Substation Facilities for Japan Railway Construction, Transport and Technology Agency for Kyushu Shinkansen West Kyushu Route (between Takeo-Onsen and Nagasaki)

Keisuke Morito

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Abstract

Construction work of the West Kyushu route of Kyushu Shinkansen by Kyushu Railway Company (JR Kyushu) is under way between Takeo-Onsen and Nagasaki.

We supplied traction power to substation facilities in this connection to feed traction power to trains. There are eight delivery posts situated in the section between Takeo-Onsen and Nagasaki, Shin-Isahaya Substation (SS), Shin-Ureshino Auxiliary Feeder Section (SSP), Shin-Higashi Sonogi SSP, Shin-Omura SSP, Shin-Funaishi SSP, Shin-Takeo Transformer Post (ATP), Shin-Nagasaki ATP, and Omura Depot SS.

The products supplied are roof-delta connected transformers, environment-friendly eco-dead tank type Vacuum Circuit-Breakers (VCBs), high withstand voltage type changeover switches, and related eco-friendly extra-high tension equipment singular to JR Shinkansen. Since VCBs are adopted, labor saving maintenance and long operational life are expected.

The products supplied are environment-friendly and specialized high-voltage/medium-voltage equipment for the Shinkansen, such as roof-delta connected transformers used for ultra-high voltage systems, eco-friendly eco-dead tank type VCBs, and high-pressure resistant type switchgears for switching. By adopting VCBs, labor saving of maintenance work and longer operational life can be expected.

1 Preface

For the West Kyushu route of the Kyushu Shinkansen, the total distance of the section between Takeo-Onsen and Nagasaki is about 67 km. In March 2008, based on the Provisional Railway Development Plan (by the super-express system), construction work began between Takeo-Onsen and Isahaya. Since then, after receiving the approval of the route to be standard gauge (1435 mm) Shinkansen in June 2012, the successive construction work commenced between Isahaya and Nagasaki. This construction work was carried out under the commissioning entity of the Japan Railway Construction, Transport and Technology Agency ("JRTT" hereafter). After the completion, JRTT will lease the facilities to Kyushu Railway Company (JR Kyushu) which operate the line providing passenger service. The commercial operation of this new railway line is scheduled to start in the fall of 2022. This paper introduces the features of feeder power substation facilities manufactured and supplied.

2 Feeder Facilities

There are eight delivery posts: Shin-Isahaya Substation (SS), Shin-Ureshino Auxiliary Feeder Section (SSP), Shin-Higashi Sonogi SSP, Shin-Omura SSP, Shin-Funaishi SSP, Shin-Takeo Transformer Post (ATP), Shin-Nagasaki ATP, and Omura Depot SS. At the Shin-Isahaya SS, 220 kV incoming power through two circuits is received from Kyushu Electric Power Company, Incorporated ("Kyuden" hereafter). This incoming voltage of 220 kV is stepped down by a 40 MVA roof-delta connected transformer to a 60 kV single-phase two-circuit line. Further, single-phase 60 kV power is transformed into a single-phase 30 kV by an autotransformer. The power of two circuits is respectively fed to the start-point and end-point sides.

At the Omura Depot SS, 66 kV incoming power through two circuits is received from the grid power of Kyuden. This incoming voltage of 66 kV is stepped down by a 15 MVA scalene Scott connected transformer to a 30 kV power line.

Features of the facilities delivered to the Shin-Isahaya SS and the Omura Depot SS are introduced below. **Fig. 1** shows an outline diagram of the main-circuit configuration at the Shin-Isahaya SS.

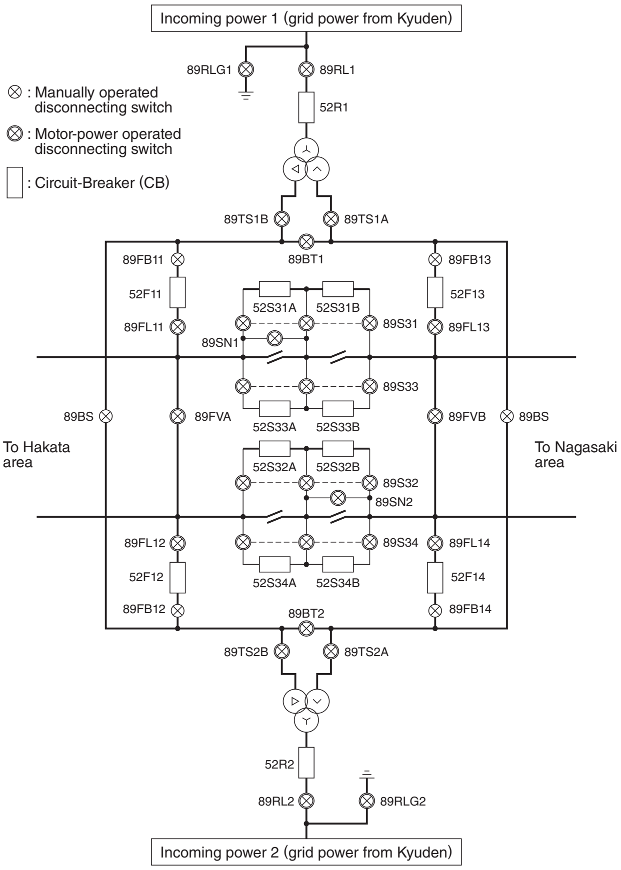


Fig. 1 **Outline Diagram of Main-Circuit Configuration at the Shin-Isahaya SS**

An outline diagram of main-circuit configuration at the Shin-Isahaya SS is shown. A 220 kV power of extra-high-voltage is received through two circuits of grid power from Kyushu Electric Power Company, Incorporated. (Kyuden). The incoming voltage is stepped down by a roof-delta connected transformer.

Fig. 2 shows an outline diagram of the main-circuit configuration at the Omura Depot SS.

2.1 Power Receiving CB

240 kV Gas-Insulated CBs (GCBs) were delivered to the Shin-Isahaya SS. Since GCBs were adopted, downsizing and reduction of equipment mass have been realized. **Table 1** shows the ratings of the installed GCB units.

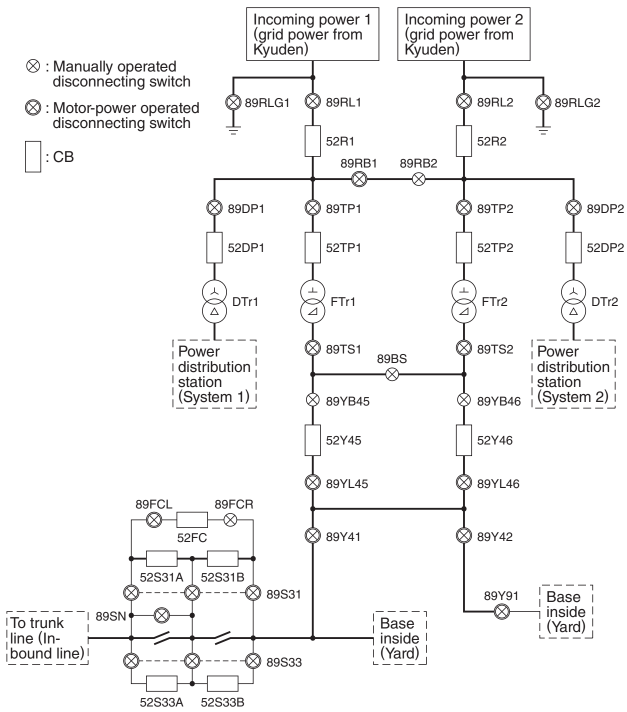


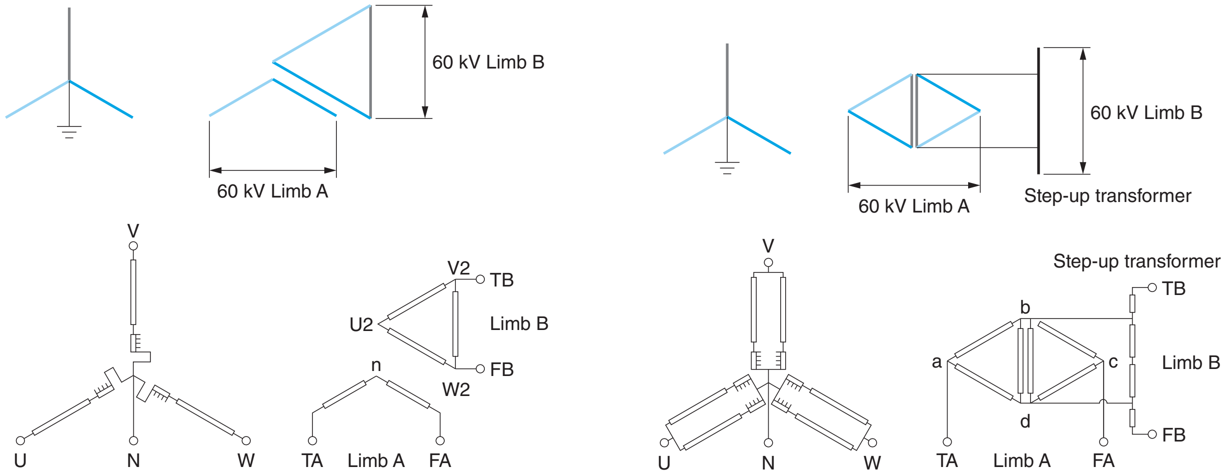
Fig. 2 **Outline Diagram of Main-Circuit Configuration at the Omura Depot SS**

An outline diagram of main-circuit configuration at the Omura Depot SS is shown. A 66 kV power is received through two circuits of grid power from Kyuden. This incoming voltage is stepped down to 33 kV by a scalene Scott connected transformer.

Table 1 **Ratings of Installed GCB Units**

The ratings of the installed GCB units for the Shin-Isahaya SS is shown.

Item	Ratings
Rated voltage	240 kV
Rated current	2000 A
Rated breaking current	31.5 kA
Rated interruption time	2 cycles
Rated gas pressure	0.6 MPa·G
Insulation medium	SF_6 gas
Operation system	Oil-hydraulic operation
Applicable standard	JEC-2300



(a) Winding structure of roof-delta connected transformer

(b) Winding structure of modified wood-bridge connected transformer

Fig. 3 Comparison of Windings for Feeder Transformers

Winding structures of (a) a roof-delta connected transformer and (b) a modified wood-bridge connected transformer are shown. In (b), windings are saved, and any step-up transformer is not required. Such a feature results in a fact that space-saving and mass reduction was realized.

2.2 Feeder Power Transformer

A 40 MVA roof-delta connected transformer was delivered to the Shin Isahaya SS and a 15 MVA scalene Scott connected transformer was delivered to the Omura Rolling Stock Base SS. The major features of the roof-delta connected transformer are as follows.

(1) Reduction of windings

This transformer is composed of Y-connected windings on the primary side, roof-connected windings (A) on the secondary Limb A side, and delta-connected windings (Δ) on the Limb B side. Compared with the modified wood-bridge connected transformer, the number of windings can be reduced to half, thus resulting in compact design and reduced mass.

(2) Omission of step-up transformers

For the roof-delta connected transformer, two 60 kV circuits can be established only with a main winding body. For this reason, no step-up transformer is needed although it is indispensable in the case of the modified wood-bridge connected transformer. Such an advantage results in space saving. Fig. 3 shows a comparison of windings for the feeder transformers.

(3) Low-noise feature with sound insulation walls

Formerly, soundproof buildings were constructed for the purpose of sound insulation for transformers. In this case, however, soundproof facilities were established to lower the noise level by using sound insulation walls for transformers. As a result, construction work was simplified.

Major features of the scalene Scott connected transformer are as follows:

(1) Thanks to the development of analytical technology on the electric field intensity, a compact design was realized.

(2) A surge arrester for Point M was omitted by the thorough insulation of the neutral point.

Table 2 shows the ratings, Fig. 4 shows an external appearance of the roof-delta connected transformer, and Fig. 5 shows an external appearance of the scalene Scott connected transformer.

Table 2 Ratings of Feeder Transformer

Ratings of the roof-delta connected transformer delivered to the Shin Isahaya SS and the scalene Scott connected transformer for the Omura Depot SS are shown.

Item	Ratings	
Connection system	Roof-delta connection	Scalene Scott connection
Cooling system	Oil-immersed self-cooled	Oil-immersed self-cooled
Rated capacity	40 MVA	15 MVA
Rated primary voltage	220 kV	66 kV
Rated secondary voltage	Limb A: 60 kV Limb B: 60 kV	30 kV
Overload durability	300% of rated current: for 2 minutes	
No. of phases	3/2	3/1
Miscellany	Radiator separately installed type with sound insulation walls	Radiator integrated type
Applicable standard	JEC-2200	

Fig. 4 **Roof-Delta Connected Transformer**

An external appearance of the 40 MVA roof-delta connected transformer is shown. Radiators were installed separately from the main body that was installed with sound insulation walls. In this configuration, a feature of low audible sound level is realized.

Fig. 5 **Scalene Scott Connected Transformer**

An external appearance of the 15 MVA scalene Scott connected transformer is shown. The terminal voltage is 66 kV on primary side and 30 kV on secondary side.

Table 3 **Ratings of Feeder CB**

Ratings of the feeder CB are shown. The mechanical section is insulated by dry air and the current interruption chamber is insulated by vacuum. This construction implies that freedom from SF_6 gas has been realized.

Item	Ratings
Rated voltage	Omura Depot SS: 36 kV Shin-Isahaya SS: 72 kV
Rated current	1200 A
Rated breaking current	25 kA
Rated current interruption time	3 cycles
Standard operation duty	Type R
Rated gas pressure	0.5 MPa·G
Insulation medium	Dry air
Operation system	Motor-powered spring system
Applicable standard	JEC-2300

Fig. 6 **Eco-Dead Tank Type VCB**

An external appearance of the 72 kV eco-dead tank type VCB is shown. Since an aluminum tank is used, any kind of coating is not required. As a result, maintenance labor hours can be reduced.

2.3 Feeder CB

Ecology tank type Vacuum Circuit-Breakers (VCBs) were supplied. For this VCB, dry air is adopted for an insulation medium to realize an eco-friendly feature. Since no SF_6 gas is used, such a design policy contributes to the prevention of climate change. In addition, since it is unnecessary to take actions of gas recovery and maintenance of the current interruption chamber, the Life Cycle Cost (LCC) is reduced. Still more, no coating process is needed because the aluminum tank is adopted. Table 3 shows the ratings, Fig. 6 shows an external appearance of the Eco-Dead Tank Type VCB, and Fig. 7 shows the generation of CO_2 (conversion) when using SF_6 gas.

2.4 Changeover Switch

Low-current operation type changeover switches were delivered. These switches are actuated by the magnetic operation system. For the Shin Isahaya

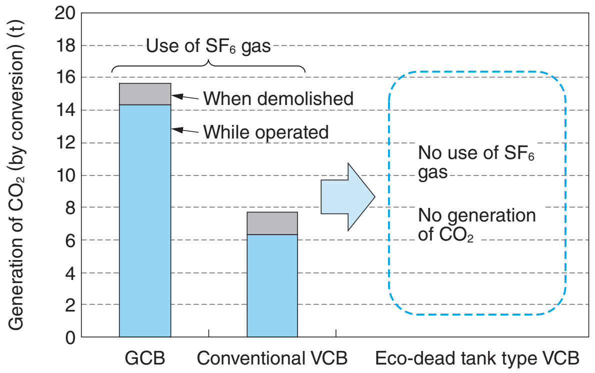


Fig. 7 Generation of CO_2 (Conversion) when Using SF_6 Gas

The adoption of an SF_6 gas-free feature contributes to the prevention of global warming. Since the insulation medium can be discharged to the atmosphere, maintenance work can be relieved.

Table 4 Ratings of Changeover Switch

Ratings of the changeover switch are shown. Although the pole-to-pole insulation voltage is generally 42 kV, this voltage was set at 60 kV for the attainment of high withstand voltage.

Item	Ratings
Type	Changeover switch (high withstand voltage specification)
Place of use	Indoors
No. of poles	Single-pole
Application	For changeover
Operation system	Electromagnetic operation
Rated voltage	36 kV
Pole-to-pole insulation voltage	60 kV (Intensified high withstand voltage)
Rated frequency	60 Hz
Rated current	1200 A
Rated closing current	31.5 kA
Rated sort-time current	12.5 kA (2 s)
Rated opening time	0.05 s or less
Pole-to-pole commercial frequency withstand voltage	140 kV (Intensified high withstand voltage)
Pole-to-ground commercial frequency withstand voltage	70 kV
Pole-to-pole impulse withstand voltage	350 kV (Intensified high withstand voltage)
Pole-to-ground impulse withstand voltage	200 kV
Operation duty	O-(1 s)-C, C-(1 s)-O

SS and Omura Rolling Stock Base SS, the high withstand voltage type is adopted so that it is possible to manage a potential difference caused by a combination of different power sources of these substations. Table 4 shows the ratings of these switches and Fig. 8 shows an external appearance of the changeover switch.

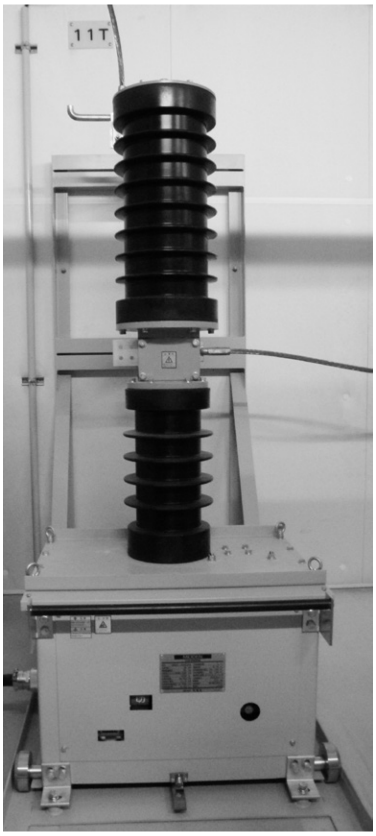


Fig. 8 Changeover Switch

An external appearance of the 36 kV changeover switch is shown. A low operation current type is adopted. In consideration of combination of different power sources, a high level of withstand voltage is specified.

Table 5 Ratings of C-GIS

Ratings of the C-GIS are shown.

Item	Ratings
Installation place	Outdoor
Rated voltage	72 kV
Rated current	1200 A
Rated breaking current	25 kA
Rated interruption time	3 cycles
Standard operation duty	Class A
No. of panels	8 panels
Applicable standard	JEM-1499, JEC-2350

2.5 Gas Insulated Switchgear (GIS)

Regarding the GIS for the Omura Depot SS, the compact design of equipment and maintenance labor-saving were realized. These facilities are essential in maintaining power supplies for the rolling stock base and traction power feeding day and night. These facilities also contribute to the reduction of labor hours for maintenance work. Table 5 shows the ratings of the C-GIS and Fig. 9

shows an external appearance of the 72 kV outdoor type C-GIS.

2.6 Electric Railway Control Switchgears

Electric railway control switchgears are of a multiple-functions-packed-together-type. These were installed at the respective posts. **Fig. 10** shows an outline diagram of the system configuration for the Shin-Isahaya SS and **Fig. 11** shows an external appearance of supervisory control panels installed at the Omura Depot SS. Major features of these switchgears are as described below.

(1) The Programmable Logic Controller (PLC) of the large-capacity and high-speed type is adopted and a ladder sequence system is established for interlinked processing. As a result, high-speed processing is realized. By adopting a duplex system, improvement of reliability is attained.

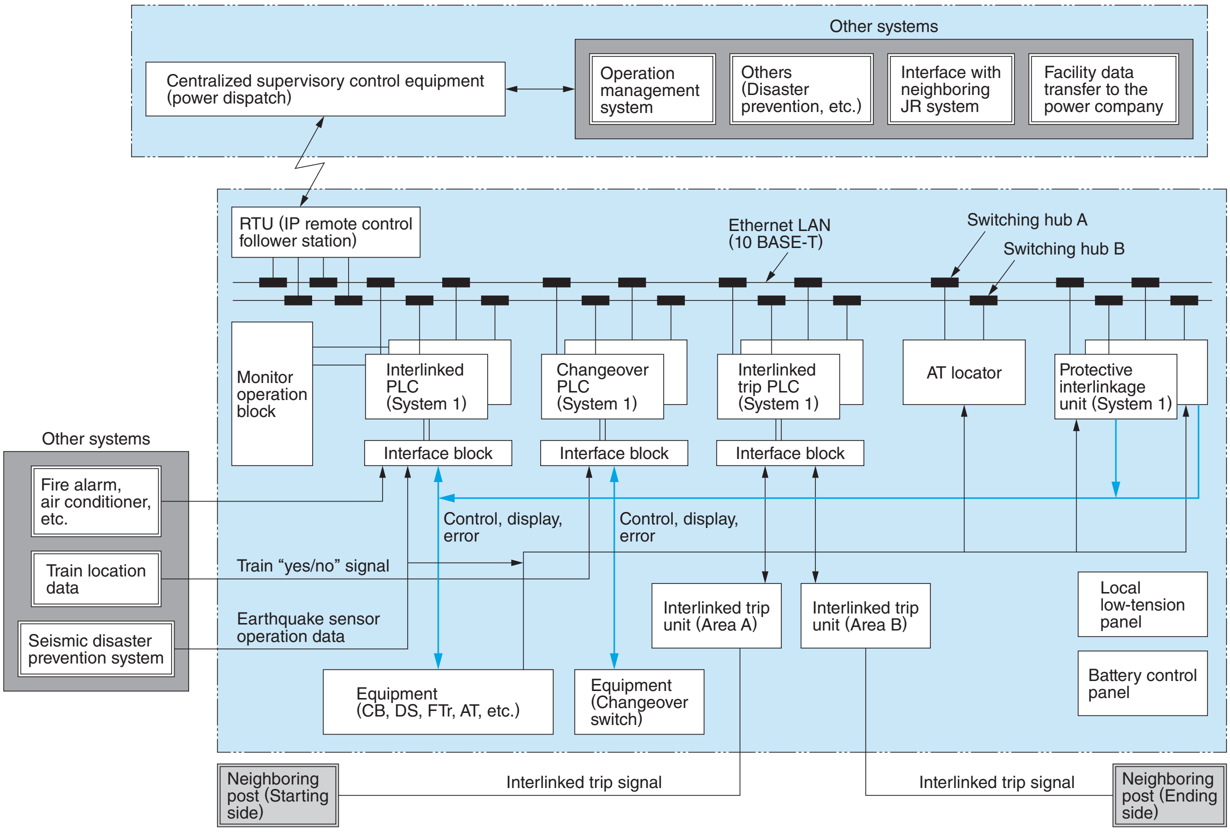
(2) Since centralized next-generation type digital relays are adopted, a high-function and high-performance system was realized. By adopting a duplex system for equipment, the system's reliability was improved.

(3) Since the respective units are combined through Ethernet LAN, system configuration can be established easily for equipment and units including products from different manufacturers.

(4) For the interlinked field testing at the time of new system establishment, a mimic simulator unit was introduced to achieve the reduction of CB oper-

Fig. 9 72 kV Outdoor Type C-GIS

An external appearance of the 72 kV outdoor type C-GIS is shown. The 2VCT type two-circuit power reception system is adopted.



CB: Circuit-Breaker DS: Disconnecting switch FTr: Feeder transformer AT: Auto-transformer

Fig. 10 Outline Diagram of System Configuration for the Shin-Isahaya SS

A configuration diagram of the switchgear system is shown. A centralized duplex configuration system is adopted for the respective functions so that large-capacity and high-speed processing can be carried out.

Fig. 11 **Supervisory Control Panels Installed at the Omura Depot SS.**

An external appearance of supervisory control panels installed at the Omura Depot SS is shown. This panel array consists of operation panels, respective PLC panels, protection interlinkage equipment, interlinked trip unit, locator equipment, and telemetry equipment.

ations and efficient center-interlinkage check.

(5) In order to reduce noise and improve reliability, optical cables are adopted for interrelated current interruption lines and simplified remote control lines.

(6) For maintenance labor saving, live-line insulation monitoring equipment is installed for local low-voltage panels and battery control panels.

(7) Telemetry equipment is introduced. This equipment is provided with functions of current value display and data logging for inspections in addition to data logging for daily and monthly reports. These functions are useful in realizing efficient security routines and on-site testing.

The major automatic functions for the SS switchgear side are as itemized below.

(1) Power intake auto-changeover and incoming power reclosure

(2) Feeder reconstruction, feeder reclosure, and feeder automatic opening

(3) Automatic switching system and automatic switching for a preliminary instrument at the time of changeover switch failure

(4) Auto-release of 89AT in the case of 63AT

3 Postscript

We hope that each of the facilities supplied this time will operate smoothly and these facilities will serve to contribute safe and high-speed operation of the Kyushu Shinkansen. In doing so, we hope this line will be a vital infrastructure for the mobility of people.

Lastly, we would like to express our deep gratitude to all the people concerned this project for your kind guidance and cooperation during every stage of engineering, production and installation of supplied products.