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Latest Technology of Power Distribution Equipment

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Latest Technology of Power Distribution Equipment

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Technical Reports

Precis

The power distribution equipment has supported society for a long time. The development of technology has led to greater safety and reliability, more compact and light-weight systems, and improved serviceability and maintainability. In recent years, technologies related to internal arc discharge, IoT/higher functions, and direct current distribution complying with international standards have progressed in line with evolving social needs and trends toward improved safety, globalization, internationalization of standards, energy saving, reduction of environmental load, IoT/higher functions, LCC reduction, and stable supply of power.

This paper describes technology development of the power distribution system, trend of products and future prospects for the benefit of society.

24/36kV C-GIS "HS-X" for Overseas Power Distribution and Transmission Market

Authors: *Naoaki Inoue**, *Toshihiro Matsunaga**, *Takatoshi Otsubo*** and *Katsunori Kawanishi**

1. Introduction

In the development of 24/36 kV class cubicle-type gas insulated switchgear (C-GIS), Mitsubishi Electric Corporation has already commercialized the C-GIS Type "HS-X" having a rated current of 1,250 A and rated breaking current of 25 kA. However, overseas markets require a maximum rated current of 2,500 A and rated breaking current of 31.5 kA and 40 kA, which means a substantial upgrade. In addition, the latest international standard (IEC 62271) stipulates internal arc resistance during a short circuit accident inside the C-GIS. Furthermore, customer requirements include the double bus specification and elimination of on-site handling of gas during installation. Faced with these market demands, we recently developed a 24/36 kV C-GIS Type "HS-X" for overseas power distribution and transmission installations (hereinafter referred to as "C-GIS Type 'HS-X'").

This paper describes the specifications, configuration, and technologies of the C-GIS Type "HS-X".

2. C-GIS Type "HS-X"

2.1 Specifications of C-GIS Type "HS-X"

Figure 1 shows a cross-sectional view and skeleton diagram of the incoming panel of the C-GIS Type "HS-X". In overseas markets, a rated current up to 2,500 A is often required. To supply a large current of 2,500 A, the cross-sectional area of the cable to be energized must be enlarged, requiring the connection of multiple cables for each phase. Overseas markets also require a double bus configuration for improved bus redundancy, which is important in power distribution/transmission installations. Furthermore, the International Electrotechnical Commission (IEC) standard stipulates internal arc resistance in consideration of human safety in the event of a short circuit accident inside the C-GIS. These requirements were taken into account during product development. Table 1 shows the specifications of the C-GIS Type "HS-X".

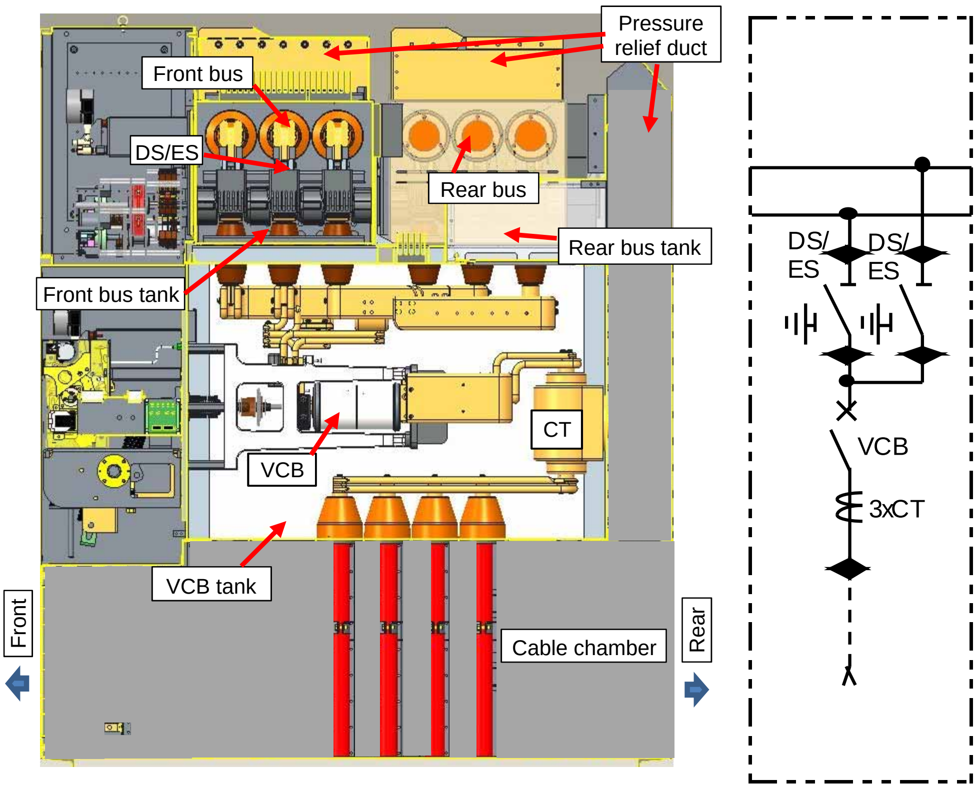

Fig. 1 Cross-sectional view and skeleton diagram of C-GIS Type "HS-X"

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Table 1 Specifications of C-GIS Type "HS-X"

	Item	Specification
C-GIS	Applicable standard	IEC 62271-200
	Rated voltage	24/36 kV
	Rated current	1250 A, 2000 A, 2500 A
	Rated frequency	50/60 Hz
	Rated short-time withstand current	31.5 kA for 3 s
	Internal arc class	AFLR 31.5 kA-1s
	Filling gas	SF6 gas
	Gas pressure	Rated: 0.03 MPa Alarm: 0.02 MPa
Circuit breaker	Applicable standard	IEC 62271-100
	Type	Vacuum circuit breaker
	Rated breaking current	31.5 kA
	Operating mechanism	Motor charged spring
	Class	S1, M2, E2, C2
Disconnector/ earthing switch	Applicable standard	IEC 62271-102
	Operating mechanism	Motor/manual

2.2 Configuration of C-GIS Type "HS-X"

To realize the single-line configuration shown in Fig. 1 and the large rated current shown in Table 1, the C-GIS Type "HS-X" is configured to allow the connection of up to four cables for each phase. Although a current transformer (CT) can be mounted on the cable section, if a larger number of cables are used, multiple CTs would be needed, adding to the cost. Therefore, for multiple cable installation, the current paths are combined into one conductor inside the tank, and the CT is placed inside the tank. The C-GIS Type "HS-X" also has a double bus configuration where the front bus tank and the rear bus tank are placed on top of the vacuum circuit breaker (VCB) tank with the VCB mounted. Placed inside the front bus tank and the rear bus tank are the disconnector/earthing switch (DS/ES) for the front bus and for the rear bus, respectively. The two DS/ES operating mechanisms are placed on the front of the panel to enable front-access operation. Furthermore, to achieve the internal arc resistance required by the IEC standard, pressure relief ducts are installed in the cable chamber, at the rear of the VCB tank, and on top of the bus tank to release high-temperature gas to the upper section during an internal arc accident and ensure the safety of people nearby.

3. Technologies used in C-GIS Type "HS-X"

In the newly developed C-GIS Type "HS-X", we employed four major technologies: (1) double bus configuration allowing front-access DS/ES operation and decreased DS/ES contact pressure; (2) gas sealing structure of the operation unit; (3) fluid analysis of high-temperature gas during internal arc fault; and (4) plug-in structure of the bus connecting part using a solid insulated bus adapter.

3.1 Double bus configuration of DS/ES

Figure 2 shows a top view of the double bus configuration of the C-GIS Type "HS-X". The width of the bus tank was made smaller than the panel width, with the front bus tank placed on the right side of the panel, and the rear bus tank on the left side, so that the double bus configuration allows front-access operation of the DS/ES of the front and rear bus. As a result, the operation rod of the rear bus DS/ES was extended to the front control box without interfering with the front bus tank, and the operating mechanisms for the DS/ES for the front and rear bus were placed on the front of the panel, to enable front access. As shown in the cross-sectional diagram in Fig. 1, the operating mechanism for the circuit breaker is also placed on the front. Thus, operability and visibility were ensured by placing all operating mechanisms on the front of the panel.

In addition, a blade-shaped switch structure is used for the DS/ES. With the conventional model, a pair of movable two-piece blades are engaged in the disconnect terminal or earth terminal to have contact at two points of both sides of the terminal, and contact pressure load is applied to the contact by a spring. This structure requires a large contact pressure load in order

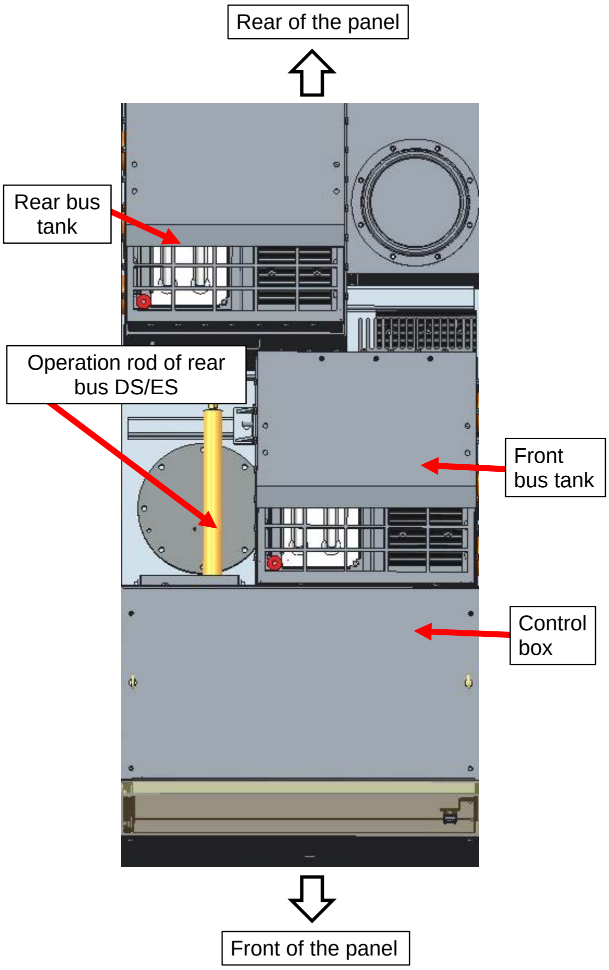


Fig. 2 Top view of double bus configuration of C-GIS Type "HS-X"

to reduce the contact resistance, which affects the conductivity of the load current, and to prevent welding of the contact during a large current flow. This also required a large control force of the DS/ES operating mechanism. In contrast, the DS/ES of the C-GIS Type "HS-X" has a blade with a slit at the tip and a multi-point contact structure, where a pair of two-piece blades contact the disconnect terminal or earth terminal at four contact points, as shown in Fig. 3, reducing the amount of current that flows at each contact point. This has made it possible to reduce the contact resistance and improve the welding resistance under a low contact pressure load. Compared to the conventional model (with flowing current of 1,250 A and short-time withstand current of 2 kA), this model has achieved a 12% reduction in contact pressure load, while improving both the conductivity and short-time withstand current performance.

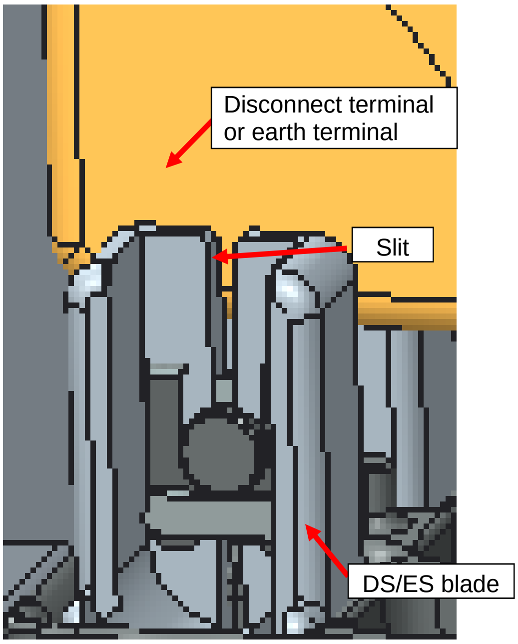


Fig. 3 Structure of DS/ES contact part

3.2 Gas sealing structure of operation units

Generally, the C-GIS's main circuit devices such as the VCB and DS/ES are enclosed inside a tank sealed with insulating gas, and must be operated using the operating mechanism placed outside the tank. This makes it necessary to transmit the driving force of the operating mechanism to the interior of the tank, while maintaining airtightness. The C-GIS Type "HS-X" has adopted a metal bellows seal structure for the driving part of the VCB. The bellows seal, a metal structure shaped like a bellows with elasticity, is also used in the moving part of a vacuum valve and has a proven record in reliable airtightness. The airtight driving part of the DS/ES has a rotating seal structure using an O-ring. There are two types of airtight drive structures using an O-ring: a linear slide seal structure and a rotating seal structure. When using the linear slide seal structure in a dust-filled environment, dust accumulated on the slide seal axis enters the O-ring seal part, possibly reducing the airtightness. In the case of the rotating seal structure, the O-ring seal part and the rotating seal axis are always in tight contact with no room for outside dust to enter. Thus, by having a structure that takes into consideration frequent opening/closing in places filled with dust, airtightness is secured even after multiple times of opening/closing.

3.3 Fluid analysis of high-temperature gas

The IEC standard specifies the classification of internal arc resistance. As shown in Table 1, the C-GIS Type "HS-X" is class AFLR 31.5 kA-1s. Class A specifies the safety requirement for authorized personnel in the vicinity of the C-GIS. FLR specifies the safety requirement up to a height of 2 m in all directions of the C-GIS (front, sides and rear). In the case of type testing, it is required that when an internal arc accident occurs while an indicator is placed near the C-GIS, the indicator does not ignite and arc burn-through does not occur. To meet these requirements, it is necessary to examine pressure increases during an internal arc accident in the tank, burn-through of the housing plate by internal arc heat, and housing strength. For this C-GIS, we carried out analysis and examination to secure the necessary tank strength. We further conducted fluid analysis of high-temperature gas in order to build a structure where the indicator would not burn out in the presence of high-temperature gas exhausted from the pressure relief duct. Figure 4 shows the results of fluid analysis conducted when an internal arc accident occurred inside a VCB tank. It was confirmed that by angling the exhaust part of the pressure relief duct in the forward and obliquely upward direction, the indicator would not burn out.

Figure 5 shows a scene from type testing. The high-temperature gas in this test also showed the same trend as the analysis results in Fig. 4. We conducted similar internal arc testing for analysis and testing on three parts: the cable chamber, VCB tank, and bus tank, and passed the type test in compliance with the IEC standard.

3.4 Plug-in structure of bus

In the case of the conventional C-GIS with a gas insulated bus, the bus must be connected and the gas must be processed when installing the C-GIS, requiring considerable installation time. To reduce on-site installation time, we adopted a plug-in structure for the C-GIS Type "HS-X", using a solid insulated bus adapter. As shown in Fig. 1, bus conductors are placed inside the front and rear bus tanks in addition to the bus DS/ES. Connection bushings are placed at both ends of the bus tanks, as shown in Step 1 of Fig. 6. At the tip of the connection bushing are contacts. During installation, a

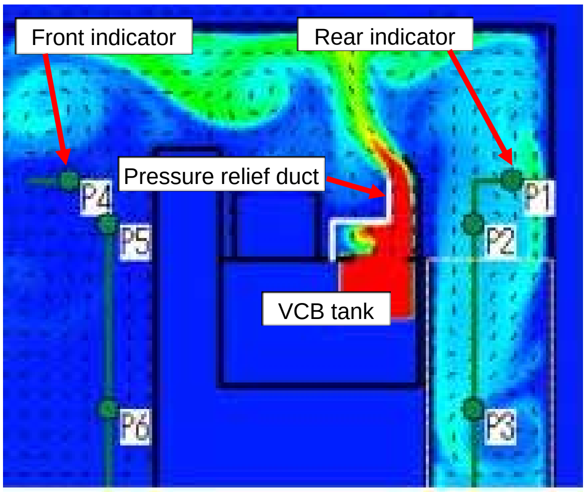


Fig. 4 Results of hot air fluid analysis during an arc accident inside a VCB tank

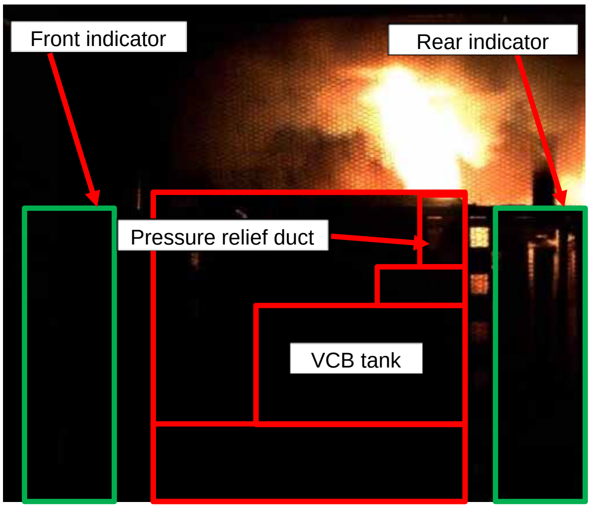


Fig. 5 Scene from type testing during arc accident inside VCB tank

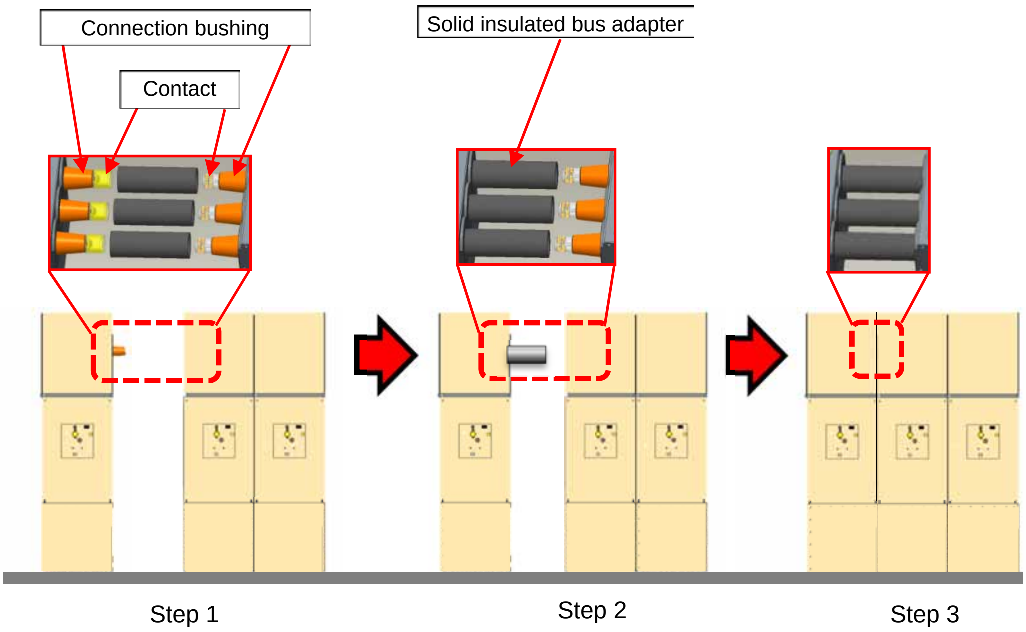


Fig. 6 Arrangement of solid insulated bus

solid insulated bus adapter is connected to the connection bushings, as shown in Step 2, and the C-GIS panels are arranged, as shown in Step 3, so as to cause the connection bushings of the neighboring panel to be inserted into the solid insulated bus adapter. By having this structure for the C-GIS body and the arrangement of panels causing the bus to be connected at the same time, we realized a configuration that eliminates gas processing during on-site installation. Figure 7 shows a top view after panel arrangement.

Current is supplied via contact at the connecting part, and solid insulation is provided. For this bus part, we also passed a series of type tests, including short-time withstand current test, load current conduction test, withstand voltage test, and long-term voltage application test, and achieved the target performance.

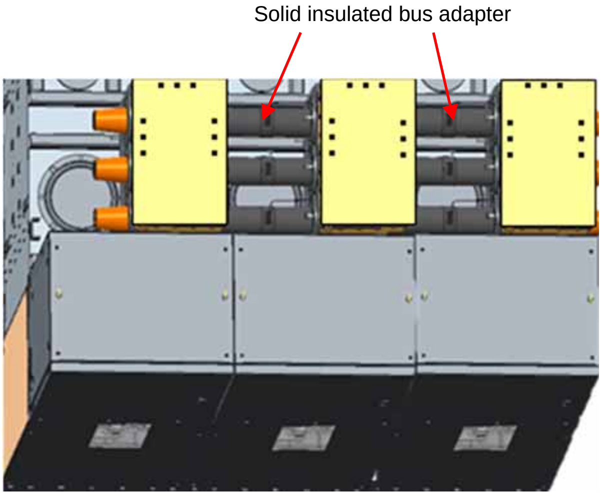


Fig. 7 Top view after panel arrangement

Fig. 8 Five-panel configuration of C-GIS Type “HS-X”

4. Conclusion

We described the specifications, configuration, and technologies of our recently developed 24/36 kV C-GIS Type “HS-X”. Figure 8 shows a five-panel configuration of this product. This time, we completed the development of breaking current class up to 31.5 kA, which accounts for the majority of the market demand. We started sales to customers in FY 2016. This product is designed for overseas markets. From the initial stage of development, we envisioned overseas production, evaluating overseas suppliers and procuring parts and materials, stabilizing quality through robot welding of tanks, and adopting a panel structure that minimizes welds. In the future, we will expand the range of specifications unique to individual customers as needed to meet the broader requirements of overseas markets.

12 kV HS-X Type C-GIS for Overseas RMU Renewal Market

Authors: *Toshihiro Matsunaga*, Teruaki Ebato** and *Kenichi Fuji***

1. Introduction

In the overseas markets for 12 kV loop-powered receiving systems, a ring main unit (RMU) comprising one vacuum circuit breaker (VCB) unit and two load break switch (LBS) units has been the typical configuration.

Recently, however, there has been an increasing demand to renew the existing RMU to a cubicle-type gas insulated switchgear (C-GIS) comprising three VCB units, for the purpose of shortening the power outage time. In response to this demand, Mitsubishi Electric Corporation has developed a 12 kV HS-X type C-GIS (hereafter, "HS-X type C-GIS").

This paper describes the arrangement, configuration, specifications, and technologies of the HS-X type C-GIS.

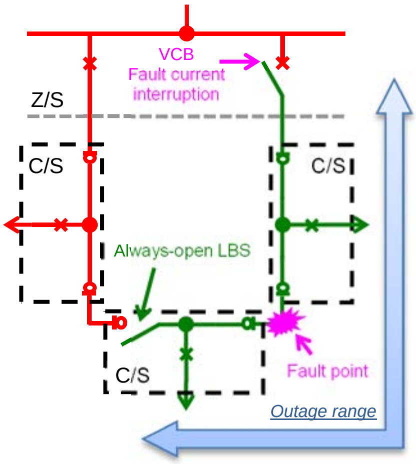
2. HS-X type C-GIS

2.1 Loop-powered receiving system and C-GIS arrangement

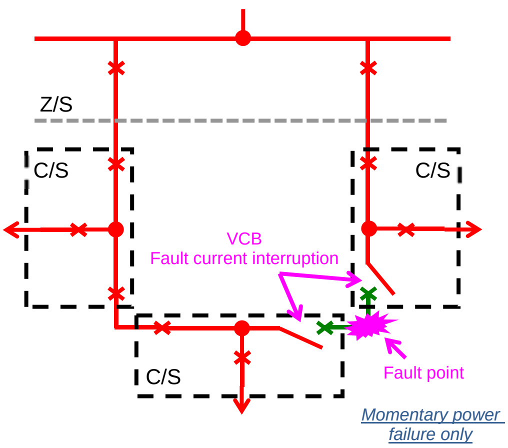
Figure 1 (a) shows an open-ring type loop-powered receiving system that uses the existing RMU. From the RMU of each consumer substation (C/S), a VCB is connected to the load side. Two LBSs are connected to a nearby C/S. A loop system is formed via the VCB of the zone substation (Z/S). This is called an open-ring system. Since one location of the LBSs in the system is always open, when a fault occurs, power will be lost from the always-open LBS to the VCB of the Z/S, with the fault point between them. Later, the LBSs on both sides of the fault point are opened, and the other systems are restored, while the power outage continues for several minutes.

On the other hand, if all LBSs were replaced with a VCB capable of fault current interruption, it would be possible to keep the loop system always closed, as shown in Fig. 1 (b). When a fault occurs, the VCBs on both sides of the fault point are instantly opened, limiting the power outage time to nearly zero (momentary power failure only). This is called a closed-ring system.

Figure 2 shows the C-GIS arrangement for a closed-ring type C/S. The minimum configuration is two incoming panel faces to be connected to the loop system and one feeder panel face to be connected to the load side. More feeder panels can be added depending on the configuration on the load side.



(a) Open-ring system



(b) Closed-ring system

Fig. 1 Loop-powered receiving system

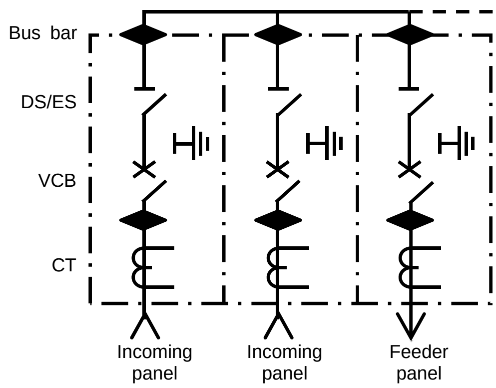


Fig. 2 C-GIS arrangement for C/S in closed-ring system

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2.2 Configuration and specifications of HS-X type C-GIS

Figure 3 shows the configuration of the HS-X type C-GIS. Table 1 shows its specifications. Placed inside the tank, which is filled with SF_6 (sulfur hexafluoride) gas as the insulation medium, are a VCB and a disconnect switch/earthing switch (DS/ES) on its bus bar side. Each device has its operating mechanism on the front, all of which are mounted on a flange as a single unit.

Bushings are mounted at the bottom of the tank in the vertically downward direction, where cables are to be connected. Current transformers (CTs) are placed on the cable compartment side (in the air) at the bottom of the tank, in such a way that the bushings penetrate them. On the tank ceiling, a plug-in type bus bar is connected via another bushing, using a solid insulated adapter.

A pressure relief plate is placed at the rear of both the tank and the cable compartment. If an internal arc fault occurs, the pressure relief plate is opened as the internal pressure rises. The internal arc classification pursuant to the IEC standard is AFL (F for front and L for lateral side), since high-temperature gas is discharged to the upper section through the space on the rear side of the C-GIS.

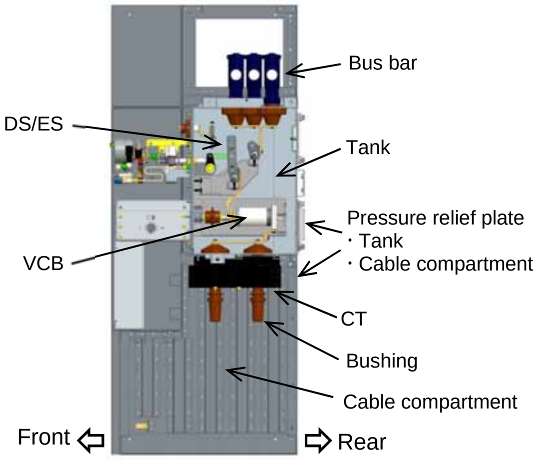


Fig. 3 Configuration of HS-X type C-GIS

Table 1 Specifications of HS-X type C-GIS

Device	Item	Specification
C-GIS	Applicable standard	IEC 62271-200
	Rated voltage	12 kV
	Rated current	630 A
	Rated frequency	50 Hz
	Short-time withstand current	21 kA, 3 s
	Internal arc classification	AFL 21 kA, 1 s
	Filling gas	SF_6 gas
	Gas pressure	Rated: 0.03 MPa-G Alarm: 0.02 MPa-G
Circuit breaker (CB)	Applicable standard	IEC 62271-100
	Type	Vacuum circuit breaker (VCB)
	Rated breaking current	21 kA
	Operating mechanism	Motor spring charged operation
	Classification	S1, M2, E2, C2
Disconnect switch/earthing switch (DS/ES)	Applicable standard	IEC 62271-102
	Operating mechanism	Manual operation
	Classification	M1, E0

3. Technologies used in HS-X type C-GIS

In the newly developed 12 kV HS-X type C-GIS, we employed five major technologies: (1) Unit downsizing and unit layout optimization; (2) high-temperature gas relief during an internal arc fault; (3) cable bushing compatible with both a compression terminal (existing cables) and a plug-in connector (new cables); (4) a plug-in bus bar using solid insulated adapters; and (5) robot welding for a gas tight tank.

3.1 Downsized unit and optimized unit layout

Figure 4 shows the configuration of the VCB-DS/ES unit of the HS-X type C-GIS. The main circuit section was renewed by changing the unit configuration of the existing 24 kV HS-X type C-GIS as a base to a 12 kV rating. The width dimension was cut by about 25% through the three-phase integration of insulators that support the pole assemblies of VCB-DS/ES. The depth dimension was also reduced by about 13% by placing the VCB operating mechanism at the lower front, which was previously dead space. By further optimizing the layout of the bushings, CT, etc., the panel exterior was downsized to width 450 × depth 820 × height 2,000 mm.

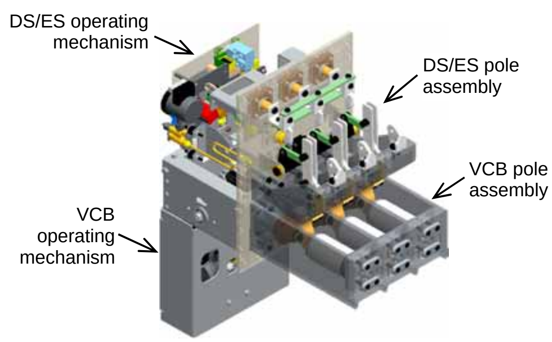


Fig. 4 Configuration of VCB-DS/ES unit

3.2 Internal arc pressure relief structure

The main target of the HS-X type C-GIS is renewal demand for the existing RMU. As such, it requires installation in a narrow electric room in a city basement, for example, which poses major restrictions on the depth dimension. Considering that such installation is against the wall, and on the assumption that personnel will not enter the rear side "R" of the C-GIS, we set the internal arc classification to "AFL," where safety against high-temperature gas relieved during an internal arc fault will be secured only on the front side "F" and lateral side "L." "A" indicates that only authorized personnel can approach the C-GIS.

Figure 5 shows comparison diagrams of the pressure relief path and the electric room outline of the 12 kV and an existing 24 kV HS-X type C-GIS. In the case of the 24 kV HS-X type, which has a pressure relief plate on the tank ceiling, a panel depth of 1,150 mm, and an "AFLR" designation that requires rear-side safety, the depth dimension including the rear-side space is 1,950 mm. On the other hand, in the case of the 12 kV HS-X type, a limited "AFL" designation allows for a pressure relief plate on the rear side; the panel depth is 820 mm thanks in part to the downsized unit as mentioned in the previous section; and high-temperature gas relieved on the rear side moves upward through the 100 mm space between the panel and the rear wall. Thus, the depth dimension including the rear-side space is 920 mm. In addition, the height of the electric room was also reduced from 3,400 mm to 2,600 mm by setting up a barrier at the front of the panel ceiling to restrict the discharge direction of high-temperature gas.

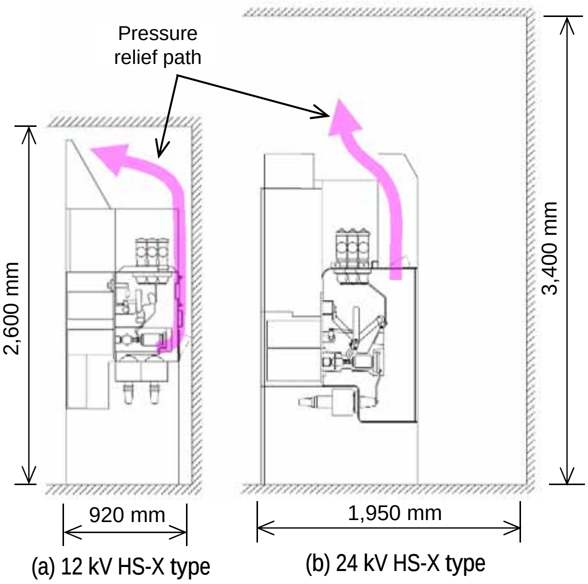


Fig. 5 Internal arc pressure relief path and electric room outline

3.3 Cable bushing

For the 12 kV HS-X type C-GIS, we developed a special cable bushing that faces the vertically downward direction so that the existing cable can be connected through the compression terminal in the air without installing a new cable equipped with a connector in compliance with common DIN (Deutsches Institut für Normung) standards (Fig. 6 (a)). This could shorten the power outage time when renewing the existing RMU.

The shape of the end resin of this bushing is the DIN standard type C. By removing the terminal, a new cable can be connected using a straight plug-in connector, as shown in Fig. 6 (b).

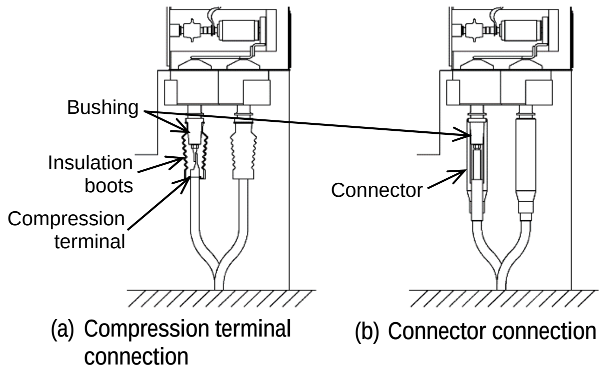


Fig. 6 Cable connection

3.4 Solid insulated plug-in bus bar

The 12 kV HS-X type C-GIS adopts a plug-in bus bar using solid insulated adapters, which have already been used in the existing 24 kV HS-X type C-GIS, successfully eliminating the need for on-site gas treatment during installation/panel arrangement. This could shorten the on-site installation time and reduce SF_6 gas consumption.

3.5 Robot welding

A robot welder (Fig. 7) has been introduced for gas tight welding of the tank. Although there are concerns to be addressed in the design or prototype stage, such as limited motion when welding inside the tank and the need for robot instruction each time a design is renewed or changed, the welding time during mass production (excluding welding preparation) can be shortened to one-half to one-third of that for manual operation. The welding state is also good.

Fig. 7 Robot welder

This C-GIS has a more reliable gas sealing structure for the mechanism using metal bellows and has eliminated the need for on-site gas treatment by using the solid insulated plug-in bus bar mentioned in the previous section, achieving an annual gas leak rate of

0.1 weight% or less. This meets the conditions required for exemption from periodical gas leak inspection during equipment operation under the revised F-gas regulation (No. 517/2014) of the EU.

4. Conclusion

We described the specifications, configuration, and technologies of the recently developed 12 kV HS-X type C-GIS. With our focus on renewal demand for the existing RMU, we have completed development conforming to internal arc classification “AFL” to accommodate narrow space installation. We plan to start offering the product to our customers in the latter half of FY2017. Figure 8 shows a three-panel arrangement of this C-GIS.

Fig. 8 Three-panel arrangement of HS-X type C-GIS

In the future, taking into consideration the demand for new installation, internal arc classification “AFLR,” and rated current and other upgrades, we will seek to increase market share, as well as expand overseas procurement and production.

7.2/12 kV Switchgear "MS-E" for Overseas Market

Author: *Toru Kimura**

1. Introduction

In the markets surrounding power distribution systems, globalization and the demand for power and social infrastructure are on the rise. In overseas markets, large-scale capital investments are being made, while engineering companies are demanding reduced assembly size to lower the construction costs of the entire electric room installation including the switchgear. In response to these market demands, we have developed the switchgear "MS-E", which offers smaller assemblies by 2-Tier VCBs.

This paper describes the MS-E and its technologies.

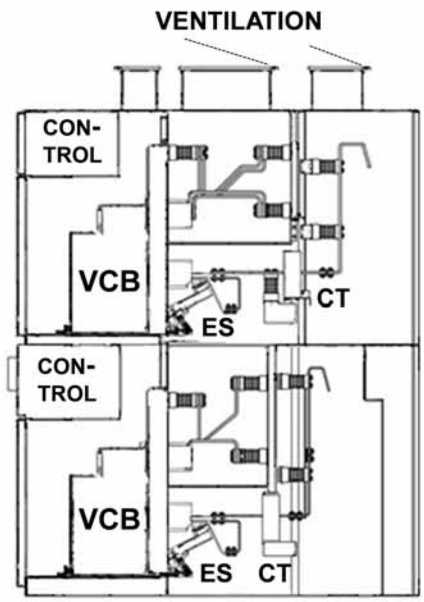
2. Outline of MS-E

2.1 Assembly structure of MS-E with 2-Tier VCBs

In developing the MS-E, we aimed to reduce the area occupied by the electric room to meet the market demand for a smaller assembly size. We achieved this by 2-Tier VCBs. By reducing the electric room area, the construction costs of the entire electric room can be cut, and the number of panels to be transported and the installation time can also be reduced. Figure 1 shows the outline of this product. Figure 2 shows the section view and a single-line diagram of the feeder panel. Figure 3 compares the model arrangement between the conventional product and this product.

2.2 Configuration of MS-E with 2-Tier VCBs

To achieve the cross-sectional configuration of this product as shown in Fig. 1, we housed a single-circuit section of the conventional product in the upper and in the lower level compartments. The main bus has a top/bottom split structure. The layout of the earthing switch (ES) in relation to the VCB is the same on the top and bottom levels, with the operating position of the ES lowered. It was also configured so that the polarity on the primary and secondary sides would not change between the top and bottom levels when a fused vacuum electromagnetic contactor is installed. Collectively



Basic section view of MS-E with 2-Tier VCBs

VCB: Vacuum Circuit Breaker
ES: Earthing Switch
CT: Current Transformer

MS-E panels with 2-Tier VCBs

Fig. 1 "MS-E" 7.2/12 kV switchgear that fulfills the required current carrying capacity, internal arc performance, and 2-Tier VCBs

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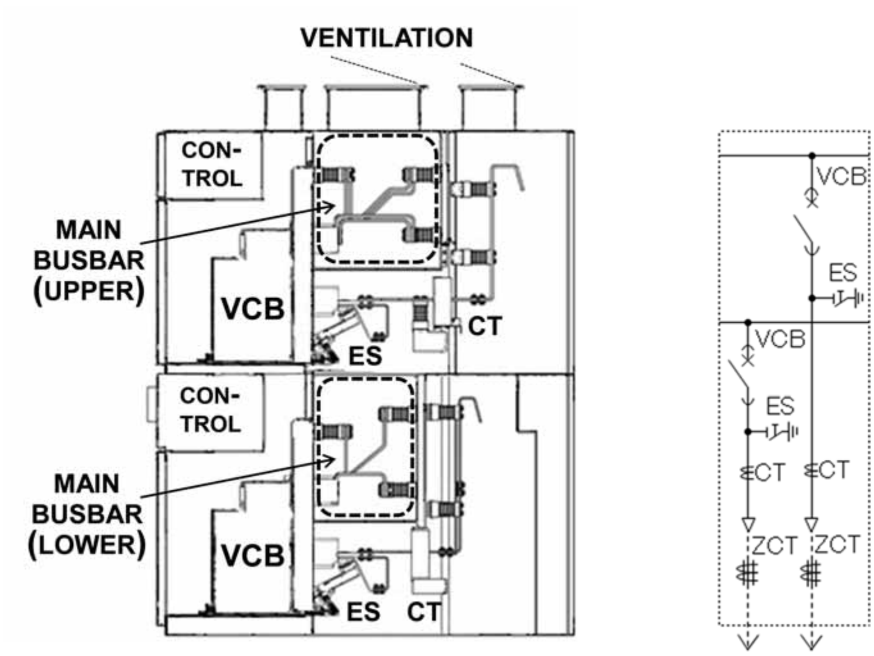


(a) Section view

(b) Single-line diagram
ZCT: Zero-phase CT

Fig. 2 Section view and single-line diagram of MS-E feeder panel

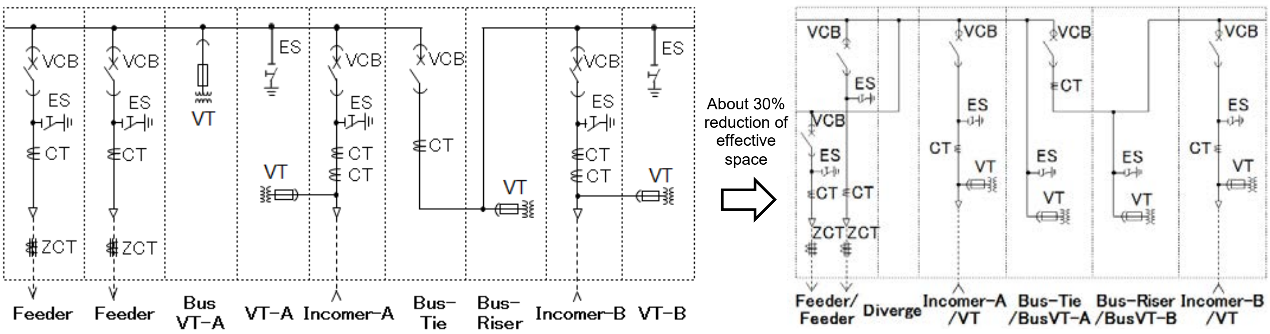


Fig. 3 Model arrangement comparison (conventional product on the left and MS-E on the right)

placed on the lower level of the control room are control devices to be used during normal operation, such as a protection relay, for improved operability, while devices not used during normal operation are housed on the upper level. For a conductor position to connect the power cable, we secured sufficient height for terminal processing when a general-purpose cable is used. A metal-framed partition plate separates the lower cable compartment from the power cable to be connected on the upper level. This allows maintenance of the lower level while the upper level is in operation, thus satisfying operation continuity (LSC2B-PM).

Since installation is indoors, we took into consideration protection from the tips of tools for some protection. The housing can be used for both 7.2 kV and 12 kV and is a standard type that controls changes in the product's exterior shape caused by rated voltage or rated current. Table 1 shows the specifications of this product.

Figure 4 compares the section views of the conventional product and this product. The standard outside dimensions of the conventional product are 800 (W) × 1,500 (D) × 2,600 (H) (mm), while the outside dimensions of this product are 800 (W) × 2,200 (D) × 2,600 (H) (mm). Although a single MS-E unit is larger than the conventional product, the assembly size reduction was achieved by 2-Tier VCBs on the feeder panel and having the VCB and VT 2-Tier on the incoming panel. This helped achieve an approximately 30% reduction of the effective space including maintenance space, in the model arrangement (refer to Fig. 3). The standard section view is shown in Fig. 4. Installation requirements for a lightning arrester, surge suppressor or non-standard cable can be accommodated by extending the depth as in the case of the conventional product. The model arrangement reduces the product mass by approximately 27% by 2-Tier VCBs and improving the housing efficiency for devices and parts. With a height of 2,600 mm, the product can be transported on a truck as in the case of the conventional product.

Table 1 Specifications of MS-E

Applicable standard		IEC62271-200
Rated voltage		7.2/12 kV
Rated breaking current		25, 31.5, 40 kA
Rated short-time withstand current		25, 31.5, 40 kA / 3 s
Rated current	Bus	3150 A
	Branch	1250 A
Rated withstand voltage	Commercial frequency	20/28 kV (1 min)
	Lightning impulse	60/75 kV
Control voltage		DC: 100/110 V
Rated frequency		50/60 Hz
IAC class (internal arc)		AFLR 40 kA / 1 s
Installation type		LSC2B-PM
Degree of protection		Enclosure: IP3X, Internal partition: IP2X
Installation location	Indoor/outdoor	Indoor
	Elevation	1000 m or less above sea level
	Relative humidity	5–95% (no condensation)
	Ambient temperature	−5°C to 40°C (average 35°C)
	Ceiling height	4.4 m or more
Access method		FR

*IAC: Internal Arc Classified
*FR: Front operation/Rear maintenance

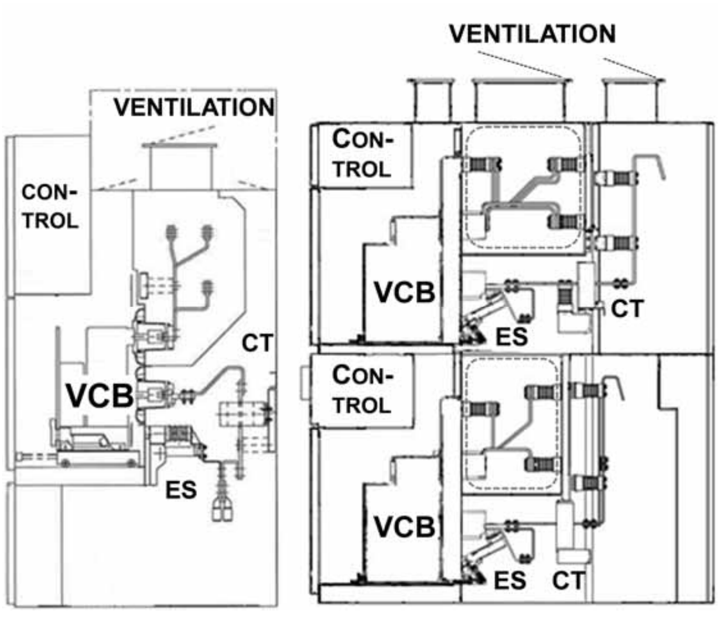
3. Technologies used in MS-E

This product requires both current carrying capacity performance to release energization heat to outside the panel, and internal arc performance (arc-proof structure) to withstand high-temperature high-pressure gas resulting from a short circuit accident inside the panel (called “hot gas”).

3.1 Current carrying capacity performance (heat dissipation structure)

The main bus of this product has a top/bottom split structure. Because of this structure, in order to supply a rated current of 3,150 A, both the top and bottom main bus on the feeder panel must be energized with 1,575 A; that from the conductor that follows the main bus to the cable via the VCB must be energized with up to 1,200 A; and the current carrying capacity specified by IEC standards must be met.

In the 2-Tier VCB structure, the upper level is affected by heat generated from the lower level, and the amount of heat generated at the main circuit is reduced by increasing the cross-sectional area of the bus conductor on the upper level. Each partition plate between compartments has a slit. A ventilation equipped with a dustproof filter and a slit is placed in the VCB compartment, bus compartment, and cable compartment on the upper level. This facilitates ventilation by natural convection. The main circuit conductor is coated with resin to improve emissivity. To ensure current carrying capacity performance during the design stage, we calculated the temperature increases by conducting a thermal fluid analysis. Figure 5 shows an example of the analysis results.



(a) Conventional product (b) MS-E

Fig. 4 Section view and single-line diagram of MS-E feeder panel

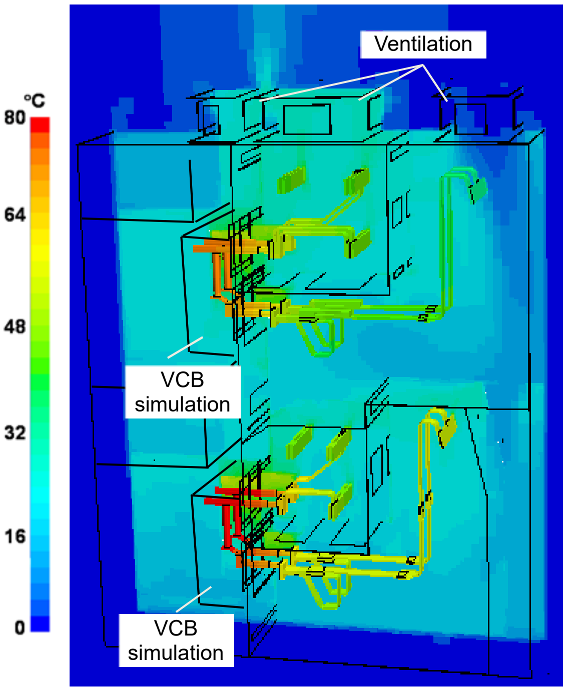


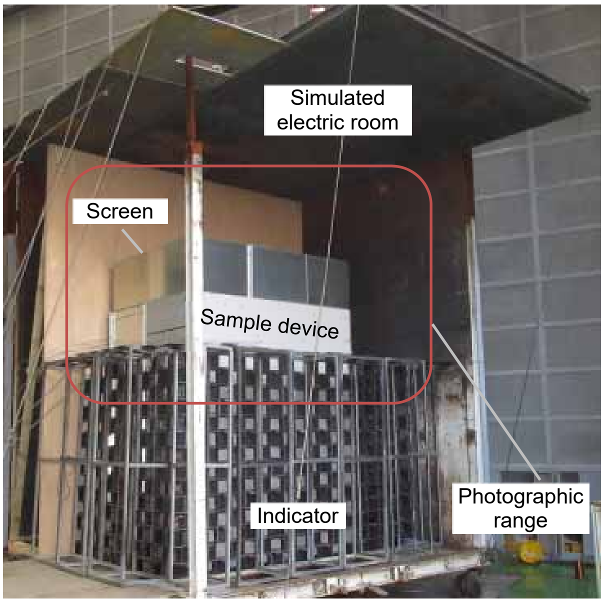
Fig. 5 Example results of thermal fluid analysis

3.2 Internal arc performance (arc-proof structure)

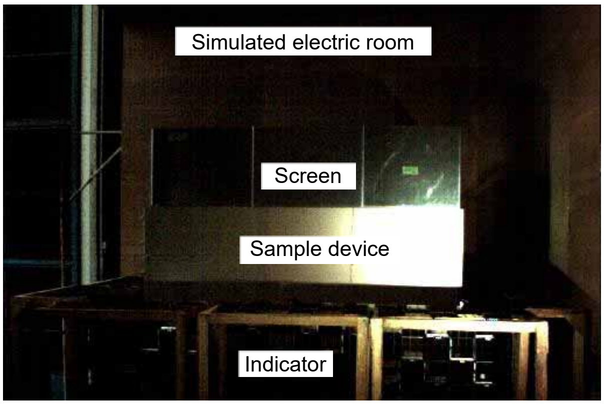
IEC 62271-200 requires internal arc performance that takes into consideration the safety of people nearby in the event of a short circuit accident inside the panel. This product supports AFLR 40 kA / 1 s, the highest class among indoor switchgears with a 7.2/12 kV rating. The uppercase letters represent types of limited accessibility to the switchgear. Type A limits access to authorized personnel only. FLR requires safety up to a height of 2 m each on the front (F), lateral (L), and rear (R) sides.

Type testing to confirm internal arc performance is conducted by installing walls and a ceiling to simulate the electric room where the switchgear will be installed and placing an indicator (black cotton cloth) near the switchgear to check the thermal impact of hot gas. The conditions for passing the test are: doors do not open when an internal short circuit is caused under specified conditions; debris weighing over 60 g does not scatter outside the switchgear; a burn-through hole does not occur in the switchgear within an accessible range of 2 m; the indicator does not burn out due to hot gas; and the housing grounding is maintained. In order to pass the test during the design stage, we conducted an analysis and calculated the pressure during an internal short circuit accident, and also examined the housing strength. We adopted a quality engineering design parameter to examine the strength. We took into consideration varying elements of the manufacturing conditions, use conditions and use environments in advance for efficient evaluation.

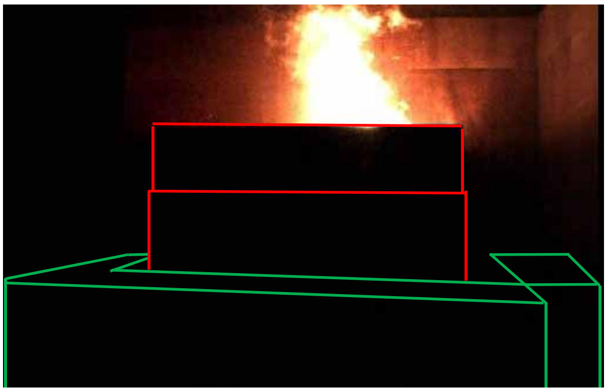
To confirm that the indicator section would not burn out due to hot gas released from the switchgear ceiling area, we further conducted hot air fluid analysis and examined the temperature near the indicator. Figure 6 shows the test scene. Figure 7 shows an example of the hot air fluid analysis results.



(a) Test form



(b) Before the test



(c) During the test

Fig. 6 Internal arc test scene

We fabricated a sample device that reflects a pressure design using the quality engineering design parameter as well as the hot air fluid analysis. Type testing was conducted by a third-party certification authority in the VCB compartment, bus compartment, and cable compartment on the upper/lower levels, a total of six compartments, all of which passed the test.

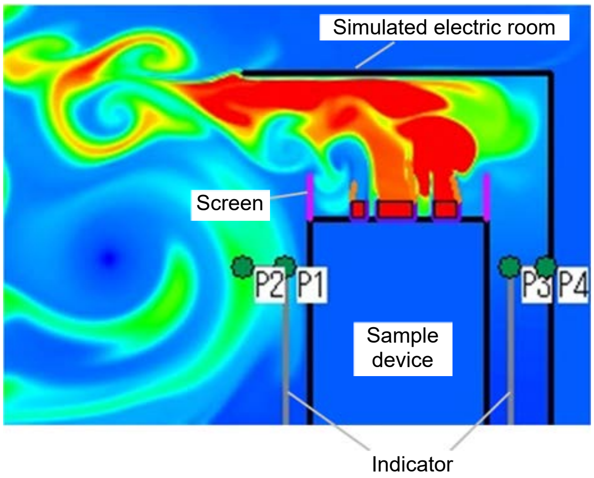


Fig. 7 Example results of hot air fluid analysis

4. Conclusion

We introduced the specifications and configuration of the recently developed MS-E with 2-Tier VCBs, along with the technologies used in the product. This completes our development through to the rated current of 3,150 A, which accounts for a majority of the market demand. Market introduction is scheduled for 2018. This product is intended for overseas markets and is designed to enable overseas production in the future.

Low Voltage Motor Control Center – Type-D for Global Markets

Authors: *Koichiro Seki*, Toshihiko Miyauchi** and *Makoto Kanemaru***

1. Introduction

The Motor Control Center (MCC) is a switchgear that collectively and centrally controls, protects, measures, and monitors a group of motors used in factories, water and sewage plants, power plants, etc. In emerging markets global such as in Southeast Asia, the Middle East, South America, etc., active investments are being made in new plant and equipment, including MCCs. In plant construction in these countries, MCCs and other electrical products are often preinstalled in a container-type substation and shipped to local sites in order to shorten the construction time, cut construction costs, and ensure consistent quality. Against this background, we developed and released the Motor Control Center Type-D (MCC-D) in 2016. The MCC-D is single-front; offers high storage capacity, superior operability and maintainability; and is suitable for installation in a container-type substation.

This paper describes the specifications and features of the MCC-D.

2. Specifications of MCC-D

Figure 1 shows the exterior of the MCC-D. Tables 1 and 2 show its main specifications.

3. Features of MCC-D

3.1 Compliance with IEC standard

The MCC-D complies with IEC 61439-1/2:2011, an international standard for low-voltage switchgear and controlgear often required in global plants.

3.2 Front access for operation and maintenance

With modifications made to the conventional parts layout and installation method, the MCC-D can be operated and serviced from the front side and can be installed against a wall (Fig. 2).

3.3 Improved efficiency in maintenance

By using the main circuit junction of the conventional model for the main circuit connecting part of the unit and a newly developed automatic coupling control connector for the control circuit connecting part (Fig. 3), we have achieved fully automatic coupling of the drawer unit and ease of attaching and detaching the unit during maintenance work. The automatic coupling control connector is movable and configured so that while the main circuit is unconnected at the test position of the unit, the control circuit is connected, allowing for safe and easy testing.

3.4 Large unit storage capacity

With the MCC-D, we developed a 1/4 unit, which can house four units in the panel width direction, and a 1/2 unit, which can house two units in the panel width direction (Fig. 4), allowing a maximum of 40 units to be enclosed per surface (compared to a maximum of 18 units per surface with our conventional model).

3.5 Space saving

Installing the incoming panel and double-front MCC of the conventional model against a wall in a container-type substation required a large space for panel

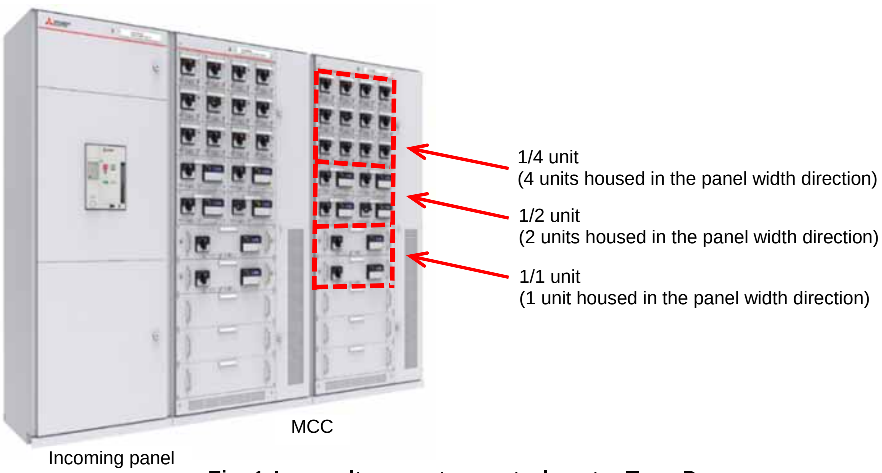


Fig. 1 Low voltage motor control center Type-D

*Power Distribution Systems Center **Advanced Technology R&D Center

Table 1 Specifications of MCC-D

Item		Specification
Standard		IEC61439-1/2:2011
Panel structure		Single-front
External dimensions (mm): Height×Width×Depth (Excluding channel base)		2200×1000×600
Rated insulation voltage		1000 V (Main circuit busbar) 800 V (Unit)
Rated operating voltage		~480 V
Rated frequency		50 / 60 Hz
Rated current of horizontal busbar		~4000 A
Rated short-time withstand current		85 kA for 1 s
Form of internal separation		~Form 4b
The degree of protection		IP20–IP43
Coordination with short-circuit protection device (Note 1)		Type 1 / Type 2
Drawer unit	Main circuit connection	Automatic
	Control circuit connection	Automatic
	Maximum capacity	Maximum 200 kW at 480 V
Internal arcing fault (Note 2)		85 kA-0.3 s at 480 V (Optional)

Note 1: Coordination between short-circuit protection devices and starters specified in IEC 60947-4-1:2009 (Contactors and motor-starters – Electromechanical contactors and motor-starters), the definition of which is provided in Table 2.

Note 2: Protection of people and equipment during internal arc accidents. To be checked using the testing methods specified in IEC/TR 61641:2014 (Enclosed low-voltage switchgear and controlgear assemblies – Guide for testing under conditions of arcing due to internal fault).

Table 2 Definition of coordination with short-circuit protection device

Coordination with short-circuit protection device	Definition
Type 1	During short-circuits, the device shall cause no danger to persons or installation. It is permissible for the device to remain inoperative without repair or replacement of parts.
Type 2	During short-circuits, the device shall cause no danger to persons or installation. The device must remain suitable for further operation.

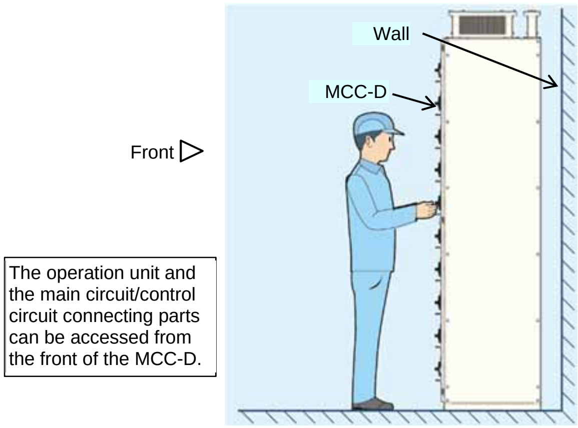
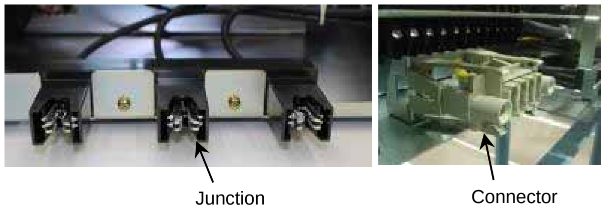


Fig. 2 Front-access operation and maintenance

installation due to the depth of the incoming panel and the need for a busbar conversion panel. In addition, since one side of the double-front MCC could not be used, improving the unit storage capacity was a challenge. With the MCC-D, by matching the depth dimensions of the incoming panel and MCC and the location of the main circuit busbar, a busbar conversion panel or dead space was eliminated. Combined with the large unit storage capacity described in Section 3.4, the panel can now be installed in a container-type substation in a space-saving arrangement (Figs. 5 and 6).



(a) Main circuit junction (b) Automatic coupling control connector

Fig. 3 Main circuit junction and automatic coupling control connector

(a) 1/4 unit (b) 1/2 unit

Fig. 4 MCC-D 1/4 unit and 1/2 unit

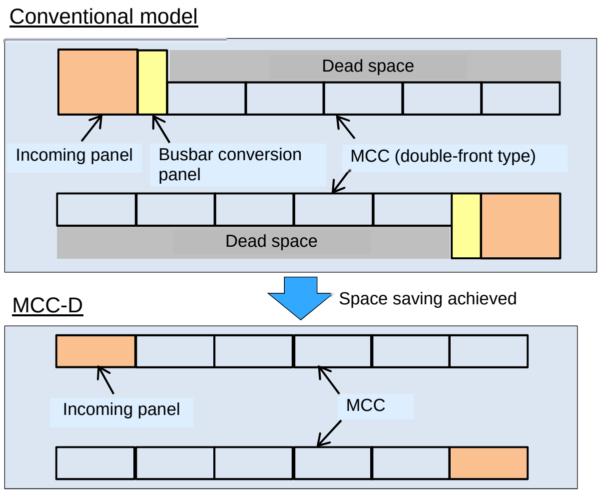


Fig. 5 MCC layout in a container-type substation (top view)

Fig. 6 Container-type substation

3.6 Improved safety

Having passed the test stipulated by IEC/TR 61641:2014 (Enclosed low-voltage switchgear and controlgear assemblies – Guide for testing under conditions of arcing due to internal fault), the MCC-D conforms to the internal arc specifications (protection of nearby persons/equipment from arc gas during short circuit accidents), which has recently been in increasingly high demand in global markets, thus improving safety.

3.7 Use of design to reduce human errors

The following three designs have been employed to reduce human errors (Fig. 7):

(1) A red line is placed at the upper front section of each panel with the number and name of the panel displayed on the line to be able to identify the equipment in question at a glance during operation/maintenance.

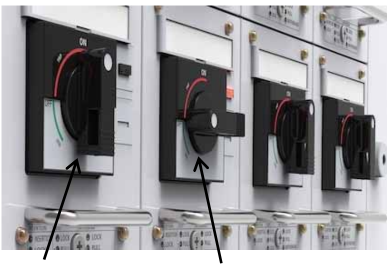
(2) The operating handle of the MCCB (Molded Case Circuit Breaker) has a high-contrast two-division design to be able to easily check the operation state even from an angle.

(3) The LED indicator, which indicates the operation state of the Type EMC-B electronic multi-function motor controller, projects from the main body to be able to easily check the operation state even from the side.

3.8 Type EMC-B electronic multi-function motor controller with load deterioration diagnosis function

As a result of extended inspection cycles at petroleum and chemical plants, which require continuous operation, it has become increasingly important to detect abnormal signs by motor diagnostic techniques. Additional problems include the shortage of maintenance staff, decreasing technological capabilities due to generational changes, lack of professional skills, and aging equipment, raising concerns for safety and efficiency. Faced with this heightened need for fault diagnosis functions, we developed a load deterioration diagnosis function to be installed on a Type EMC-B electronic multi-function motor controller.

(a) Upper front section of MCC-D



(b) MCCB operating handle

(c) LED indicator of EMC-B

Fig. 7 Design to reduce human errors

3.8.1 Mechanical system abnormality detection function

This function detects mechanical system abnormalities (eccentricity, misalignment, abnormal bearing, abnormal vibration, etc.) during motor operation by conducting frequency analysis (fast Fourier transform [FFT] analysis) on the motor stator current obtained by the current transformer and monitoring its feature components.

(1) Detection principle

When a mechanical system abnormality occurs, mechanical vibration affects the spatial magnetic flux in the air gap between the stators and the rotors, which is reflected in the stator current by back electromotive force (Fig. 8). As a result, the motor's mechanical vibration is converted to a current signal, causing a change in the specific frequency signal intensity near the power supply frequency of the current spectrum. Thus, by analyzing the frequency and monitoring the feature components, a mechanical system abnormality can be detected.

(2) Detection technique

Figure 9 shows the mechanical system abnormality detection technique. FFT analysis is performed on the stator current obtained by the current transformer. Features that symmetrically occur as sideband waves on the right and left sides of the power supply frequency (60 Hz for instance) are captured, and feature components A and B are extracted. The two feature components depend on the rotation speed of the motor, and the frequency band can be theoretically identified from the rated information of the motor. This is followed by trend monitoring performed on the signal intensity of extracted feature components A and B. After ascertaining the signal intensity in a normal state and determining a threshold, a mechanical system abnormality judgment is made when the signal intensity reaches or exceeds the threshold.

3.8.2 Stator winding turn fault detection function

This function detects a stator winding turn fault during motor operation by monitoring unbalanced components of the motor stator current and power supply voltage obtained by the current transformer and the instrument transformer.

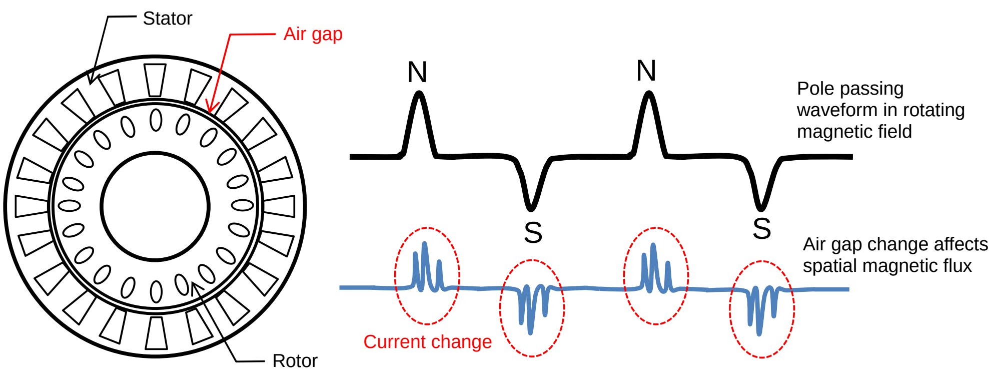


Fig. 8 Detection principle

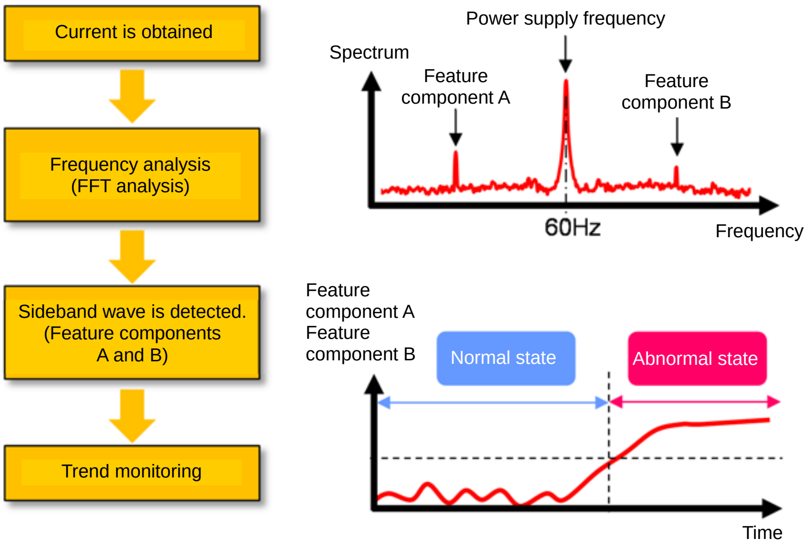


Fig. 9 Mechanical system abnormality detection technique

(1) Detection principle

When a stator winding turn fault occurs, the motor winding impedance becomes unbalanced (Fig. 10). By analyzing the imbalance between the stator current and power supply voltage, turn faults can be detected.

(2) Detection technique

Figure 11 shows turn faults detection technique. Motor stator current information is obtained by the current transformer and power supply voltage information by the instrument transformer. Next, the obtained stator current and power supply voltage are transformed to a symmetric coordinate using formulas (1) and (2), and negative-sequence current I_n and negative-sequence voltage V_n are calculated. I_a, I_b, and I_c are three-phase stator currents. V_a, V_b, and V_c are three-phase power supply voltages. α is a vector operator.

$$I_n = \frac{1}{3}\left(I_a + \alpha^2 I_b + \alpha I_c\right) \quad (1)$$

$$V_n = \frac{1}{3}\left(V_a + \alpha^2 V_b + \alpha V_c\right) \quad (2)$$

Since negative-sequence components change during unbalanced power supply, the turn fault evaluation value ΔI_n in formula (3) was defined in consideration of both negative-sequence current I_n and negative-sequence voltage V_n.

$$\Delta I_n = \left| I_n - Y_n V_n \right| \quad (3)$$

where Y_n is the initial negative admittance and can be calculated at the beginning of the measurement. Trend monitoring is performed on the turn fault evaluation value ΔI_n, and turn fault judgment is made when the signal intensity increases.

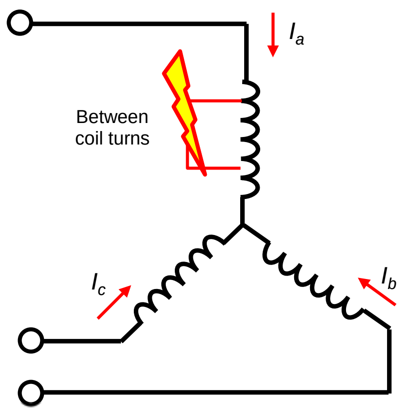


Fig. 10 Principle of layer short

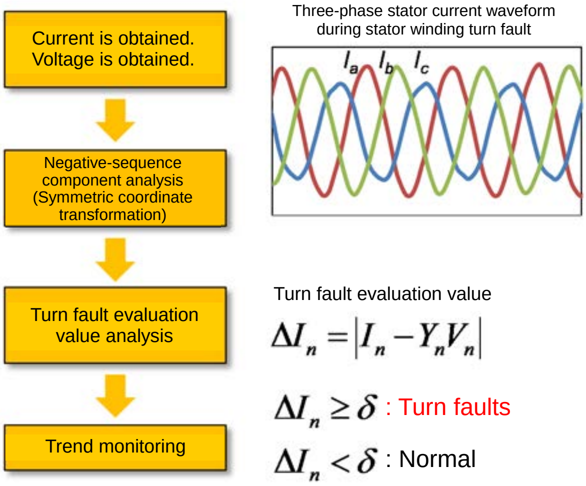


Fig. 11 Stator winding turn fault detection technique

3.8.3 Load torque estimation/monitoring function

This function is used to estimate/monitor the load torque by analyzing the motor stator current and power supply voltage obtained by the current transformer and by the instrument transformer.

The load torque T_e is theoretically expressed by formula (4), using the stator current and flux linkage. P is the number of poles, φ_d and φ_q are the stator coil flux linkages, and i_d and i_q are the stator currents.

$$T_e = \frac{3}{2} \cdot \frac{P}{2} \left(\phi_d \cdot i_q - \phi_q \cdot i_d \right) \quad \text{............................ (4)}$$

4. Conclusion

We have developed a low-voltage motor control center, “MCC-D,” for global markets. We will continue our development efforts for the domestic market to meet customer demands.

Reference

(1) Seki K., et al.: Low Voltage Switch Boards for New Market, Mitsubishi Denki Giho, 88, No. 11, 705–708 (2014).

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