and removed by removing the dustproof cover. A small door is provided on the dustproof cover to allow the circuit breaker to be operated manually in case of an emergency and a window allows the state of the circuit breaker to be checked visually at any time while the switchgear is in use (see Fig. 5).

The dustproof cover is also fitted with a pressure-equalizing filter.

When the VCB or VDS in the AIO unit is carrying a current it becomes a source of heat, and a pressure differential can occur due to the expansion or contraction of the air inside the dustproof chamber after the power is turned on to the switchgear or if there is a sudden change in the temperature of the surroundings. A pressure-equalizing filter has been fitted to release this pressure. This filter also allows any humidity that enters when the dustproof cover is open to pass out of the chamber.

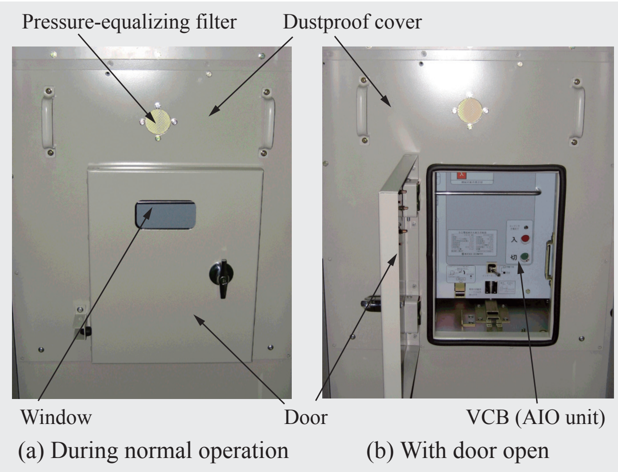

Fig. 5—Dustproof Cover.
The dustproof cover during normal operation and with the door open is shown. The door can be opened in an emergency to operate the switchgear manually.

(3) Longer inspection cycles

A grease-less electromagnetic actuator is used in the VCB and VDS to eliminate the need for the periodic lubrication and other maintenance required by spring-operated units. The new switchgear also uses long-life materials such as silicon rubber for the packing around the dustproof cover. Accordingly, the combination of a dustproof design and a grease-less electromagnetic actuator makes lubrication and cleaning unnecessary and this eliminates the need to open the dustproof cover except for periodic inspections or in case of an emergency and allows the inspection cycle to be made longer.

Consideration for environment

Because the switchgear with solid-insulated bus bars uses solid insulation on its bus bars and air insulation for some parts of the circuit breaker, it provides the safety and reliability of GIS (gas-insulated switchgear) without using SF_6 gas. Whereas SF_6 gas needs to be handled and managed carefully because it has an extremely high global warming coefficient, the new switchgear is an environmentally friendly product for which such concerns are unnecessary.

APPLICATION IN PRODUCTS

Space Saving Enhancements

Whereas VTs were produced as standalone units in the past [see Fig. 6 (a)], the new switchgear integrates the VT into the VCB unit to allow a three-tier design. As a result, a device that previously comprised two panels can now be produced as a single panel [see Fig. 6 (b)].

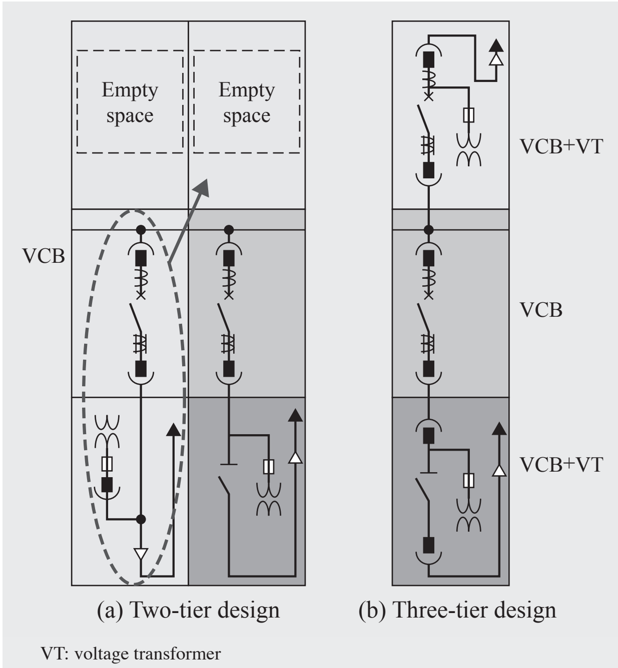

Fig. 6—Space Savings Achieved by Three-tier Design.
The two-tier design used previously was changed to a three-tier design to save on space.

Fig. 7—View of Switchgear with Solid-insulated Bus Bars.
Switchgear are installed at a substation for the Shinkansen rail system.

Actual Installations

The first switchgear with solid-insulated bus bars produced using the technologies described above were delivered to a customer in September 2008 (see Fig. 7). The switchgear with solid-insulated bus bars in this installation comprised a number of panels in a row.

CONCLUSIONS

This article has described the features and example applications of the switchgear with solid-insulated bus bars.

The switchgear with solid-insulated bus bars developed based on the concepts of “safety,” “maintenance savings,” and “consideration for the environment” are next-generation switchgear that combine the reliability of GIS with the extendibility of open-air panels. Future demand for these highly reliable and environmentally friendly products is anticipated to come from various different sectors.

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