Development of a 24 kV Double-busbar Cubicle-type Gas-insulated Switchgear (C-GIS) for SP PowerGrid Limited (SPPG)

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Abstract

Switchgears are key components of power transmission and distribution (T & D) equipment, and we have supplied over 10,000 single-busbar switchgears to overseas customers, primarily the SP PowerGrid Limited (SPPG). In 22 kV main substations, there was a request from SPPG to change specifications from conventional single-busbar operation to double-busbar operation to improve system reliability. In response to these requests, we developed a new 24 kV double-busbar cubicle-type gas-insulated switchgear (C-GIS). This equipment is designed based on the technology proven in our single-busbar C-GIS. The main features include a reduced panel width achieved by locating the operating rod for busbar B inside the tank, as well as improved operability by grouping the controls at the front of the equipment. This equipment has a rated voltage of 24 kV, a busbar rated current of 2000 A, and a rated short-time withstand current of 25 kA-3s. It also complies with international standards such as IEC 62271-200 Ed. 3.0 (2021). This equipment was developed considering the timing of our customers' operational changes. This facilitates the transition from single-busbar to double-busbar systems, enabling responses to diverse grid system operation requirements.

1 Preface

Switchgear is a key component of power transmission & distribution (T & D) equipment. Our company has supplied over 10,000 units, primarily 24 kV class cubicle-type gas-insulated switchgear (C-GIS), to overseas customers. In Singapore, in particular, we have been supplying single-bus C-GIS to SP PowerGrid Limited (SPPG) since the 1990s, earning a reputation for high reliability and maintainability[(1)]. In recent years, with the increasing demand for electricity in urban areas, there has been a growing need for improved reliability in power supply. Against this backdrop, SPPG is promoting the conversion of its main substations to dual-bus systems. To meet this demand, our company has developed a new 24 kV C-GIS (hereinafter referred to as "this equipment") compliant with the requirements of dual bus systems, based on our proven single-bus C-GIS technology. This paper describes the equipment's ratings, structure, and main features.

2 Ratings and Structure

Fig. 1 shows the internal structure of this equipment (feeder (F) panel as a representative example), and Table 1 shows the ratings and specifications.

3 Features

3.1 Vacuum Circuit Breaker (VCB) Structure

The vacuum circuit breaker (VCB) unit of this equipment was designed based on existing units with a proven track record of numerous deliveries. This configuration ensures the reliability and tripping performance of the equipment.

A dual trip structure is employed in the tripping coil section. This structure features two tripping coils that operate in response to the tripping signal. Even if one coil fails, the other coil will operate. This reduces the risk of events where the tripping command does not function. Fig. 2 shows a comparison

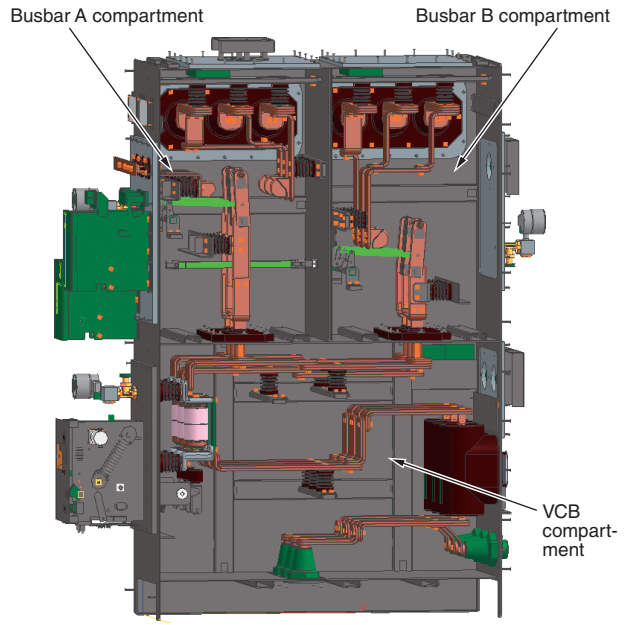


Fig. 1 Internal Structure of 20 GB for a Double Busbar

The internal structure of 20 GB for a double busbar is shown. It consists of three compartments: a busbar A compartment, a busbar B compartment, and a vacuum circuit breaker (VCB unit) compartment. The controls for each compartment are located on the front of the panel for ease of operation.

Table 1 Ratings and Specification of 20 GB for a Double Busbar

A comparison between the main ratings and specifications of 20 GB for a double busbar and for a single bus is shown.

Item	Ratings and specifications	
Model name	20 GB (Single busbar)	20 GB (Double busbar)
Rated voltage	24 kV	
Busbar rated current	1250 A	2000 A
Rated frequency	50 Hz/60 Hz	50 Hz
Rated short-circuit breaking current	25 kA	
Rated short-time withstand current	25 kA-3 s	
Short-time power frequency withstand voltage	50 kV	
Lightning impulse withstand voltage	125 kV	
Busbar arrangement	Single busbar	Double busbar
Ambient temperature	−5℃～40℃	
Altitude	1000 m or less	
Rated gas pressure	0.05 MPa·G	
Insulation gas	SF_6	

of single-busbar type and double-busbar type VCB units.

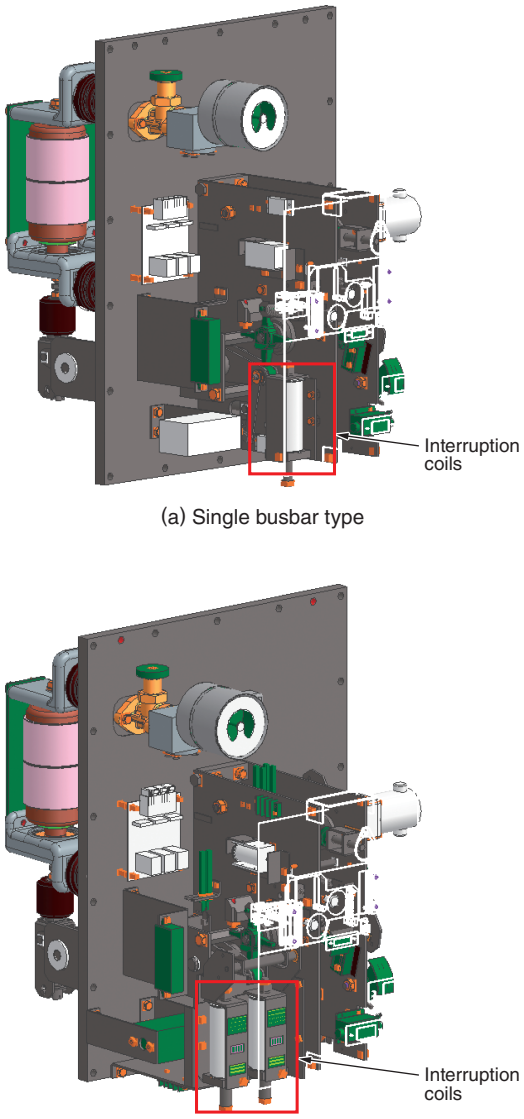


Fig. 2 VCB Unit Comparison

The basic structure uses a single-busbar-type VCB unit, and reliability has been improved by adopting dual trip coils.

3.2 Structure of the Three-Position Disconnector (EDS)

Fig. 3 shows a comparison of this equipment with a 30 GB for a double busbar for overseas markets. In a double-busbar configuration, operating mechanisms are required for both the busbar A compartment and the busbar B compartment. To facilitate maintenance, the operating mechanisms of this equipment are concentrated on the front side of the panel. In the conventional 30 GB for a double busbar, the EDS in the busbar B compartment was operated by means of an operating rod arranged on the side of the tank. In contrast, this equipment has a structure where the operating rod passes through

the inside of the tank. This arrangement reduces the panel width. In C-GIS, mechanical and electrical interlock mechanisms are generally provided to prevent incorrect operations among the circuit breaker (CB), disconnector (DS), and earthing switch (ES). Since this equipment is intended for application in primary substations, a higher level of system reliability is required. To address this requirement, a key interlock mechanism was added to the incoming transformer (T66m) panel. This further enhances the safety measures of the system. Fig. 4 outlines the key interlock scheme, including the upstream 66 kV system. The key exchange box is used to manage key access and prevent incorrect operations caused by human error.

3.3 Gas-Insulated Switchgear (GIS) Structure

Three-phase spacers and flanges are provided at the inter-panel connections of the busbar compartment. This design allows individual panels to be isolated and replaced independently. Even in the event of a fault, the impact on adjacent GIS busbar compartments can be minimized. In the conventional design, expansion joints were installed between panels. In contrast, this equipment employs a structure in which the flanges are mounted from the inside of the enclosure. This allows panel replacement simply by removing the flanges. As a result, expansion joints are unnecessary, thereby preventing an increase in panel width.

Furthermore, this device employs a hot gas

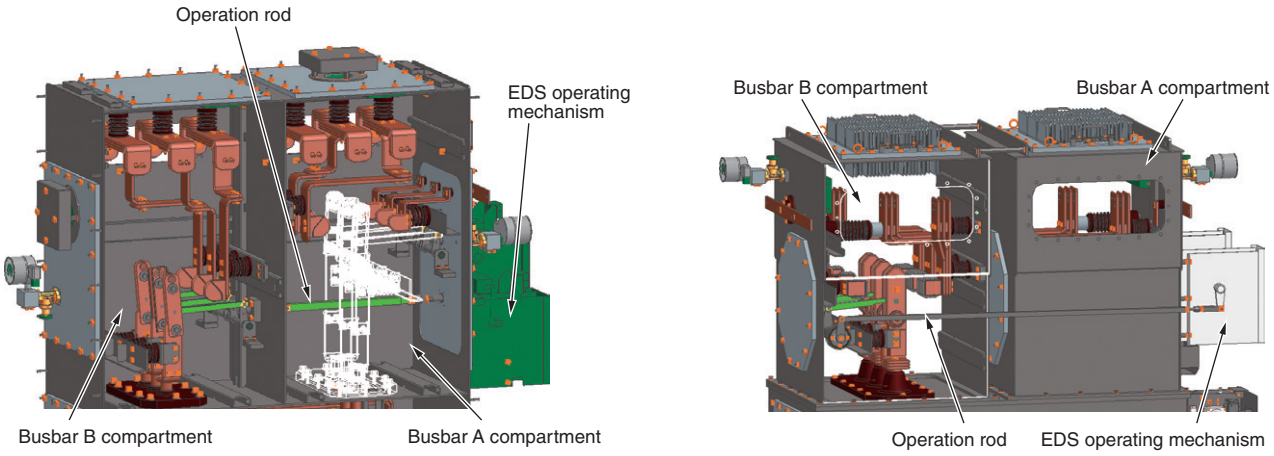
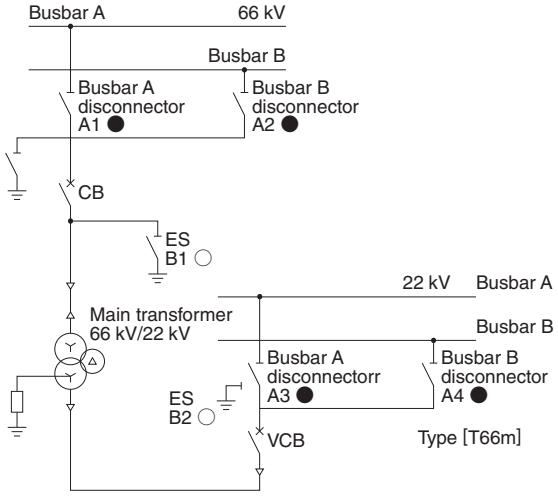


Fig. 3 **EDS Unit Comparison**

The panel width was reduced by locating the operating rod for busbar B inside the tank.



●: Locking device (with key)
○: Locking device (no key)

Key exchange box					
A1	A2	A3	A4	B1	B2
○	○	○	○	●	●

The keys A1, A2, A3, and A4 are released from the key exchange box only when keys B1, B2 are inserted into the key exchange box. (Keys A1, A2, A3, and A4 are not released from the key exchange box unless keys B1, B2 are inserted into the key exchange box.)

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Fig. 4 **Overview of Key Usage**

The B1/B2 keys can only be used when the A1–A4 keys have been placed in the exchange box, and the A1–A4 keys can only be used when the B1/B2 keys have been placed in the exchange box.

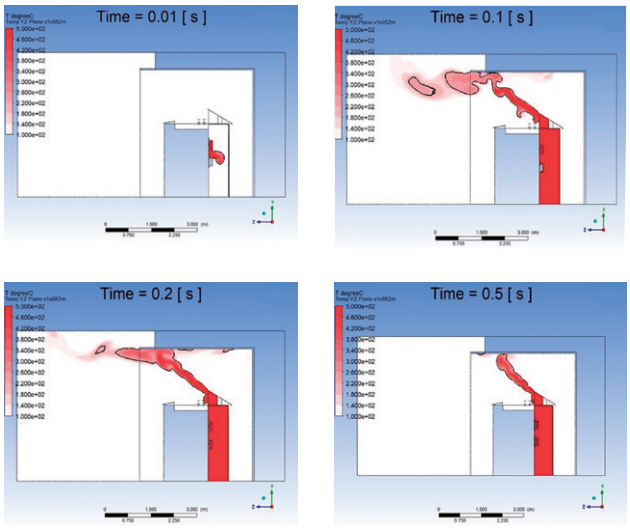


Fig. 5 Thermal Fluid Analysis Results

The results of the internal arc analysis for the busbar B chamber. The temperature distribution over time was evaluated to visualize the hot-gas dispersion behavior.

release structure in the event of internal arc fault, with a duct at the gas outlet to guide the hot gas. Structural analysis was performed using thermal fluid analysis to obtain temperature distribution and visualize the gas dispersion behavior. This allowed for optimization of the duct shape. Fig. 5 shows the thermal fluid analysis results. Verification tests confirmed that the hot gas is released in a safe direction due to the effect of the duct.

4 Test Results

4.1 Third-Party Test Results

Based on customer requirements, this equipment underwent type tests at an overseas third-party testing laboratory. The testing was conducted at the KEMA Labs in the Netherlands, a member laboratory of the International Short Circuit Testing Association (STL). The test subjects were panel types: F panel, T66m panel, and busbar connection (BC) panel. The busbar section (BS) panel was also subject to type testing. Since the BS panel has a structure similar to that of the BC panel, the tests were conducted at the High Power Testing Laboratory in Meiden Numazu Works. This laboratory is a member of the Japan Accreditation Board (JAB).

Each testing facility conducted a series of type tests in accordance with the standards, including dielectric withstand tests, short-circuit current breaking tests, internal arc tests, and continuous

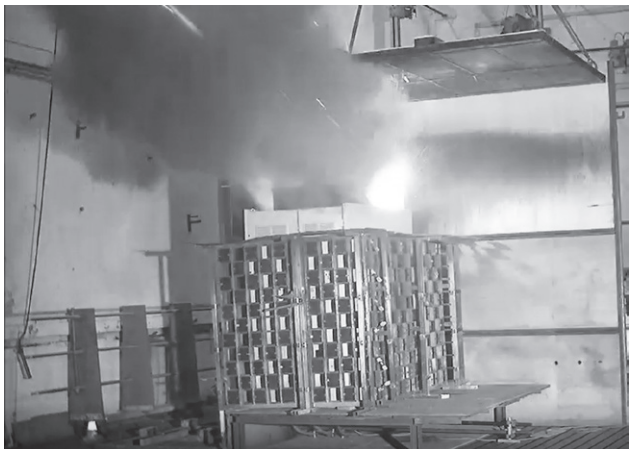


Fig. 6 Internal Arc Test Status at a Third-Party Test Site

An internal arc test simulating an internal fault within a C-GIS. The safety of personnel in the vicinity and the impact on adjacent compartments were evaluated.

Table 2 Bus-Transfer Current Switching Test Conditions

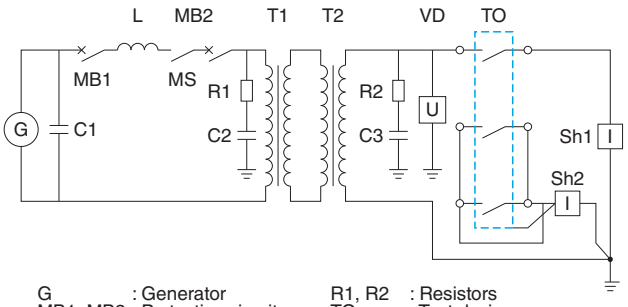
The test conditions for the bus-transfer current switching test conducted as a supplementary reference test.

Item	Conditions
Test method	Single phase test
Recovery voltage	10 V (Rated 52 V or higher)
Opened or closed current value	1000 A
Test frequency	60 Hz (Performance inclusion under 50 Hz conditions)
Circuit power factor	＜0.50
Number of tests	100 times
Control/operation voltage	DC26 V, AC200 V
Gas pressure	0.02 MPa·G

current tests. Fig. 6 shows the internal arc test. Post-test inspections confirmed that all test objects complied with the applicable standards and demonstrated satisfactory performance. As a result, type certification was obtained.

4.2 Reference Tests

As a reference test other than mandatory type testing, busbar loop current switching tests were conducted at the High Power Testing Laboratory for F-panels and T66m-panels. This test is specified in the IEC standard for voltage classes above the rated 52 kV. For this equipment, the test was conducted to verify performance considering the customer's actual usage conditions. As a result, it was confirmed that there were no problems with busbar loop current switching performance. Table 2 shows the test



G : Generator
MB1, MB2 : Protective circuit breaker
MS : Injector
L : Reactor
C1, C2, C3: Capacitor
T1, T2 : Transformer
R1, R2 : Resistors
TO : Test device
VD : Instrumental voltage divider
Sh1, Sh2: Splitter

Fig. 7 Bus-Transfer Current Switching Test Circuit

The test circuit used for the bus-transfer current switching test conducted at our JAB-accredited high-power testing laboratory.

Table 3 Bus-Transfer Current Switching Test Results

The results of the bus-transfer current switching test performed as a reference test are shown.

Item	Measurements
Recovery voltage	5.5 V
Breaking current	1016～1040 A
Arc time	31.4～60.5 ms
Degree of opening	5.1～8.8%
The number of times	100 times
Result	Good

conditions for busbar loop current switching. Fig. 7 shows the test circuit, and Table 3 shows the test results.

5 Postscript

For SPPG, we developed a 24 kV C-GIS that meets the requirements for a double-busbar configuration while reducing panel width and improving operability. The first unit of this equipment was delivered.

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

《Reference》

(1) Mitsuaki Serizawa and Yusuke Matsuzawa, "Series Development of 24 kV Cubicle-Type Gas-Insulated Switchgear (C-GIS)", Meiden Jiho No.372, 2021/No.3, pp.22-26