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RECENT TECHNOLOGY ON GAS INSULATED SWITCHGEAR

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1 FOREWORD

Gas insulated switchgear (GIS) has many features, such as small and compact size, high reliability, maintenance and inspection labor saving, etc. and its development in the past ten years is amazing. GIS for rated voltage up to 550 kV have been put into practical use and ultra-high-voltage (UHV) substations adopting GIS are planned.

Structurally, GIS have been advanced from single phase enclosed type to three phase common enclosed type up to 204 kV class and three phase common enclosed type for 300 kV is under development. Recently, GIS components have been compounded (e.g. busbar and isolator in one tank) and the cubicle type GIS (C-GIS), also known as the "line batch type", is also being put into service. During this time, reliability has been improved by numerous records of operation and experience and design, production, and test technology. In the past, mainly miniaturization and high reliability were demanded. Currently, in addition to these, high performance GIS that meet the needs of automatization and unmanned operation is demanded.

2 RECENT TECHNOLOGY TREND

Recent GIS technology trends are summarized in *Fig. 1*. The current state of development and future trends of this technology are described below.

2.1 Miniaturization of GIS

2.1.1 Three phase common enclosing

At present, three phase wholy common enclosed GIS up to 204 kV and three phase common enclosed busbar for 500 kV have been put into practical use. (*Fig. 2*) Realization of these is considerably owing to improvement of numerical analysis technology and of production and testing technology.

2.1.2 Compounding

To reduce the size of three phase common enclosed type GIS further, a new type of GIS with compounded components was developed for 72/84 kV class.

(1) Miniaturized type GIS

In 1984, Fuji Electric began development of a miniaturized type GIS (type name SDH) that substantially reduced the size of the conventional GIS by compounding the component devices and has already supplied many units. Its external view is shown in *Fig. 3* and its gas system and internal structure are shown in *Fig. 4* and *Fig. 5* respectively. This GIS consists of a circuit breaker unit, cable connection unit, PT and arrester unit, and bus units, as shown in *Fig. 5*.

The needs for a compact type GIS and the features of the Fuji Electric compact type GIS are shown in *Fig. 6*.

Fig. 1 GIS technology trend

	Needs	Corresponding technology	Current state	Future
Aiming high performance GIS	Miniaturization	Three-phase common enclosing	(1) All components three-phase common enclosing up to 204kV (2) Main bus three-phase enclosing up to 550kV	Expansion up to 300kV class
		Compounding of component	72/84kV only	Expansion to 168/204kV
		Improvement of interrupting performance	300kV one interrupting unit 550kV two interrupting unit	Miniaturization of arc quenching chamber
		Miniaturization of operating mechanism	320kgf/cm² oil hydraulic operating mechanism	Introduction of electronics into control circuit
	Automatic operation Unmanned operation	Improved reliability Improved maintenanceability	Reduction of number of parts, air-less mechanism	
		Preventive maintenance	Sensor development Data transmission and processing system	Overall monitoring Self diagnostic system

Fig. 2 168/204 kV three-phase common enclosed type GIS

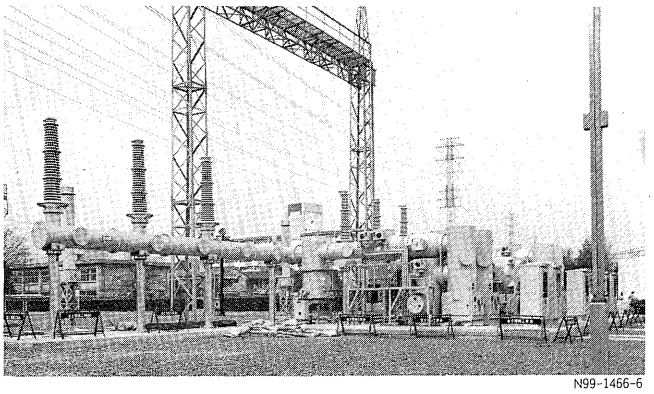

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Fig. 3 Conventional type GIS (background) having the same skeleton as the 72/84 kV compact type (SDH type) GIS (background)

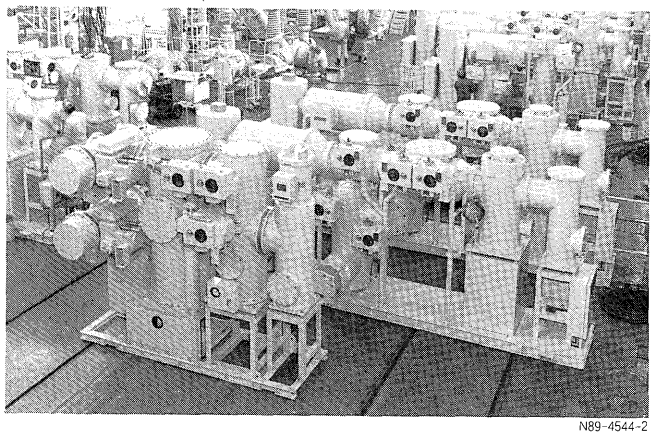

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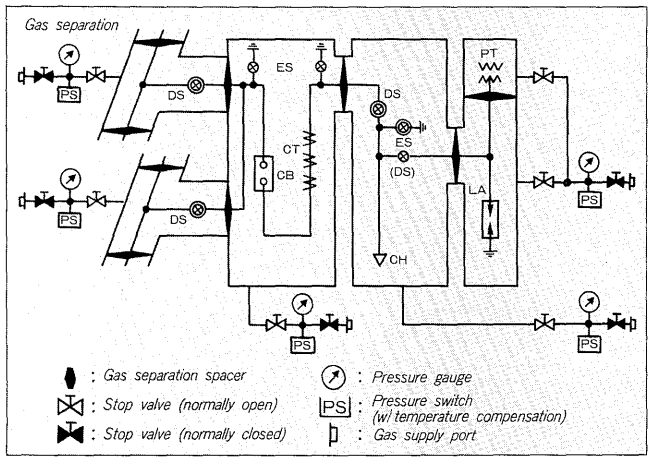
Fig. 4 72/84 kV compact type (SDH type) GIS gas system



Regarding compounding, obtaining the same reliability as conventional GIS, use of a corrugated spacer, suppression of the tank surface electric field and moulded insulator internal electric field, etc. were considered. Moreover, to simplify dealing with a fault, if one should occur, the layout of the bus and other devices was refined and the gas is also separated for each compound unit. The specific procedure for dealing with faults is shown in *Fig. 7.*

The effect of size reduction is shown in *Fig. 8.* GIS technological advances can be read by this. The application of compounding to higher voltage class based on the experience with the 72/84 kV class is forecast for the future.

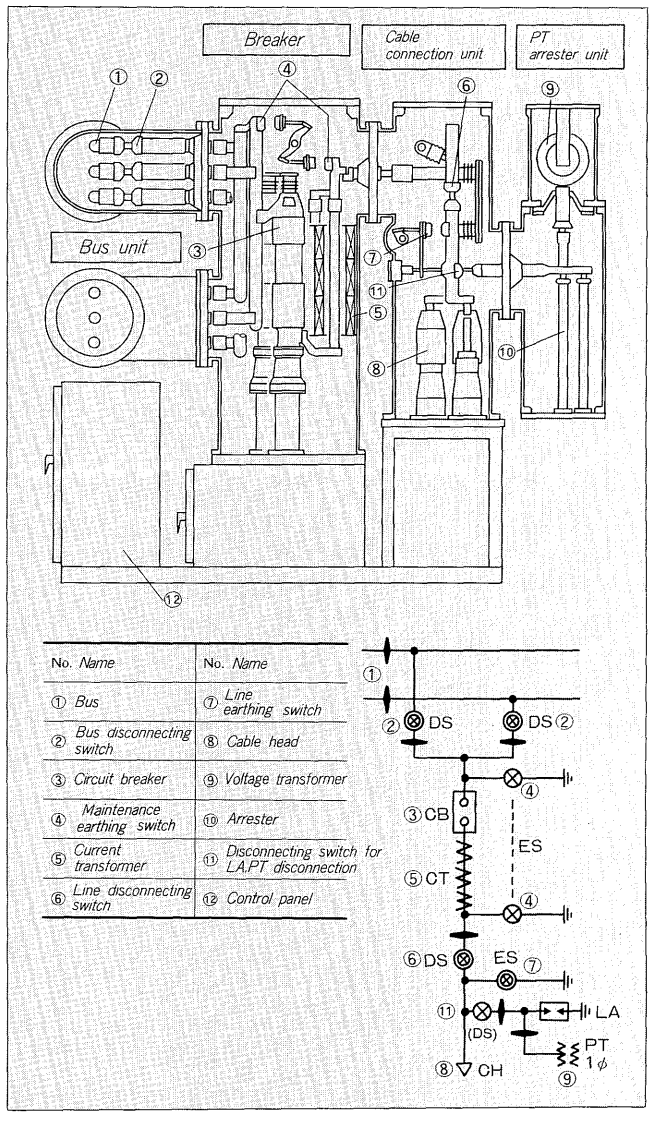
(2) C-GIS

The C-GIS is a line batch type GIS having a different concept than that of the conventional GIS. That is, it houses all the components for one feeder in a container filled with low pressure gas. Its external view is shown in *Fig. 9* and its internal structure is shown in *Fig. 10.*

The needs behind the development of the C-GIS and the features of the Fuji C-GIS are shown in *Fig. 11.*

The C-GIS is mainly used at 84 to 120 kV distribution substations, but some distribution panel styles applicable to

Fig. 5 Internal structure of 72/84 kV miniaturized type GIS (transmission line circuit)



No. Name	No. Name
① Bus	⑦ Line earthing switch
② Bus disconnecting switch	⑧ Cable head
③ Circuit breaker	⑨ Voltage transformer
④ Maintenance earthing switch	⑩ Arrester
⑤ Current transformer	⑪ Disconnecting switch for LA,PT disconnection
⑥ Line disconnecting switch	⑫ Control panel

Fig. 6 Miniaturized type GIS needs and features

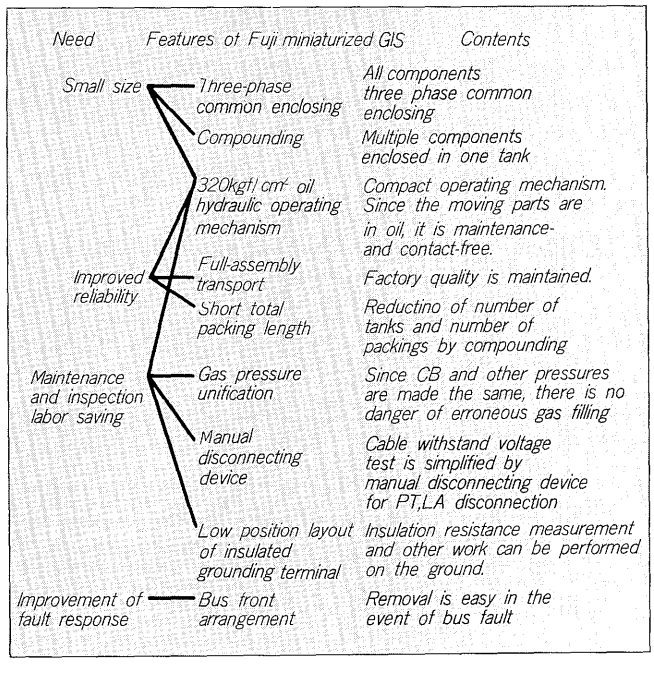
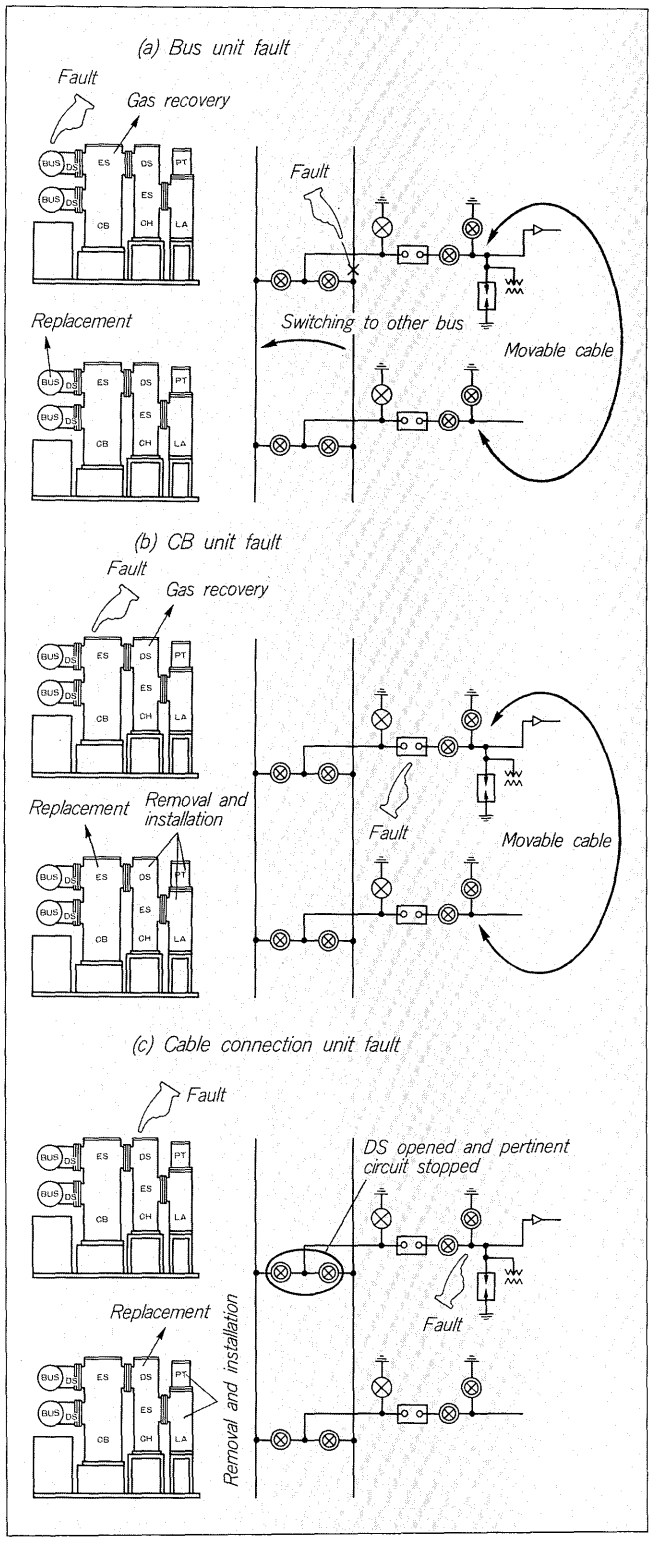


Fig. 7 Dealing procedure when a compact GIS fault occurs



row were also developed. Its external view is shown in *Fig. 12.*

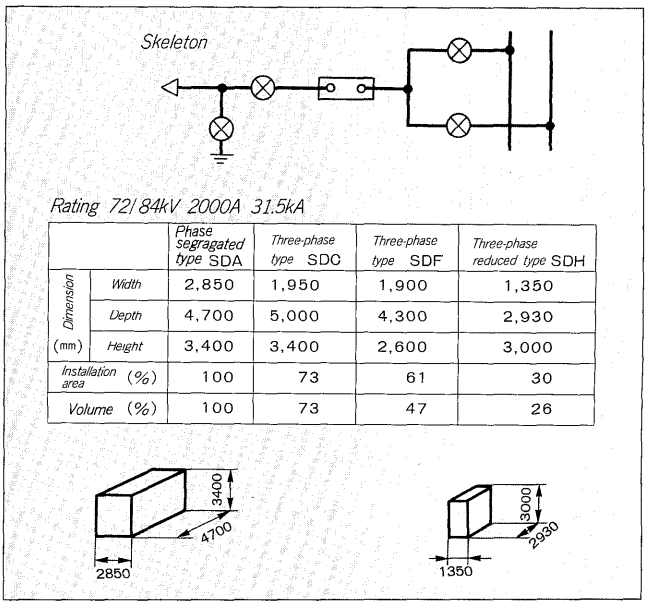
The C-GIS for 120 kV distribution and the row arrangement type C-GIS are described here.

(a) C-GIS for 120 kV distribution

(1) Rated gas pressure

The rated gas pressure of the 84 kV C-GIS is

Fig. 8 Comparison of dimensions of each type of GIS



		Phase segragated type SDA	Three-phase type SDC	Three-phase type SDF	Three-phase reduced type SDH
Dimension (mm)	Width	2,850	1,950	1,900	1,350
	Depth	4,700	5,000	4,300	2,930
	Height	3,400	3,400	2,600	3,000
Installation area (%)		100	73	61	30
Volume (%)		100	73	47	26

Fig. 9 C-GIS for 84 kV distribution

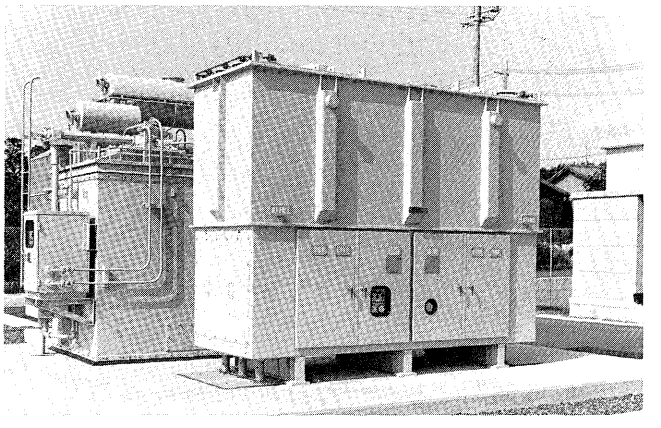


Fig. 10 Internal structure of GIS for 84 kV distribution

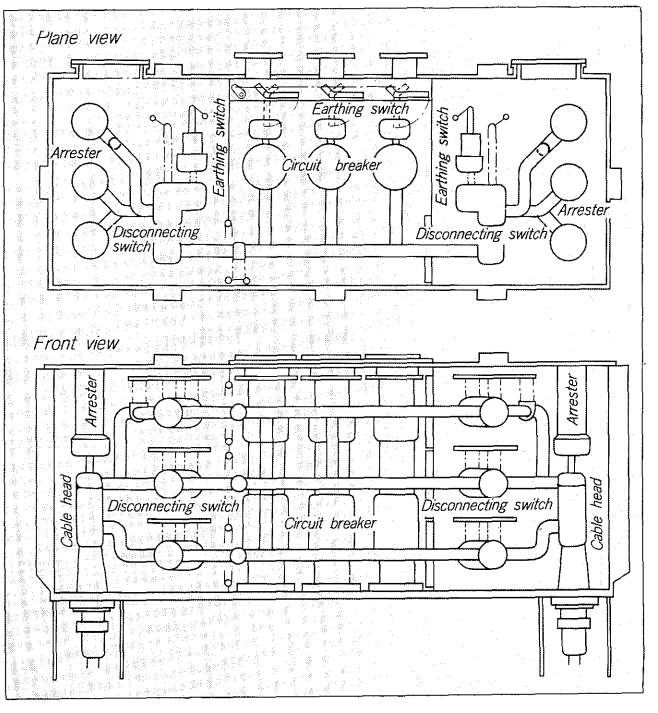


Fig. 11 C-GIS needs and features

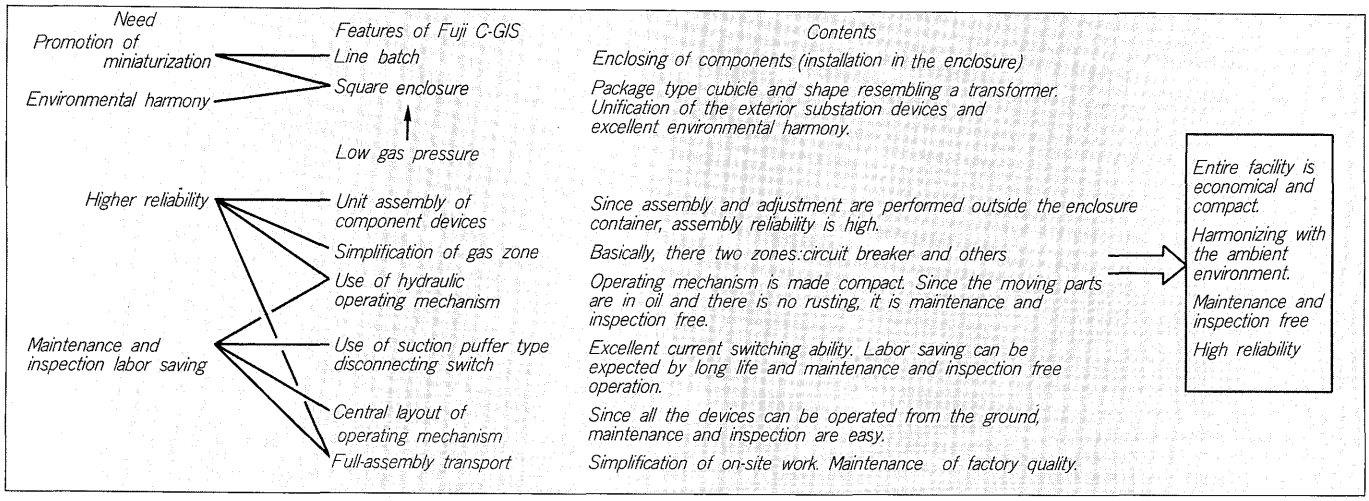
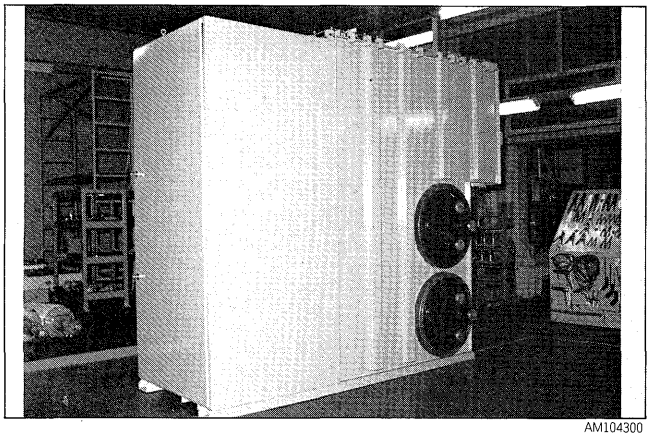


Fig. 12 72 kV row arrangement type C-GIS



0.5 kgf/cm^2. However, in the case of 120 kV C-GIS, the rated gas pressure was raised to 1.3 kgf/cm^2 and the insulation spacer, support insulator, and other parts were made common with the 84 kV C-GIS. That is, since the insulation performance of SF_6 gas is proportional to the 0.8 square of the gas density, the insulation dimensions are made the same as the 84 kV C-GIS and the 84 kV parts can be used by making the rated pressure 1.3 kgf/cm^2.

(2) Circuit breaker

The circuit breaker is 320 kgf/cm^2 oil hydraulic pressure operation separate phase tank type circuit breaker installed vertically and housed in the C-GIS enclosure.

(3) Disconnecting switch and earthing switch

All the disconnecting switches are motor spring operated high-speed type and are capable of switching exciting current and charging current. A suction puffer type is used as the bus section disconnecting switch to provide a loop current switching capability (6000V, 300A). A motor spring operation suction puffer type is also used as the line earthing switch, the same as the bus section disconnecting switch, to provide an induced current switching capability (1500V, 300A). The earthing switches other than for line use are the rotating blade type suitable for the C-GIS and belong to the disconnecting switches and compactly housed.

(4) Testing

Besides the routine test items, temperature rise test and over load test, short-time current test, withstand voltage and internal flash over test, circuit breaker and disconnecting switch continuous switching test, and disconnecting switch and line earthing switch switching capacity test are performed and that all performances are ample is certified.

(b) Row arrangement type C-GIS

Since the C-GIS for 84 and 120 kV distribution have an operation box at the bottom of the square enclosure, when interconnecting units, about 1m of space is necessary between units for operation, inspection, and connection. Since the layout is determined by the distance in the air for over head line connection and by the dimensions of the transformer for direct connection with a transformer and a space of 1m or more is inevitably possible between units, the conventional C-GIS is applied in such cases. However, building of a substation with many feeders and in which lead in and feed out are mainly performed by cable is difficult. The row arrangement C-GIS of *Fig. 12* is applicable in such cases.

This row arrangement type C-GIS has a switchboard construction in which the control room is at the front and the gas enclosure is at the rear and the operating mechanisms and control devices and housed in the control room at the front in a batch. The rear gas enclosure is separated into a line chamber and two bus chambers to prevent the spread of internal faults. Since bus connection between units is performed by opening a handhole at the back of the bus chamber, a connection and inspection space is unnecessary between units and multiple units can be connected at a width of 1.3 m/panel.

2.1.3 Miniaturization of hydraulic operating mechanism

In the past, Fuji Electric uses a 200 kgf/cm^2 operating

mechanism as the circuit breaker operating mechanism, but has developed a new 320 kgf/cm^2 hydraulic operating mechanism. Its external view is shown in *Fig. 13*. The size of this operating mechanism has been made considerably smaller than the conventional type and the number of parts has also been reduced substantially. That is, compared to the conventional type,

volume	50%	50%
weight and number of parts	60%	60%
seals	50%	50%

and it contributes to miniaturization of the circuit breaker

Fig. 13 320 kgf/cm^2 hydraulic operating mechanism

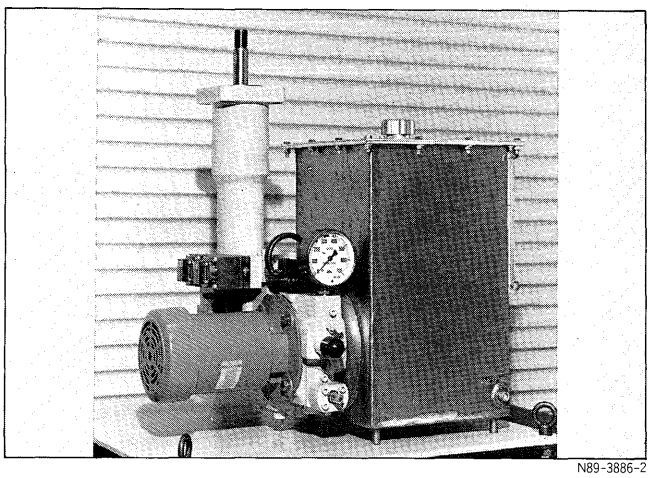


Fig. 14 GIS forecast maintenance

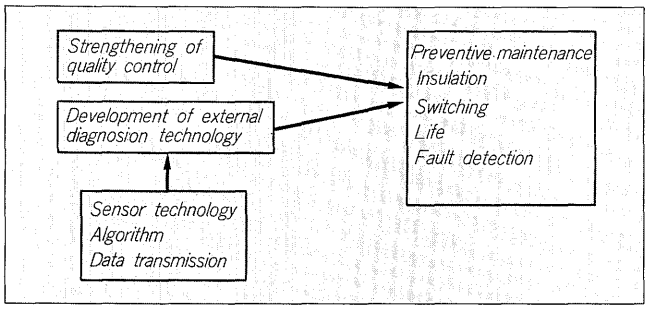


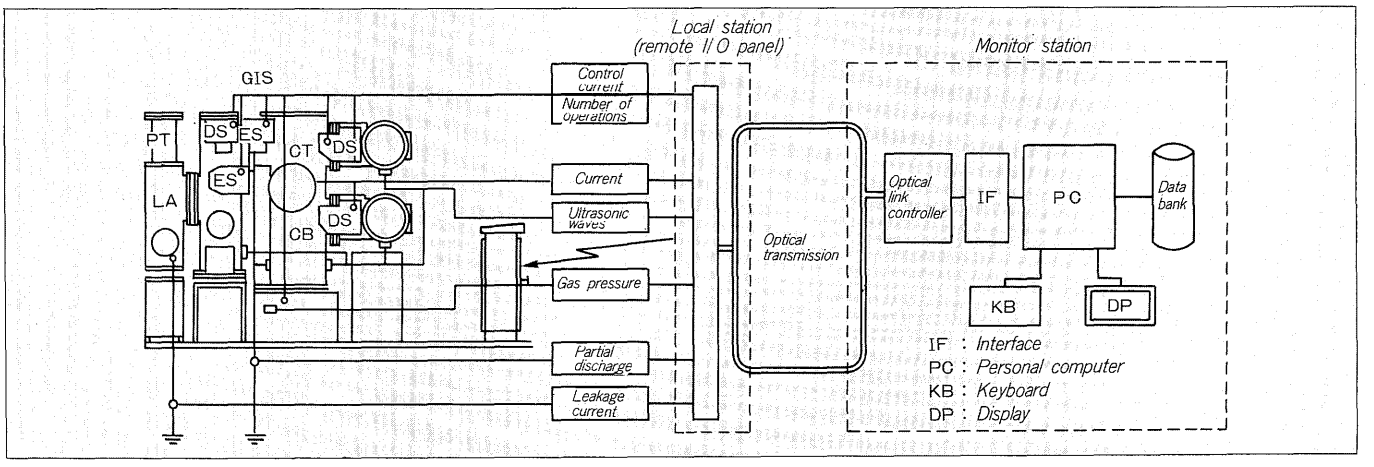
Table 1 C-GIS application range

Rated voltage (kV)	72, 84	120
Rated current (A)	800, 1,200, 2,000	
Rated short-time current (kA)	20, 25, 31.5	
Rated gas pressure (kgf/cm^2)	0.5	1.3
Application examples	Power distribution Power receiving Secondary substation Mobile substation Power generation barge	

Table 2 GIS external diagnosis and preventive maintenance technology

Monitored item	Event	Diagnosis method example
Insulation performance	Internal partial discharge	Insulation spacer method Electromagnetic coupling method Vibration detection method Gas checker
	Low gas density	Pressure gauge Density switch
	Metal particle generation	Ultrasonic microphone method
	Increase of water in gas	Moisture gauge
Current carrying performance	Increased contact resistance	Voltage drop method
	Local overheating	Infra-red image device Acceleration sensor
Switching characteristic	Abnormal switching time	Switching time sensor
	Abnormal stroke	Stroke measuring device
	Change of operation and control current	Current detector
Deterioration of arrester element	Increased leakage current	Current detector
Internal state	Deformation, looseness	X-ray

Fig. 15 Concept of high performance GIS



and entire GIS. This new type hydraulic operating mechanism is also used in the tank type circuit breakers and more then 1000 units have already been delivered.

2.2 GIS automation and unmanned operation

Automation and unmanned operation, one more pillar of the high performance GIS, are realized by application of a GIS diagnostic function and preventive maintenance system and optoelectronics.

An example of the external diagnosis and preventive maintenance technologies currently developed is shown in *Table 2*. When these technologies are combined with data transmission, processing, and decision technology, a high performance GIS with a decision function is possible and automatic operation and unmanned operation are realized. Its concept is shown in *Fig. 15*.

3 CONCLUSION

Recent technology was described about miniaturization of the GIS.

Future topics are:

(1) Promotion of miniaturization and improvement of handling ease
(2) Development and establishment of preventive maintenance technology
(3) Further pursuit of maintenance-and inspection-free operation

The most important thing in tackling these and developing GIS technology is improved reliability and we will continue to advance for this purpose. The guidance of all users is solicited.

TOPICS

ISA'86

The ISA'86 (Instrument Society of America 1986) was held from October 13 to 16, 1986 in the Astrohall, Houston, Texas. In this most authoritative exhibition of instrumentation in the U.S.A., 645 firms from all over the world participated.

Fuji Electric exhibited at a center booth on the main hall a Fiber Optic Field Instrumentation System (FFI), Compact Controller-S (single loop controllers), Master Controllers (FFI multi-loop controllers), and an example of the application of a personal computer as the operator station for these components. About 3 thousand people out of a total of 25 thousand visitors to the ISA'86 visited the Fuji Electric's booth.

At the ISA'86, the exhibits of Fuji Electric were highly appraised by U.S. users; the FFI and Compact Controller, in particular, were of strong interest to more than 10 major oil and chemical companies in the U.S.A.