Commercialization of 6 kV Solid-Insulated Switchgear (Smart SIS)

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Abstract

The 6 kV switchgear for power companies may be applied (1) for power transmission to the power distribution line from a distribution substation or (2) for circuit breaking in faulty conditions. Often, a solid insulation system is adopted because of its compact design and safety.

For the replacement of equipment used for more than 40 years, we recently developed a new type of Solid-Insulated Switchgear ("Smart SIS" hereafter) where an effective specification design and adoption of digital control systems are implemented. For the Smart SIS, specifications ratings have been lowered for the breaking current, lightning impulse withstand voltage, and the temperature-rise limit at the main circuit contact so that overall mechanisms can be simplified and a general-purpose protection control unit can be accommodated. In addition, various sensors are adopted to grasp the status of equipment performance for saving maintenance labor. The first Smart SIS was delivered in March 2020 and continues to operate well.

1 Preface

The 6 kV switchgears installed in the distribution substations of power companies are applied for (1) power transmission to the power distribution line from distribution substation or (2) for circuit breaking in faulty conditions. For many years, cubicles designed by the air insulation method have been applied. The compact and safe Solid-Insulated Switchgear (SIS) has also been adopted in many cases. As a result, the installation space has been reduced to 47% than that of the Air Insulation Switchgears (AIS).

It has been more than 40 years since the initial SISs were adopted. Due to rust and corrosion in the supporting structure of equipment, renewal of such equipment is necessary.

This paper introduces a new type of 6 kV SIS ("Smart SIS" hereafter) where we applied measures for the structure and adopted and developed effective specifications and digital control systems.

2 Specifications of Smart SIS

Table 1 shows the ratings of the SIS (conventional model) and the Smart SIS. Fig. 1 shows a cross-sectional view of feeder panel as a typical panel of the Smart SIS.

Table 1 Ratings of SIS (Conventional Model) and Smart SIS

The rated breaking current, rated lightning impulse withstand voltage, and the temperature rise limit (silver contact part), are compared and shown here between a conventional SIS and the Smart SIS.

Items	SIS (Conventional model)	Smart SIS
Rated voltage	7.2 kV	
Rated normal current	600 A (Feeder)/2000 A (Busbar)	
Rated breaking current	50 kA, peak 20 kA, 5 cycles	31.5 kA, peak 12.5 kA, 5 cycles
Rated lightning impulse withstand voltage	Main circuit: 60 kV Control circuit: 4.5 kV	Main circuit: 45 kV Control circuit: 4.5 kV
Temperature rise limit (Silver contact part)	65 K	75 K
Control voltage deviation range	Closed circuit: 75～125 V Open circuit: 60～125 V	Closed/open circuit: 85～125 V

3 Features of Smart SIS

Features of the Smart SIS compared with

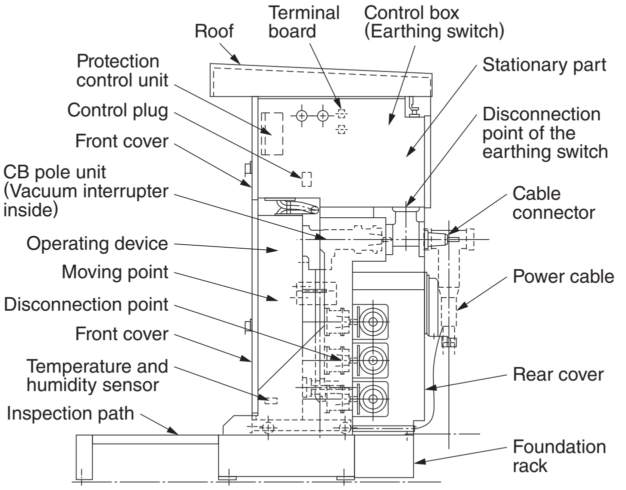


Fig. 1 Cross-Sectional View of Smart SIS (Feeders)

The status monitoring function is realized for the SIS through the implementation of an information communication device, such as a protection control unit, which was not previously installed in conventional model.

those of a conventional SIS are described below.

3.1 Structure Optimization by Effective Design of Specifications

During the development of the Smart SIS, specification ratings were lowered as shown in **Table 1**.

(1) Rated breaking current (20 kV → 12.5 kA)

(2) Rated lightning impulse withstand voltage (Main circuit: 60 kV → 45 kV)

(3) Temperature rise limit at the silver contact part (65 K → 75 K)

As a result of lowering the ratings of the specifications, the circuit breaking distance around the disconnection part is reduced and the main circuit mold case and mechanisms, including the Vacuum Interrupter (VI), were made compact. In addition, the lightning impulse withstand voltage of the control circuit is specified as 4.5 kV conforming to the Japanese Standard of protective relays for electric power applications (JEC-2500). Consequently, a general-purpose protection control unit can be used. As a result, compact protection control units can be dispersedly allocated in various panels other than the house-transformer panel. Such a feature realizes the simplification of equipment configuration, compared with separately installed conventional protective relay panels. **Fig. 2** shows the allocation of a protection control unit.

In the case of verification testing related to the downgraded requirement of the temperature rise limit (65 K → 75 K) for the silver contact part, continuous switching operation was repeated 1000 times under the condition that grease is applied to the disconnector contact point and that 115℃ (75 K + ambient temperature 40℃) is maintained. According to the test result, we confirmed that there is no problem in regard to the temperature rise around the contact point.

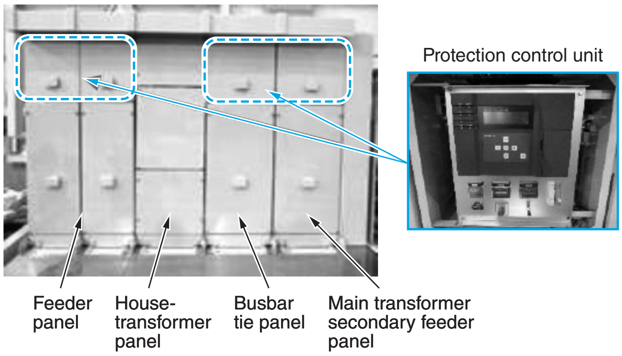
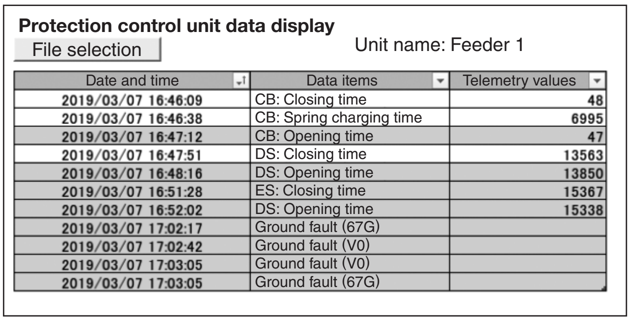


Fig. 2 Allocation of Protection Control Unit

The Protection control units are installed on the top of the main transformer secondary panel, the tie busbar panel and the feeder panels. During operation, these are protected by the front cover from the outside.



Protection control unit data display

File selection

Unit name: Feeder 1

Date and time	Data items	Telemetry values
2019/03/07 16:46:09	CB: Closing time	48
2019/03/07 16:46:38	CB: Spring charging time	6995
2019/03/07 16:47:12	CB: Opening time	47
2019/03/07 16:47:51	DS: Closing time	13563
2019/03/07 16:48:16	DS: Opening time	13850
2019/03/07 16:51:28	ES: Closing time	15367
2019/03/07 16:52:02	DS: Opening time	15338
2019/03/07 17:02:17	Ground fault (67G)	
2019/03/07 17:02:42	Ground fault (V0)	
2019/03/07 17:03:05	Ground fault (V0)	
2019/03/07 17:03:05	Ground fault (67G)	

Fig. 3 Display Screen for Sensing Data Information (Operating Time and Ground Fault Detection)

The sensing data information (date, time, data items, and measured values) can be displayed.

3.2 Equipment Going Smart

Equipment maintenance formerly involved periodic patrol and inspection routines were carried out to examine the status of equipment. In the case of the Smart SIS, however, a protection control unit is installed in each panel. Such technology improves system reliability substantially because equipment status is continually monitored based on telemetry data from each panel. **Fig. 3** shows an example of a display screen for sensing data information (operating time and ground fault detection). The contents of sensing information available from the Smart SIS are as described below.

(1) By measuring the operating time of the Circuit Breaker (CB), the Disconnecting Switch (DS), and the Earthing Switch (ES), it becomes possible to evaluate the performance level of operating mechanisms and identify any lack of grease.

(2) By measuring the zero-phase sequence voltage and current, the intermittent discharges that caused inside the equipment, and the low-level ground faults in the feeder system that caused outside the equipment, can be detected so that the performance level of the insulation can be evaluated for the main circuit.

(3) The performance level (good or bad) of the waterproof gaskets can be evaluated through continuous monitoring with temperature and humidity sensors in the panels.

As described in (2), the Smart SIS is equipped with temperature and humidity sensors with a wireless communication function in each panel (rather than at the substation feeder panel) while around-the-clock measurement is carried out. Due to this feature, the intrusion of water into panels can be sensed to evaluate the performance of waterproof gaskets, which cannot be discovered by conventional monitoring. Fig. 4 shows an example of temperature and humidity measurement data output continued for one week by using a test device simulating the inside of a moving part box (outdoor model).

By virtue of this function, labor-saving maintenance can be realized, and adequate inspection timing can be determined. Still more, since equipment control for the CB, DS, and ES can be managed by software-based interlocking, conventional mechanical interlocks can be reduced to simplify the overall mechanisms.

In addition to a high design freedom in selecting an installation location and reduction of cables, by making the wireless transmission of a temperature and humidity sensor data transmit wirelessly, this facilitates easy maintenance and replacement. By swapping out the vent filter mounted on the front cover to one with a higher ventilation property, the risk of gasket damage due to a sudden pressure change within the box can be reduced.

3.3 Compliance with International Standard Specification: IEC 61850

Fig. 5 shows the Smart SIS network system configuration. For data communication between the Smart SIS and up-stream remote monitoring and control system ("Tele-Control" or "TC" hereafter), a digital transmission system is adopted. It conforms to an International Standard Specification: IEC 61850. A former SIS used multiple control cables for the connection with the TC while the Smart SIS uses only a single optical cable. As a result, it is possible to reduce the amount of time for on-site cabling work and cable connection conformation test. Since IEC 61850 is applied, it is easy to make connections with TCs made by other manufacturers.

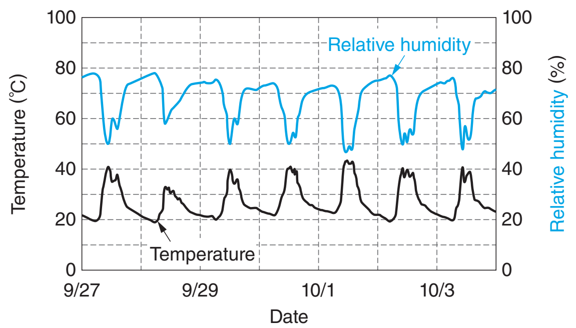


Fig. 4 Example of Temperature and Humidity Measurement Data Output Inside of Moving Part Box

An example of temperature and humidity measurement data output by using a test device simulating the inside of a moving part box is shown. The lower waveform shows temperature changes and the upper waveform shows relative humidity variations.

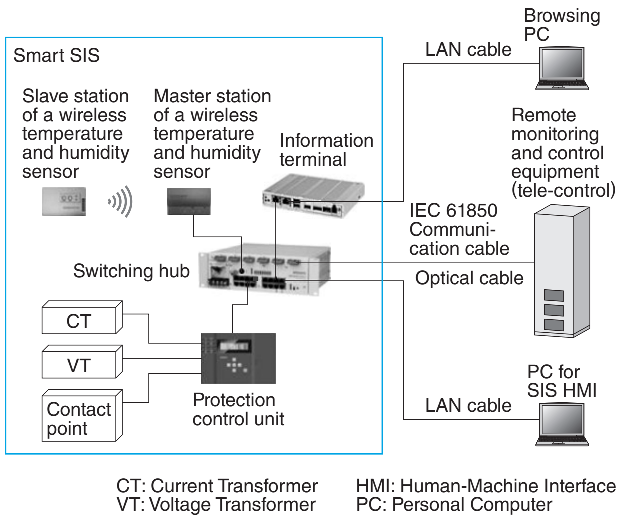


Fig. 5 Smart SIS Network System Configuration

Protection control unit data are saved at the information terminal via the switching hub and simultaneously monitored at the remote monitoring and control system (tele-control). When a PC for HMI is connected to the switching hub, various equipment units can be operated from a PC. Data from a slave station of a temperature and humidity sensor are automatically transmitted to its master station by wireless communication.

4 Postscript

By making an effective design on specifications for ratings, we developed a new type of SIS called the “6 kV Smart SIS”. We realized an optimum structure design and adopted a digital control unit for the equipment. This equipment uses information communication devices such as a protection control unit. By going smart, equipment reliability can improve by monitoring the operating conditions of the SIS. Labor-saving maintenance can also be realized. The first unit of the Smart SIS was delivered in March 2020, and it continues to run well. Currently, we are replacing the installed conventional SISs with Smart SISs, one at a time.