Power Supply System for MRT Link to Taiwan Taoyuan International Airport

Overseas Installation Satisfying Diverse Requirements

The Taiwan Taoyuan International Airport Access MRT System commenced operation on March 2, 2017, the culmination of approximately 11 years of design and construction work. Hitachi's role in the project included responsibility for the system design, equipment manufacture, installation (including of power distribution cables), commissioning, and integration testing of the power supply system. This article provides an overview of the airport MRT system and describes the supplied equipment and systems.

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1. Introduction

The Taiwan Taoyuan International Airport Access Mass Rapid Transit (MRT) System provides access to the airport, running for 51.6 km from Taipei Station via the airport to Huanbei Station in the Zhongli district of Taoyuan City, stopping at 21 stations (15 above ground and 6 underground). The line between Taipei Station and the airport provides a mix of express and commuter services that it is hoped will relieve traffic congestion in the region around Taipei City (see **Figure 1** and **Figure 2**).

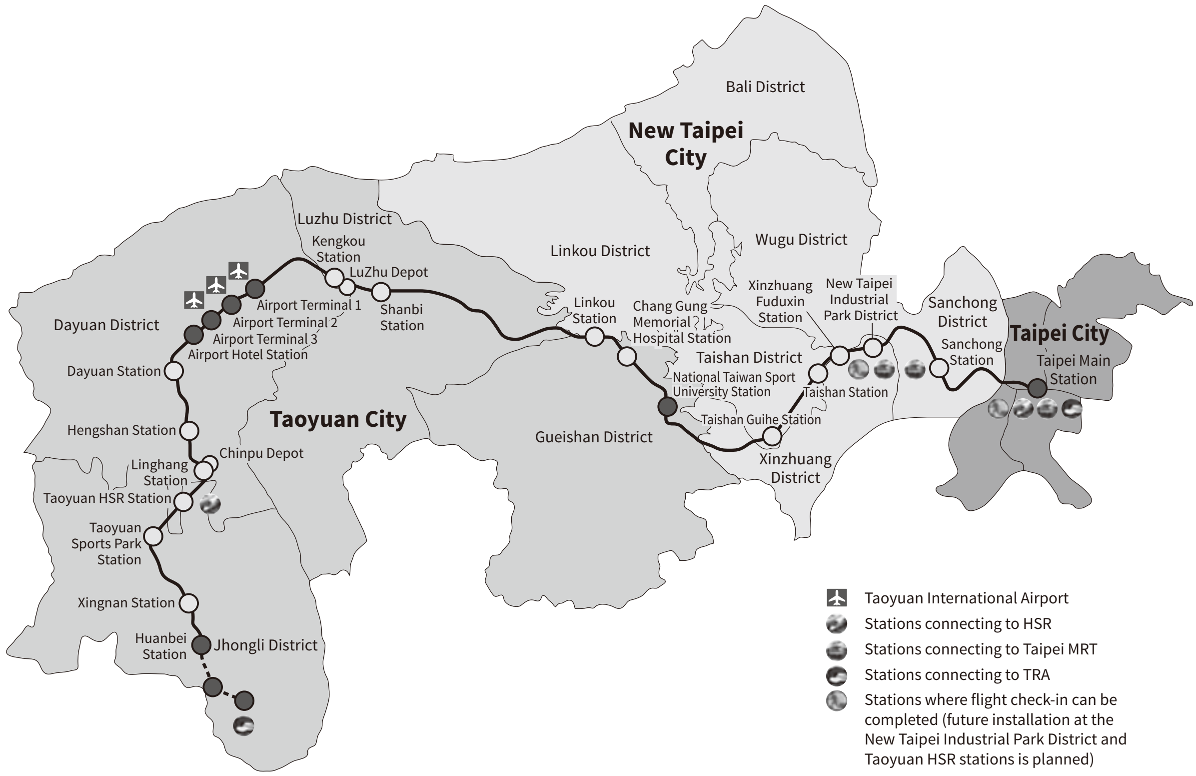
Figure 1 — Train Running on Airport MRT Link
Regenerative inverters were installed at a substation located in the mountainous area where gradients are steep.

Having won the order to supply the power supply system for the project, Hitachi went about its work from the signing of the contract in January 2006 through to the opening of the line in March 2017 with the primary objective of satisfying both the Railway Bureau at the Ministry of Transportation and Communications (formerly the Bureau of High Speed Rail) and the passengers using the airport MRT system by supplying a power supply system with high quality and reliability.

This article provides an overview of the railway line and its power supply system, also describing the high-speed vacuum circuit breakers (HSVCBs) that form a key part of the system and the stray current monitoring system (SCMS) that was developed as part of the project and deployed here for the first time.

Figure 2 — Track Map of Airport MRT System

The line has improved access between the outskirts of Taipei and Taoyuan International Airport.



HSR: high-speed rail MRT: mass rapid transit system TRA: Taiwan Railway Administration

2. Overview of Railway Line

Taiwan Taoyuan International Airport is the main aviation gateway to Taiwan, being used by more than 40 million people each year. The main ways of getting to the airport from Taipei in the past were express buses or taxis. Although Taiwan High Speed Rail (a system based on Japan's Shinkansen) commenced operation in 2007, the need to change trains limited its convenience and this prompted the idea of opening an airport line.

The opening of the MRT link not only significantly improves access to the airport from central Taipei, providing an express service from Taipei Station that takes only about 35 minutes to cover the 39.6 km to the airport, it also helps alleviate rush hour traffic congestion by providing commuter services for workers and students living along the rail corridor.

Moreover, an in-town check-in service is available at the line's terminal station (Taipei Station) that people can use to drop off their luggage and check in up to 3 hours prior to their flight boarding time. The station also has a customs counter for passengers taking advantage of the Taiwan Tax Refund option.

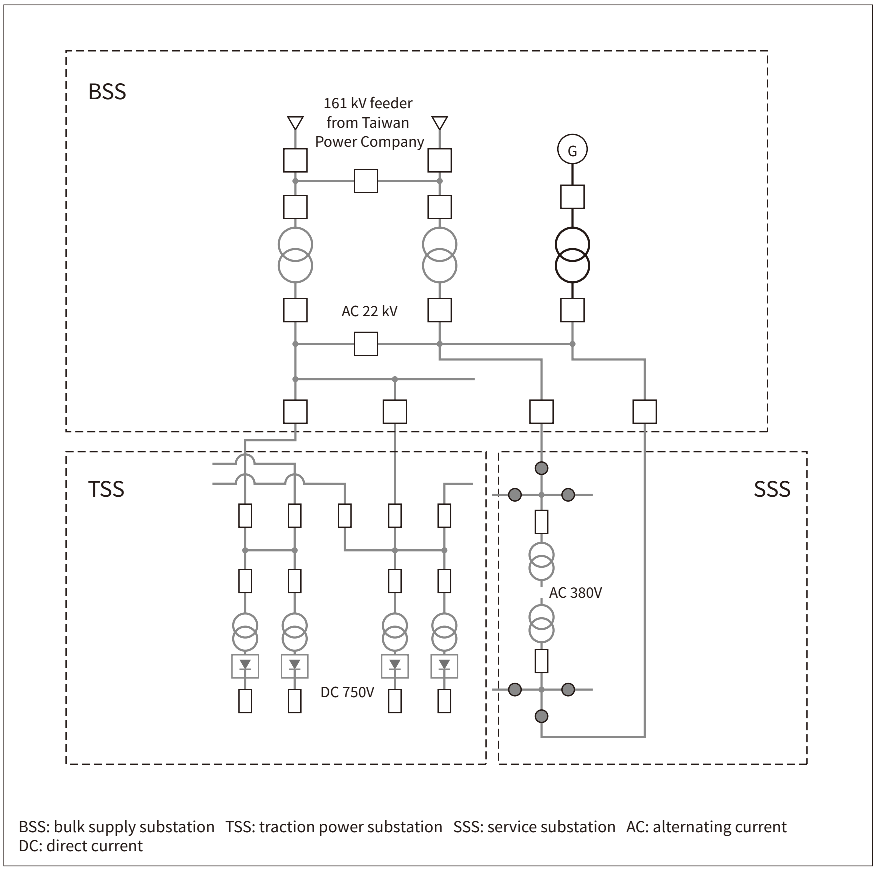
The line is used by commuter services that stop at every station and run all the way to Huanbei Station at the far end of the line, and an express service that runs between Taipei Station and Airport Terminal 2. Free Wi-Fi* is available all along the line.

3. Overview of Power Supply System

Tendering for the project was split between construction work (excluding the depots) and the electrical and mechanical (E&M) systems (including construction of the depots). The construction work was awarded to a Taiwanese contractor and a consortium of three Japanese companies, Hitachi among them, won the contract for the E&M systems.

* Wi-Fi is a registered trademark of Wi-Fi Alliance.

Figure 3 — Diagram of Power Supply System for Airport MRT
Redundancy is used throughout the system to improve reliability.



Hitachi's role covered the system design, equipment manufacture, installation (including of distribution cables), commissioning, and integration testing of the power supply system. As the customer included a stipulation for the local production of equipment, preliminary work on the system produced a configuration that combined products made in Japan with those procured from local suppliers to ensure the best outcome, taking account of factors such as delivery and cost without compromising reliability.

3. 1 BSS

Bulk supply substations (BSSs) are fed from the 161-kV grid of Taiwan Power Company. Because the total length of the line is more than 50 km, three of these substations are needed (see **Figure 3**). Each BSS steps down the voltage to 22 kV and supplies the main transformers (MTrs) (see **Figure 4**) of the traction power substations (TSSs) and service substations (SSSs) via gas-insulated switchgear (GIS) (see **Figure 5**). For

Figure 4 — 35/43.75-amMVA MTr
Main transformers (MTrs) like this are installed at the three BSSs.

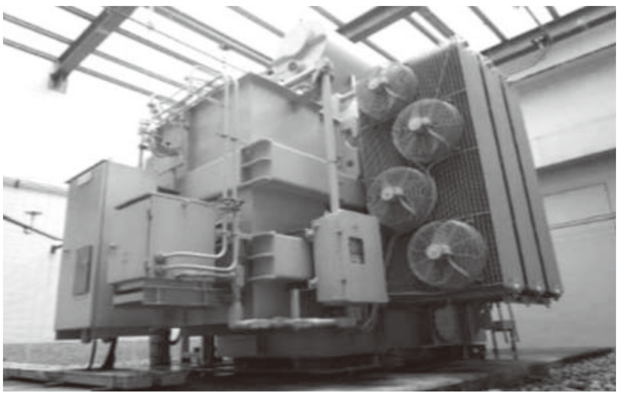


Figure 5 — 161-kV GIS
Gas-insulated switchgear (GIS) like this is installed at the three BSSs.

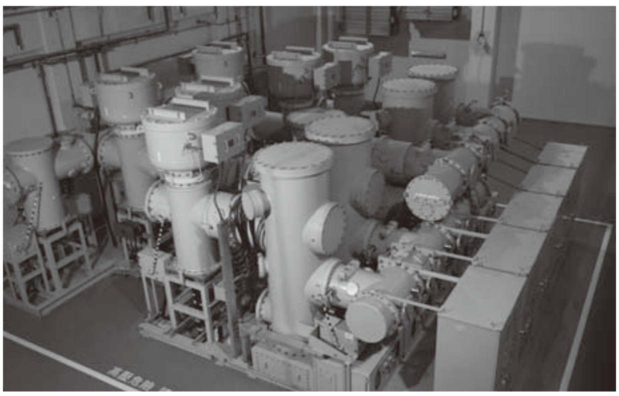


Figure 6 — 24-kV C-VIS

A total of 187 of these cubicle-type vacuum-insulated switchgear (C-VIS) are installed across 27 sites.

Figure 7 — HSVCB

A total of 247 of these high-speed vacuum circuit breakers (HSVCBs) are installed across 27 sites.

electric power distribution, Hitachi supplied 24-kV cubicle-type vacuum-insulated switchgear (C-VIS) designed for environmental compatibility (see **Figure 6**). Each BSS is also equipped with an emergency generator that serves as an emergency backup able to supply vital and essential loads at each station in the event of a disaster that interrupts the supply from Taiwan Power Company.

3. 2
TSS

TSSs are located at 27 sites, including the two depots. Each TSS is fed at 22 kV and combines C-VIS and two rectifier transformers with different phase angles using the equivalent of 24-pulse rectification to minimize harmonics. After conversion to 750 V direct current (DC) by the rectifier, the electric power is supplied via HSVCBs (see **Figure 7**) that comply with IEC 61992-1/2 to the third rail.

Regenerative inverters are installed at two TSSs located near long sections of track with steep gradients to take advantage of the regenerative electric power from the trains by returning it to the 22-kV power system. The system is designed to have redundancy so as to enable the train to continue running via a bypass circuit in the DC system in the event of a TSS outage caused by a DC system fault, for example, and TSSs able to remain in operation using the supply from an adjacent BSS in the event of a cable fault in the alternating current (AC) system or an outage in their BSS supply.

3. 3
SSS

The SSSs supply all of the electric power for stations, including elevators and ticket gates as well as lighting and air conditioning. Like the TSSs, they are fed at 22 kV. The power is distributed via a ring main unit (RMU) and is stepped down to 380 V by a transformer before being supplied to the low-voltage loads. The SSS uses the ring main distribution method that is the common system in Europe. The system is designed with redundancy to prevent disruption to passengers' use of the station. This is achieved by installing dual systems for all equipment, including the RMU, transformers, and uninterruptible power supplies (UPS), so that power supply can continue by switching over to the working backup system in the event of an equipment fault or an outage in the supply from the BSS.

4. HSVCB

The running of trains in a railway system relies on a reliable supply of electric power. HSVCBs are key items of equipment in DC power supply systems for railways. They have a vital role, instantaneously detecting current overloads when a fault occurs to prevent flow-on faults in other equipment, and ensuring that the power supply can quickly be restored.

The high-speed circuit breakers (HSCBs) used in the past had issues with maintenance due to the wear on contactors and arc chutes caused by switching load currents and disconnecting fault currents, and also safety concerns due to the generation of arcs at atmospheric pressure. Conditions in Taiwan and the fact that the airport line has numerous sections of elevated track puts it at very high risk of DC short-circuit and similar faults caused by debris blowing onto the line during the typhoon season. This makes it likely that fault current disconnections will occur frequently. Accordingly, Hitachi chose to install HSVCBs on the line, recognizing the benefits of their superior maintenance and safety characteristics compared to HSCBs.

4. 1 Specifications

Table 1 lists the specifications of the HSVCBs supplied for the railway line. They conform to the IEC 61992-1/2.

4. 2 Protection and Control

Normally in Japan, the way of dealing with faults in the power feed circuit is for the HSCB to trip automatically when the current exceeds its preset over-current limit, to use ΔI fault selective relays (50F) to provide protection for cases not covered by the over-current setting, and to install contact breakers (85F) for rapidly disconnecting opposing HSCBs at the adjacent substation that provides a parallel power supply during a fault.

On the new railway line, in contrast, 50F protection was not installed because of the system characteristics, namely that over-current detection is ineffective for protection because of the short distance between TSSs and that 50F detection is difficult because the comparatively high inductance of the third rail means that fault currents have a slow rise time.

To satisfy the customer's requirements, the HSVCBs used in the project were modified by adding a function similar to conventional load measuring. Distinguishing between train overloads and short-circuit faults is done by having the static-type over-current tripping device (SOTD) that serves as the HSVCB's controller calculate di/dt for overload relay (76) detection. Rates of change up to 1.5×10^6 A/s are treated as overloads (76L), in which case the circuit breaker is reset 30 seconds after tripping. Rates of change of 1.5×10^6 A/s or more, in contrast, are treated as short-circuit faults (76H) and remain locked out after tripping (see **Figure 8**).

The HSVCB selection characteristics can be specified, with the breaker tripping at the specified automatic trip current when the selectivity is 100%, but it also being possible to trip rapidly based on the di/dt of the detected current when a different selectivity is specified. While recent mechanically restrained HSCBs do not typically have selection characteristics, it is simple to specify the selectivity of HSVCBs to suit different types of operation. Accordingly, this can be done to suit how the customer operates.

Moreover, given the potential noted above for high-resistance ground faults on this railway line, DC

Table 1 — HSVCB Specifications
The main specifications of the HSVCB are listed below.

Standard		IEC 61992-1/2
Rated voltage		DC 900 V
Rated current	**For rectifiers**	4,000 A
	For feeder	3,150 A/4,000 A
	For regeneration system	2,000 A
Rated braking current		31.5 kA
Over-current setting		4,000 to 12,000 A
Selectivity		65, 75, or 85%
Mechanism		Hybrid electromechanical

Figure 8 — HSVCB Load Measuring Function
The graph shows how the HSVCB load measuring function works.

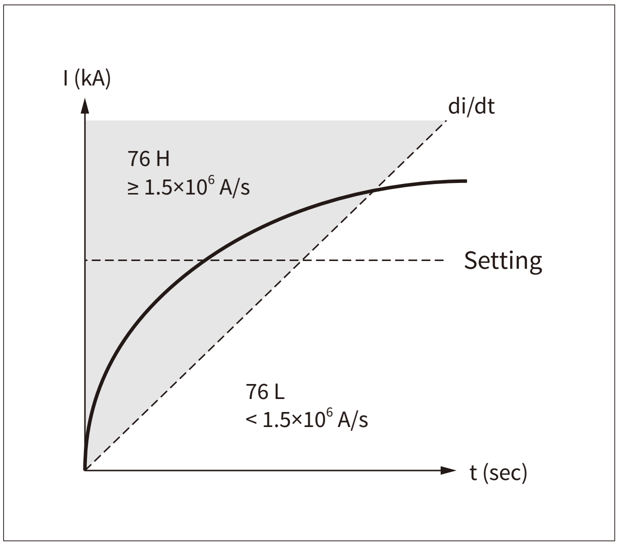


Figure 9 — Overview of High-resistance Ground Fault Protection

The diagram shows 64D ground fault protection.

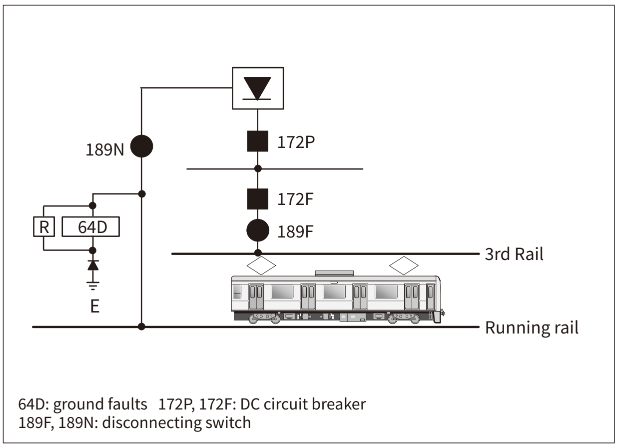
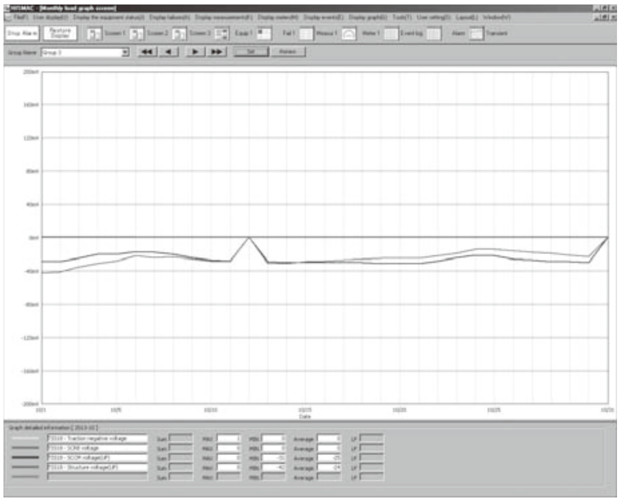


Figure 10 — SCMS Monitor Screen

The monitor units can be used to analyze how the various potentials vary over the short, medium, and long terms.



ground fault protection from a monorail in Japan was adopted, using current-operated ground fault (64D) protection with low resistance in parallel with ground fault relay (64P) (see **Figure 9**).

This facilitates protection and detection for high-resistance ground faults while also keeping the rail voltage low and lowering the touch voltage by providing a low-resistance connection to system ground.

5. Development of SCMS

Although stray current from the rails flows via earth and is fed back to the rails near the TSS, electrolytic corrosion can occur in metal objects that have a lower resistance than earth if they are located close to the railway line. Examples include underground water or gas pipes.

As for other MRT lines in Taiwan, stray current collector mats (SCCMs) made of metal is laid in the track bed under the rails of the airport railway line to prevent electrolytic corrosion by actively collecting stray currents. However, because the customer required continuous monitoring of stray currents in accordance with EN 50122-2, Hitachi developed and installed a SCMS to measure the effects of these currents over the short, medium, and long terms and to monitor and verify these effects at each station along the airport line.

The SCMS is made up of sensors for measuring rail potential, SCCM potential, and structure earth potential installed at 29 locations along the entire length of the line, and monitor units for collating and displaying the information at the depots using an optical network.

The measured data is saved on storage devices attached to the monitor units and can be output as daily, monthly, or yearly reports. This allows for short term verification and also for medium- to long-term monitoring of the effect of stray currents over a period of years (see **Figure 10**).

Installation of the system provides a capacity both for verifying trends in electrolytic corrosion at each station and for the comprehensive assessment and verification along the entire line of whether or not external infrastructure is having an effect.

6. Cable Laying Work

In addition to equipment installation, Hitachi also undertook the procurement and work of laying cables along the entire length of the line, including 161-kV and 22-kV cables, DC cables, and optical cables.

Hitachi laid a total of 562 km of cable, using armored cables with single-core aluminum conductors for the 22-kV distribution cables and securing each of the three phases independently at 1-m intervals along the railway track. **Figure 11** shows the cable laying work in progress.

Figure 11 — Cable Laying in Progress
The picture shows 22-kV cables being installed on elevated track.

7. Conclusions

The development of railway infrastructure in Taiwan progressed rapidly during the time it was under Japanese administration, with a structure that continues to this day in the form of the Taiwan Railway Administration (TRA). Recent years, meanwhile, have seen ongoing improvements in service, including the MRT systems in Taipei and Kaohsiung cities and Taiwan High Speed Rail that runs from Nangang to Zuoying. There are also extensive plans that include new MRT lines or expansion of existing areas in cities such as Taoyuan and Taichung.

The Taiwan Taoyuan International Airport Access MRT System described in this article has an important role in these plans both as a means of transportation used by overseas visitors and as a way to relieve traffic congestion by carrying users who live along the rail corridor. The expectations for the power supply system, which includes HSVCBs, the SCMS, and other equipment, are that it will have the reliability to ensure that this role will be adequately fulfilled and that it will continue to operate reliably into the future.

Despite equipment problems and accidents, the flow-on effects of work interruptions caused by various accidents, and damage to equipment during the Great East Japan Earthquake, this long-running project successfully commenced operation thanks to the extensive efforts of everyone involved. Hitachi will continue contributing to the improvement of railway system reliability by building power supply systems and developing products that meet customer needs for high quality and reliability combined with environmental performance and low maintenance, whether in Japan or elsewhere.

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