Traction Substation Facilities for the Hokkaido Shinkansen (Between Shin-Aomori and Shin-Hakodate Hokuto) for Japan Railway Construction, Transport and Technology Agency

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Abstract

The Hokkaido Shinkansen started its business for the line between Shin-Aomori and Shin-Hakodate Hokuto on March 26, 2016. This line is scheduled to extend as far as Sapporo in the future.

For this construction project, we supplied traction substation facilities which feed power to trains in service.

The supplied main products include 204kV live tank type Vacuum Circuit-Breakers (VCB) with the world's highest voltage, and also roof-delta connected transformers for ultra-high voltage power network systems, eco-friendly eco-tank type VCBs, and high-voltage withstanding changeover switches. By adopting the VCB, we can expect maintenance labor saving and long operational life.

1 Preface

As part of the total distance of the Hokkaido Shinkansen line between Shin-Aomori and Shin-Hakodate Hokuto (149km), the section of 82.1km already started operation in March 1988 as the line called the "Tsushima Strait Line." At the time of construction of this line, the Shinkansen Standard (including broad gauge) was adopted for this line. Since then, this section has been used for both conventional line (narrow gauge) and Shinkansen (broad gauge) traffic. All sections other than this common section were newly constructed as broad gauge for Shinkansen only.

Fig. 1 shows a traction power feeding system diagram for the Hokkaido Shinkansen. The main contractor for this new section was the Japan Railway Construction, Transport and Technology

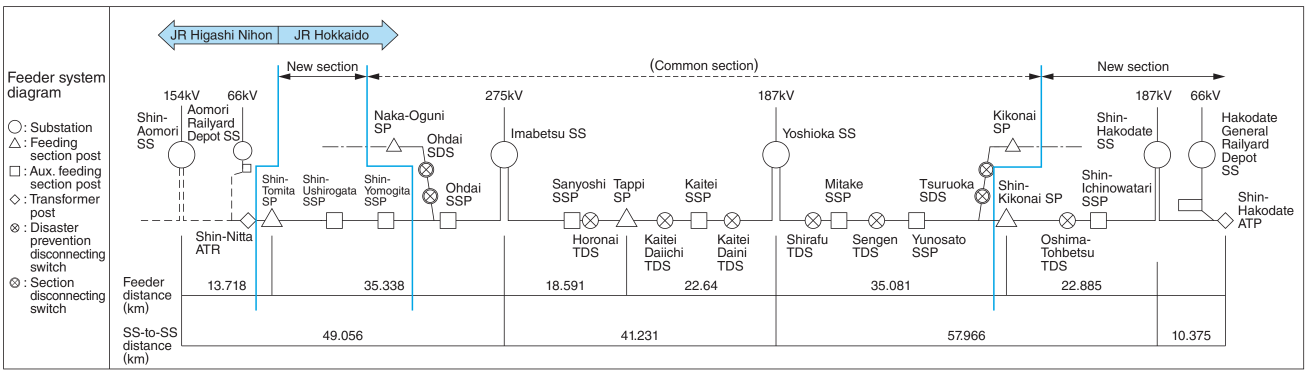

Fig. 1 Traction Power Feeding System Diagram for the Hokkaido Shinkansen

A traction power feeding system diagram is shown for the Hokkaido Shinkansen (between Shin-Aomori and Shin-Hakodate Hokuto).

Agency (JRCTTA) who took on the work. This paper introduces traction substation facilities. We manufactured and supplied these facilities for this project.

2 Traction Power Feeding Equipment

Three posts were delivered. They are Shin-Hakodate Substation (SS), Sin-Kikonai Feeding Section Post (SP), and Shin-Ichinowatari Supplemental Feeding Section Post (SSP).

The Shin-Hakodate Substation receives power from Hokkaido Electric Power Co., Inc., through two circuits at 187kV. At the roof-delta connected transformer, the incoming voltage is stepped down to two circuits at 60kV single-phase. This 60kV single-phase power is transformed into 30kV single-phase at the auto-transformer. The output power is fed to operating trains. As a typical example, equipment delivered to Shin-Hakodate Substation is introduced. Fig. 2 shows the main circuit connection diagram of the Shin-Hakodate Substation.

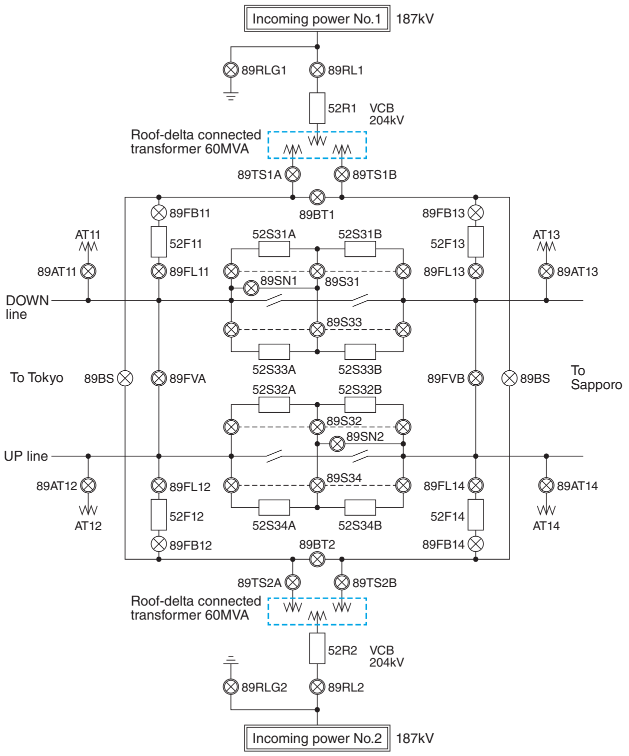

Fig. 2 **Outlined Main Circuit Connection Diagram of the Shin-Hakodate Substation**

A main circuit connection diagram of the Shin-Hakodate Substation is shown. Electric Power is received from Hokkaido Electric Power Co., Inc., through two circuits at ultra-high voltage of 187kV. The received power is stepped down by a roof-delta connected transformer.

2.1 Power Receiving Vacuum Circuit-Breaker (VCB)

A 204kV live tank type VCB was delivered to Shin-Hakodate Substation, which is a world's first product. Table 1 shows the ratings of this VCB and Fig. 3 shows its external appearance. The major features are described below.

(1) High voltage at the point of current interruption

The double-break Vacuum Interrupter (VI) is adopted. In order to maintain a uniform voltage on the source side and ground side at the time of cur-

Table 1 **Ratings of Power Receiving VCB**

Ratings are shown for the Power Receiving VCB delivered to the Shin-Hakodate Substation. We could realize the commercialization of this type of VCB by establishing the double-break current interruption technology.

Item	Ratings
Rated voltage	204kV
Rated current	1200A
Rated breaking current	25kA
Rated breaking time	3 cycles
No. of breaking points	2
Rated gas pressure	0.15Mpa･G
Insulation medium	SF_6 gas (VI for current interruption)
Operating system	Motor-charged spring action
Applicable standard	JEC-2300

Fig. 3 **Power Receiving VCB**

An external appearance of a 204kV VCB is shown. This is the world's first live-tank type VCB applicable to ultra-high system voltages.

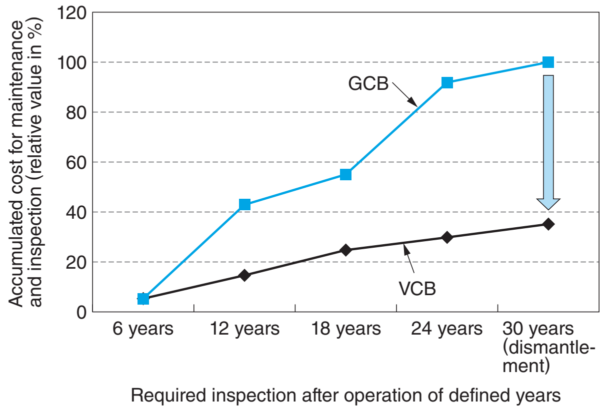

Fig. 4 **Approximate Comparison of LCC between VCB and GCB**

According to the comparison of maintenance cost for 30 years, maintenance cost for VCB is reduced approximately by 50% compared with that for GCB.

rent interruption, voltage sharing capacitors are used for optimization.

(2) High voltage and large capacity for VI

The axial magnetic field system is adopted for the electrode construction. Current breaking performance has been improved and we realized frequent switching performance of 10,000 times. As a result, we expect a long operational life.

(3) Reduction of Life Cycle Cost (LCC)

Compared with Gas insulated Circuit-Breakers (GCB), overhauled inspection of current breaking parts can be omitted through 2000 times of switching. It is also unnecessary to treat decomposed gases at the time of disposal. Such a feature leads to the reduction of LCC.

Compared with the GCB, about 50% of LCC reduction can be expected for the VCB when the equipment is used for 30 years. In other words, the reduction of maintenance cost can be expected. **Fig. 4** shows an approximate comparison of LCC between VCB and GCB.

2.2 Feeder Transformer

A 60MVA roof-delta connected transformer was delivered to Shin-Hakodate Substation. The major features are described below.

(1) Decrease in the number of windings

The transformer is composed of the primary wye-connected winding, the secondary Phase A side roof winding (A), and the Phase B side delta connected winding (Δ). Compared with a modified Woodbridge connected transformer, the number of windings was decreased and we could realize a compact and lightweight design.

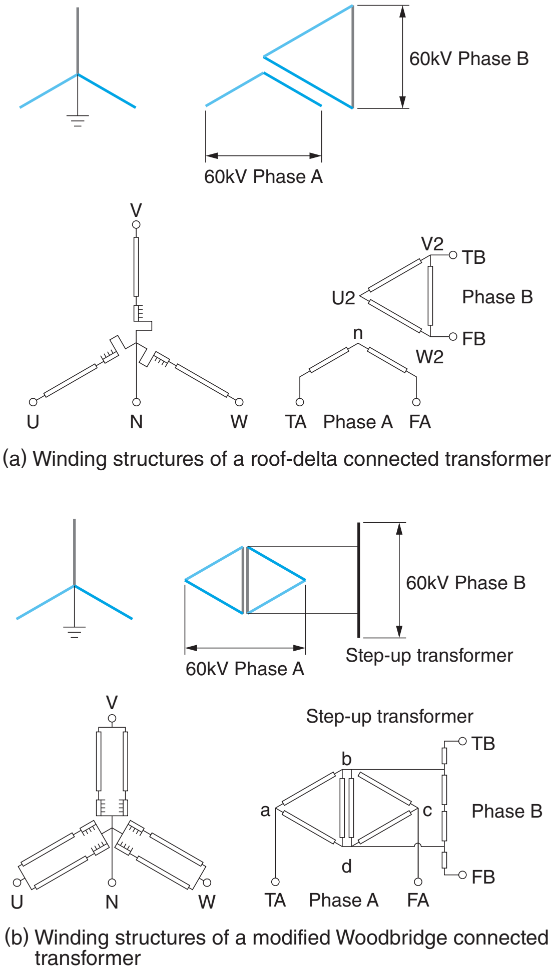

Fig. 5 **Comparison of Feeder Transformer Connections**

Winding connections for a roof-delta connected transformer and a modified Woodbridge connected transformer are shown. Windings can be decreased and no step-up transformer is required. This leads to the reduction of installation space and total mass.

(2) No need for any step-up transformer

For a roof-delta connected transformer, two 60kV circuits can be established only with its main body. Accordingly, it is unnecessary to use any step-up transformer, though it is needed for a modified Woodbridge connected transformer. For this reason, we could expect substantial space saving. **Fig. 5** shows comparison of transformer connections.

(3) Low audible sound level with sound insulation wall

A wall structure of sound insulation is adopted for the Shin-Hakodate Substation. For this reason, no soundproof substation building is needed. As a result, construction work was simplified. **Table 2** shows the ratings and **Fig. 6** shows an external appearance of the roof-delta connected transformer.

Table 2 Ratings of Feeder Transformer

This table shows the ratings of the roof-delta connected transformer delivered to the Shin-Hakodate Substation. Incoming system voltage of 187kV is stepped down to 60kV through two circuits.

Item	Ratings
Cooling system	Oil-immersed self-cooled
Rated capacity	60MVA
Rated primary voltage	187kV
Rated secondary voltage	Phase A: 60kV Phase B: 60kV
Overload capability	300% of the rated current for 2min
Connection system	Roof-delta connection
Others	Radiators installed separately Main body with sound insulation walls
Applicable standard	JEC-2200

Fig. 6 Roof-Delta Connected Transformer

An external appearance of a 60MVA roof-delta connected transformer is shown. Radiators are installed separately to enable installation of sound insulation walls on the transformer main body in order to lower the audible sound level.

Table 3 Ratings of Traction Power Feeding Circuit-Breaker

Ratings of the traction power feeding circuit breaker are as shown below. The mechanical block is insulated by dry air and the current breaking block is of the vacuum insulation. This design concept is intended to reduce SF_6 gas consumption.

Item	Ratings
Rated voltage	36/72kV
Rated current	1200A
Rated breaking current	25kA
Rated breaking time (cycles)	3 cycles
Standard operating duty	Class R
Rated gas pressure	0.5MPa·G
Insulation medium	Dry air
Operating system	Motor-charged spring action
Applicable standard	JEC-2300

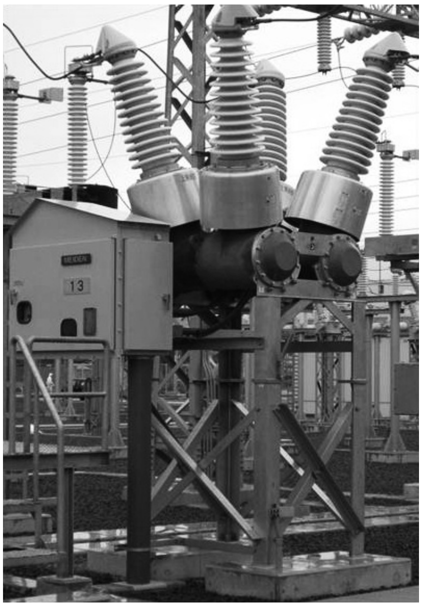

Fig. 7 Eco-Tank Type VCB

An external appearance of 36/72kV eco-tank type VCB is shown. Since an aluminum tank is adopted, no coating is required and we could realize labor reduction for maintenance work.

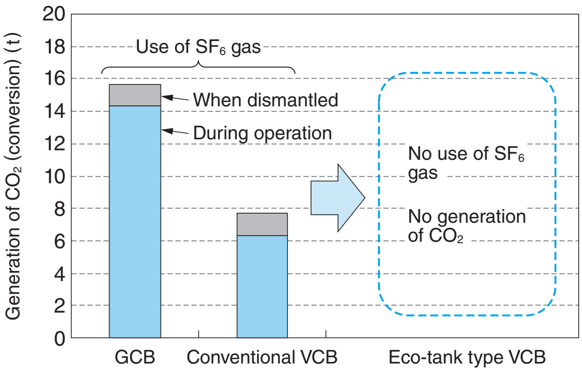

Fig. 8 Amount of CO_2 Gas Generation (Conversion) where SF_6 Gas is used

Since there is no use of SF_6 gas, this equipment contributes to the prevention of climate change. Since the insulation medium can be discharged to the atmosphere, maintenance labor can be reduced.

2.3 Traction Power Feeding Circuit-Breaker

Environment-friendly eco (ecology)-tank type VCBs were supplied. This type of VCB employs dry air for its insulation medium. Table 3 shows the ratings and Fig. 7 shows an external appearance of the eco-tank type VCB. Since no SF_6 gas is used in this VCB, its design concept addresses issues of climate change. Since labor for gas recovery is not needed, no labor for coating and VI maintenance is required. This leads to the reduction of LCC. Fig. 8 shows the amount of CO_2 gas generation (conversion) where SF_6 gas is used.

Table 4 Ratings of Changeover Switch

The ratings of the changeover switch are specified. The electrode gap voltage is generally 42kV. In this case, however, it is 60kV as we achieved a higher withstand voltage.

Item	Ratings
Type	Changeover switch (Spec. for high withstand voltage)
Place of operation	Indoors
No. of poles	Single pole
Application	For changing over
Operating system	Magnetic operation
Rated voltage	36kV
Electrode gap voltage	60kV (High withstand voltage)
Rated frequency	60Hz
Rated current	1200A
Rated closing current	31.5kA
Rated short-time current	12.5kA (2s)
Rated contact parting time	0.05s or less
Pole-gap power frequency withstand voltage	140kV (High withstand voltage)
Line-to-ground power frequency withstand voltage	70kV
Pole-gap impulse withstand voltage	350kV (High withstand voltage)
Line-to-ground impulse withstand voltage	200kV
Operating duty	O-(1s)-C, C-(1s)-O

Fig. 9 Changeover Switch

An external appearance of a 36kV changeover switch is shown. A low operating current type is adopted. Specifications for high withstand voltage are adopted to address the issue of different asynchronous power sources batting.

2.4 Change-Over Switch

Electromagnetic operation type changeover switches of the low operating current system were supplied. The high withstand voltage type is adopted for the Shin-Hakodate and Shin-Kikonai Substations because it is necessary to cope with a potential difference generated as a result of the butting of different power sources at the Hakodate Depot. **Table 4** shows the ratings of changeover switches and **Fig. 9** shows an external appearance of a changeover switch.

2.5 Control Switchgear for Electric Railways

Each post is equipped with integrated functions type control switchgear for railways. **Fig. 10** shows an outlined diagram of a system configuration for the Shin-Hakodate Substation and **Fig. 11** shows the supervisory control panels. The major features of these panels are as follows:

(1) Large-capacity high-speed Programmable Logic Controllers (PLCs) are adopted. It realized the higher speed interactive processing rate. Since the system is made with a redundant design, we aimed to improve system reliability.

(2) Since concentrated next-generation type digital relays are adopted, a high-function and high-performance system has been established. Since equipment is made duplex, reliability has been improved.

(3) Since the Ethernet LAN is used for connections among equipment, we were able to make a system configuration easily even with products by other suppliers.

(4) During the on-site interlocking test, we introduced a simulator unit to effectively reduce the number of Circuit-Breaker (CB) operation times.

(5) Optical cables are adopted for interlinked breaker lines and simplified remote monitor controller lines to lower the noise level and improve reliability.

(6) For the current status display and data logging for daily and monthly report, telemetry units were introduced. As a result, the maintenance routine work and on-site inspection work were streamlined.

(7) The major automatic functions of the switchgear side at each substation are as itemized below.

(a) Auto-changeover of power receiving circuit and the reclosure of power receiving.

(b) Traction power supply reconfiguration, reclo-

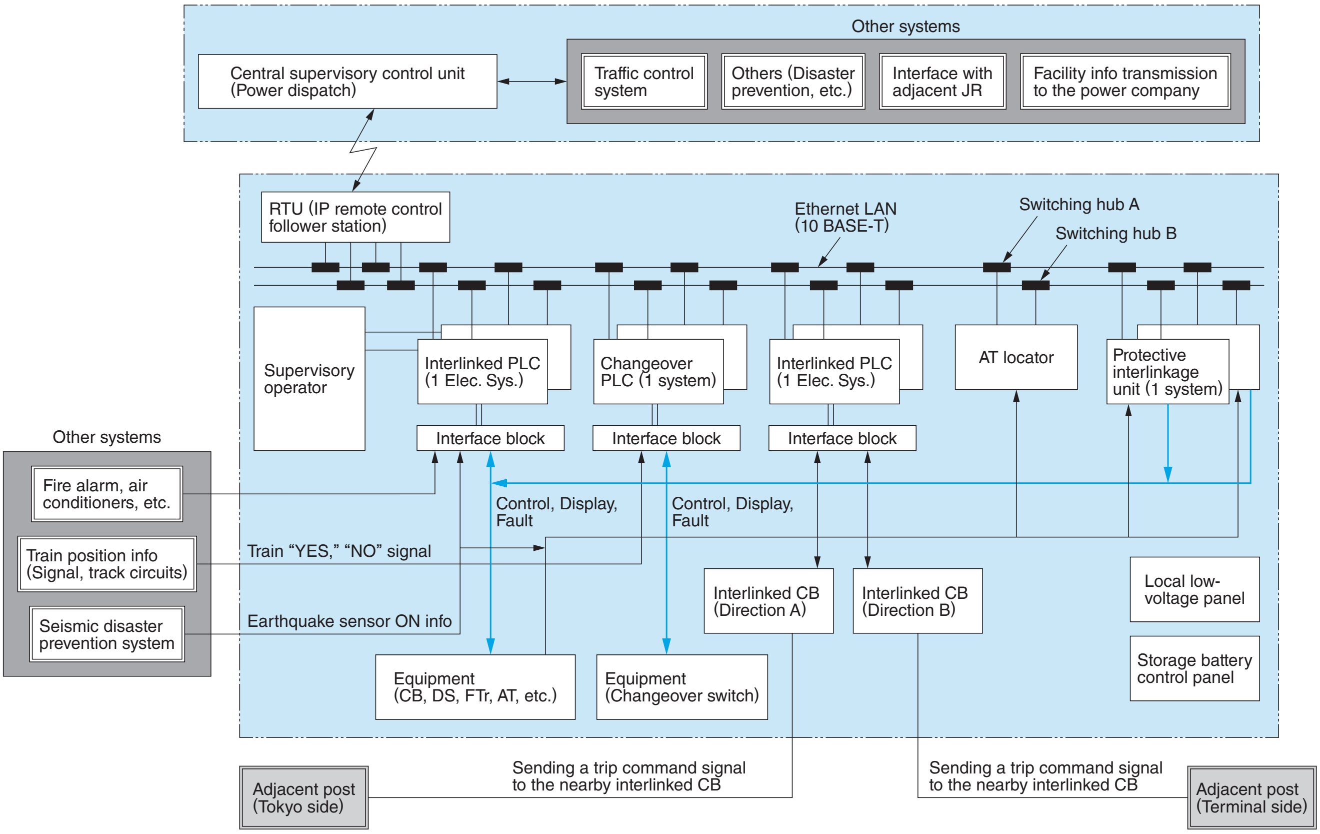

Fig. 10 Outlined Diagram of System Configuration for the Shin-Hakodate Substation

A switchgear system configuration diagram is shown. A functionally classified concentrated duplex configuration is adopted. As a result, large-capacity data processing and high-speed operation have been realized.

Fig. 11 Supervisory Control Panels for Shin-Hakodate Substation

An external appearance of the supervisory control panels for the Shin-Hakodate Substation is shown. In general, switchgears are consisted of operator panels, PLC panels, interlinked protection unit, connection CB unit, locator unit, and telemetry units.

sure of traction power, and automatic feeder opening

(c) Automatic interlinked switching on individual unit and auto-switching of emergency switching units in the case of the main changeover switch failure.

(d) 89AT auto-opening at the time of 63AT occurrence

3 Postscript

It is a source of great pride that we could join this section of the Hokkaido Shinkansen project.

In the future, the Hokkaido Shinkansen is scheduled to extend its line as far as Sapporo.

We expect that our contribution to the Shinkansen assures safety and stability of our supplied various equipment and facilities and that the Hokkaido Shinkansen can be an important key to people's mobility between Tokyo and Hokkaido.

Lastly, we express our deepest gratitude to the project-related people for your valuable suggestions and cooperation during the production, supply and installation of the equipment.