Serialization of Standard Gas Insulated Switchgear

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OVERVIEW: To survive in the competitive electric industry, Hitachi needed to manufacture substation equipment efficiently by avoiding waste and developing more compact and reliable equipment. Toward this goal, Hitachi has standardized a new GIS (gas insulated switchgear) and serialized the standard GIS. The important design concept is a fully assembled bay transported directly from the factory. This design makes the equipment more reliable. The modular components, which reduce the number of parts, also have improved the reliability. For more compact components, a new smaller interrupter without a condenser between poles has been developed for CBs (circuit breakers) as a key component of GIS. Smaller DSs (disconnecting switches) were achieved by adopting the three-position DS of the blade and linear systems for a 168-kV or less GIS and for a 245-kV or larger GIS, respectively. Since the enclosures of main buses of all ratings are the three-phase common type, installation volume has definitely been decreased. The average installation volume as a whole is only 50% of the current GIS. A rational series of standard GIS could be brought about by using the same design concept for all rated-voltage classes and only two types of operation mechanisms for the CB; the motor-spring and hydraulic mechanisms.

INTRODUCTION

WITH the deregulation of electricity, the market price of substation equipment is going down rapidly. Also, as the number of substations installed in urban areas is increasing, downsizing of equipment is required more than ever. Since IT (information technology) has been integrated into the substation equipment, reliability of equipment is becoming more important.

30 years have passed since the GIS came to be a major piece of substation equipment. Over that period, GIS has been improved by technological advancements; increasing the interrupting capacity of CB, decreasing the number of breaks per single CB, and not using an air condenser.

The configuration of the GIS comes in several arrangements, such as the single bus, double bus, and ring-bus types. Because the arrangement is determined by a user's specifications, we must create a different design each time.

It is difficult to compete in the global market with the current design manners considering the above conditions. There is an urgent need to establish an effective production method to provide compact and reliable equipment. Therefore, besides reducing the size and weight of the GIS, Hitachi has standardized the GIS and serialized the standardized GIS. Here, the series of the standard GIS is introduced.

CONFIGURATIONS

Design Concepts and Features

Table 1 shows the design concepts of the standard GIS. In order to minimize the installation volume, all enclosures are three-phase common type for a 204-kV or less GIS, and only main bus enclosures are three-phase common for a 220-kV or larger GIS. Parts applicable to indoor and outdoor uses have been designed. For outdoor use, liquid packing is injected into the flanges of main circuits to keep the environmental resistance high.

Improvements of reliability of assembly and installation works are achieved by assembling one bay each and transporting it as a fully assembled GIS. Insulating spacers are vertically arranged so as to not be affected by particles so that insulation reliability increases.

Modular Components

Thanks to the following modular components which have decreased the number of parts, the reliability of the GIS has increased and the GIS has become smaller.

TABLE 1. Design Concepts of Standard GIS
GIS could be standardized and serialized by applying the same design concepts to all rated voltage classes.

GIS	(1) Reliability is improved by reducing the number of parts and the size and weight of the GIS. (2) The same modular components are applicable to every configuration. (3) Transportable structure as a fully assembled GIS (4) CTs are arranged at both sides of GCB. (5) Insulating spacers are arranged vertically. (6) Applicable for both of outdoor and indoor uses
GCB	(1) No condenser between poles (2) Three-phase common type motor-spring operated system for up to 245-kV GCB, and single-phase hydraulic operated system for 300-kV or larger.
DS/GS	(1) Three-phase common buses are standard. But, isolated-phase buses are also available without changing the structure of GIS. (2) Motor-spring operation system for high-speed grounding switch for line
Main bus	(1) Three-phase common buses are standard. But, isolated-phase buses are also available without changing the structure of the GIS. (2) A bellows is provided at each bay.

GCB: gas circuit breaker
DS/GS: disconnecting switch/grounding switch

Gas-circuit breaker

(1) 72-kV–204-kV GCB with three-phase common enclosures is motor-spring-operated. 245-kV GCB with isolated-phase enclosures is of the motor-spring type. 300-kV–420-kV GCB with isolated-phase enclosures is of the hydraulic type. For a 168 kV– 245 kV GCB, it is applicable to either single-phase or three-phase common operation (see Table 2).

(2) No condenser is provided between poles. In addition, a new smaller interrupter has been developed to achieve a compact GCB.

(3) CTs (current transformers) are provided at both sides of the GCB as the standard structure. However, specifications that call for a CT at only one side are also supported.

Main buses

(1) Main buses are arranged at the upper location. A bellows is provided at each bay so that each bus can be removed independently. Each feeder can be removed from the GIS independently, too.

(2) Though three-phase common buses are the standard, isolated-phase buses are also available without any change to the major configurations.

Disconnecting switches/grounding switches

(1) Size and weight reductions were accomplished by using three-position switch blade systems for 168/204 kV or less three-phase common-type GIS and linear systems for 220 kV or larger isolated-phase type.

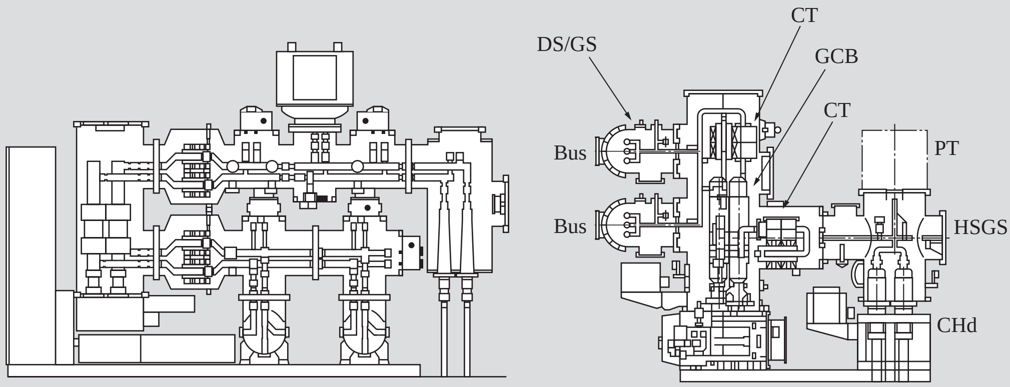
(2) Operating mechanisms are fully automated. Adoption of plated printed control circuits makes wiring unnecessary.

Lightning arresters

LAs (lightning arresters) have been made compact owing to the use of zinc oxide elements having high-pressure resistance. Reduction of insulation level has made it possible to reinforce the insulation coordination.

TABLE 2. Serialization of GCB for Standard GIS
Limiting CB operation systems to only two kinds, motor-spring and new type hydraulic operations, has made it possible to standardize and serialize.

Rated voltage (kV)	Interrupting current (kA)					GIS configuration
	25	31.5	40	50	63	
72 – 84	Motor-spring operation			–	–	All three-phase common type
100 – 145	Motor-spring operation			–	–	
168 – 204	Motor-spring operation (single- or three-phase common operation)				–	
220 – 245	Motor-spring operation (single- or three-phase common operation)					Isolated-phase type with three-phase common main buses
300 – 362	New type hydraulic operation (one-break, no condenser between poles)					
420	New type hydraulic operation (one-break, no condenser between poles)					
550	New type hydraulic operation (two-break)					



(a) Current model (b) New model

HSGS: high-speed grounding switch CHd: cable head PT: potential transformer

Fig. 1—Structure Comparison between New 145-kV GIS and Current Model.
Enclosures for new standard GIS are decreased in size compared with the current model. Vertical arrangement of insulating spacers makes the GIS more reliable.

TABLE 3. Reduction Ratio of Installation Volume
New standard GIS can drastically reduce installation volume in comparison with the current models.

Rated voltage	Reduction ratio of installation volume (ratio of current to new models)
110 –145 kV	26%
168 –204 kV	33%
220 –245 kV	25%
362 kV	44%
420 kV	40%
550 kV	50%

Cable heads

Compact connectors of the plug-in type are used for 2,000 mm^2 or less cable heads for the 72-kV–168-kV class, regardless of the International Electrotechnical Commission (IEC) standards.

STRUCTURES

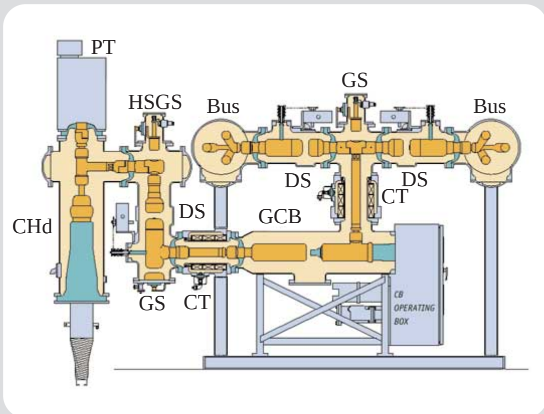
New and Current Structures

Fig. 1 shows a structural comparison between the new 145-kV GIS and the current one. Table 3 indicates the reduction ratio of the installation volume for each rating class. The installation volume of the new standard GIS has been reduced to at least 50% of the current model.

Structures

Fig. 2 shows an example of the appearance and the internal structure. The structure has been designed so

(a) External appearance



(b) Internal structure

Fig. 2—External Appearance and Internal Structure of Standard 245-kV 50-kA GIS.
Installation volume is reduced by using three-phase common main buses.

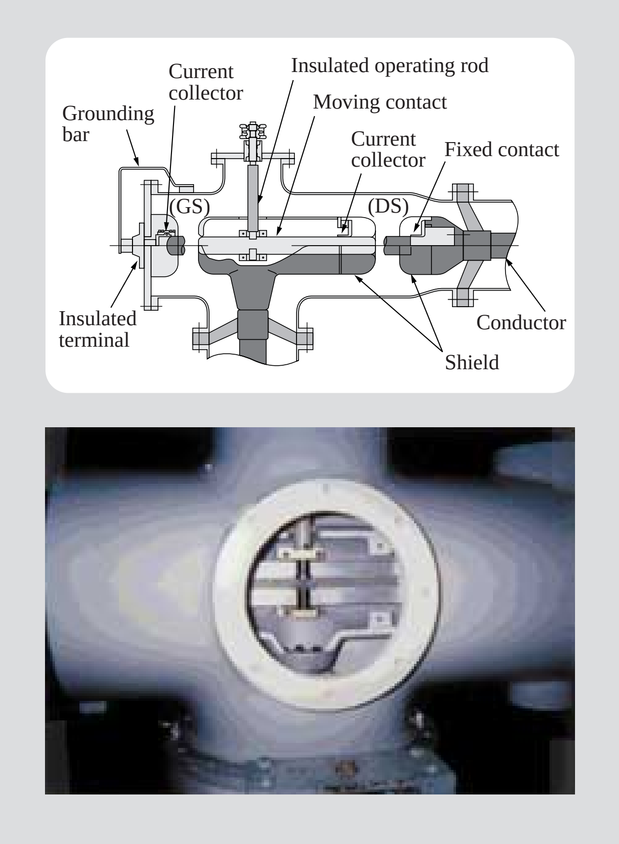


Fig. 3—Three-position DS/GS Structure.
A moving contact is used for DS and GS in common and driven by gear mechanism. Driving force is transmitted between phases by using chains.

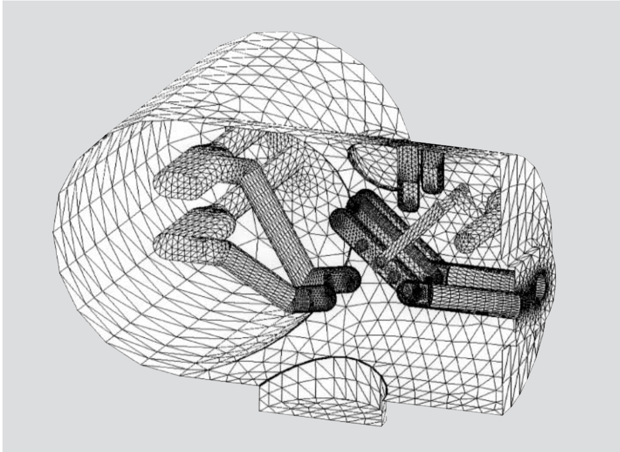


Fig. 4—Analytic Electric Field of 168-kV Bus DS.
3D electric field analytic result, which was performed based on 3D CAD data, is shown. Moving contact is three-position type of blade system. All electric field values at each point are under the design tolerance.

as to transport each bay as a fully assembled GIS to the site.

Since a moving contact for DS (disconnecting switch) and GS (grounding switch) is in common use, the GS cannot close without opening the DS (see Fig. 3). A mechanical interlock is therefore formed. Reduction of the number of parts has resulted in the devices being smaller and lighter.

DESIGN TECHNIQUES

Use of Three-dimensional Data

To design the standard GIS, CAD (computer-aided design) techniques were used positively. The CAD logically makes it possible to check the practicability of assembling/disassembling parts and the reliability of equipment.

For the maintainability of equipment, it is also possible to verify operability and workability with using CAD. We have manufactured an actual sample, and our design techniques have been found to be useful.

Application of Accurate Analyses

The optimum structure of each device has been determined by doing 3D (three-dimensional) analyses of the electric field, mechanism, and structure, linking to the 3D CAD data. Evaluation of the design configurations determined by analyses has been verified with a real-scale model and these configurations have been applied to actual devices.

Fig. 4 shows an example of 3D electric field analysis. This analysis has calculated electric fields in pole-to-pole, pole-to-ground and phase-to-phase with the bus DS open. The results of analysis were evaluated by area survey and it was proved that every point in the electric field was lower than the design tolerance.

Verification Results of Design Data

To evaluate the design techniques, a test sample of each rating class was manufactured and compared with the design data. For conductivity, it was found that temperature rise of internal conductors and enclosures were under the tolerance at any point. The rated short-time current could flow without any problem. To evaluate the mechanical strength, seismic analysis was applied to the GIS and the strength of the GIS was found to be sufficient. Similarly, the transportation test verified that all stresses produced during transportation at the fixing points of the internal conductors, bottoms of enclosures and supports were within the allowable range (see Fig. 5).

For the evaluation of the strength of the switchgear, a continuous switching test was applied on each device.

Fig. 5—Transport of GIS.
Transportation tests demonstrated that one fully assembled bay could be transported without any problem.

Fig. 6—Withstand Voltage Test on GIS.
The test confirmed withstand voltage performance at all parts as specified.

The mechanisms could smoothly move and no wear was apparent at the mechanism and internal parts. 20,000 times life tests were carried out on the hydraulic operating mechanisms and the motor-spring operating mechanism for the GCB. 10,000 times continuous switching tests (rated valule: 1,000 times) were performed on the new three-position DS. The strength of the internal and drive mechanisms were satisfactory.

The power frequency withstand tests and the impulse withstand tests applied on equipment of each voltage class showed each piece of equipment satisfied the specified values (see Fig. 6). According to the results of flashover tests, the GIS was found to have 20% or more tolerance against the specified values.

Thus, it was confirmed that the standard GIS developed at this time satisfied all of the specified values.

CONCLUSIONS

Hitachi has developed a new compact and reliable gas insulated switchgear that is serialized based on the configurations, the structures, and the design techniques as mentioned above. From now on, we intend to use low-burden CTs and PTs with digital relays and predictive maintenance devices to build intelligent GIS.

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