

# Commercialization of Thyristor Rectifier Unit

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## Abstract

Rectifier units that use diodes as rectifying elements are often used as rectifier units in substations for DC electric railways. In a diode rectifier unit, the DC voltage fluctuates due to voltage fluctuations on the AC side or load fluctuations due to the number of trains in operation and train schedule. It is desirable that the DC voltage is always constant because the DC voltage fluctuation reduces the regenerative effect of train cars.

In order to control the voltage at a constant level, we developed a rectifier unit that uses thyristor elements as the rectifier elements. We supplied it for Sapporo Transportation Bureau in Sapporo City, Hokkaido, Japan.

## 1 Preface

Sapporo Transportation Bureau in Sapporo City, Hokkaido, Japan, manages three railway lines, Tozai Line, Namboku Line, and Toho Line. Renewal work is currently under way for the substations situated on the east side of Tozai Line. To improve the effect of power regeneration for train cars, Tozai Line is conducting voltage-constant control for the traction power fed from the substation. To maintain the DC feeder constant voltage, silicon rectifier units currently adopted by Namboku Line and other railway operators are not applicable. This is because the diode used in the diode rectifier unit cannot control the ON/OFF of the element, so the DC voltage fluctuates due to fluctuations in the AC side voltage and load current. To control the DC current constant voltage, it is necessary to use a switching control element as the rectifying element.

Against such a technical background, we developed a rectifier unit that uses thyristors as the rectifier elements. We updated the rectifier unit that had been supplied to Shin-Sapporo Substation and Nango Substation in 1982. This paper introduces the thyristor rectifier unit newly developed for this time.

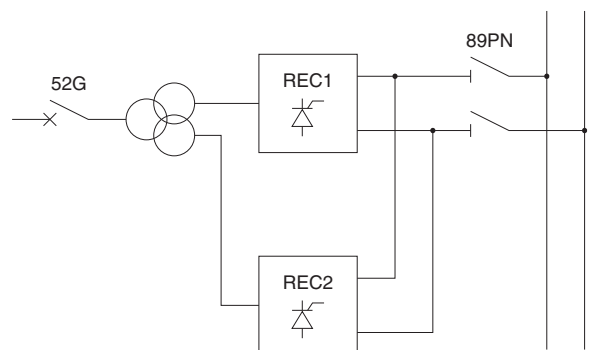
## 2 Specifications and Configuration of Thyristor Rectifier Unit

Table 1 shows the basic specifications of thyristor rectifier unit and Fig. 1 shows an example

**Table 1** Basic Specifications of Thyristor Rectifier Unit

The basic specifications of thyristor rectifier unit are shown.

Item	Specifications
Connection system	3-phase double bridge
Capacity	4000 kW
Rated DC voltage	1500 V
Overload capacity	Class D 100% continuous, 150% for 2 hours, 300% for 1 minute
AC frequency	50/60 Hz
Cooling system	Evaporative self-cooling system (Heat pipe system)
Applicable standard	JEC-2410-2010



**Fig. 1** Example of Single Line Diagram for Thyristor Rectifier Unit

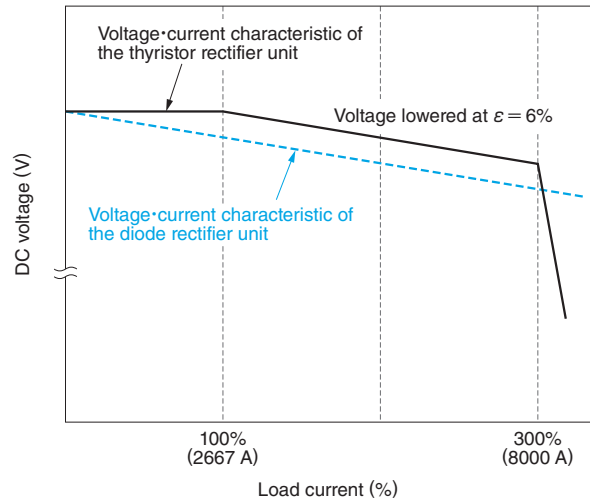
Major components and configuration of the thyristor rectifier unit are shown. The thyristor rectifier unit is composed of disconnecting switches, power transformer, and thyristor rectifier units. An AC incoming power is converted into a DC traction power.

of single line diagram. This equipment is applicable in case the rated DC voltage is 1500 V and the rated capacity is 4 kW or below.

### 3 Functions and Features of Thyristor Rectifier Unit

#### 3.1 Power Supply for Power Running

In the case of a diode rectifier unit, the traction power feeder voltage changes according to the train carload and the AC side voltage. With this thyristor rectifier unit, the DC voltage can be controlled to be constant if the load is within 100%. By controlling the DC voltage at a constant level, stable power supply and effective use of regenerative power are realized. If the load exceeds 100%, the DC voltage will be reduced at a variation rate of 6%. Fig. 2 shows the relationship between the load current and the DC voltage.

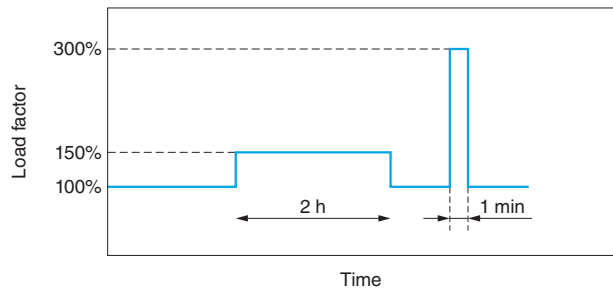


**Fig. 2 Relationship between Load Current and DC Voltage**

The relationship between load current and DC voltage of the thyristor rectifier unit is shown. A constant DC voltage is maintained up to 100% load. If 100% load is exceeded, however, the voltage begins to lower at a gradient of 6%. For comparison, the characteristics of the diode rectifier unit are shown.

#### 3.2 Overload Suppression Function

Fig. 3 shows the overload capacity. The overload capacity of the thyristor rectifier unit is 100% continuous, 150% 2 hours, and 300% 1 minute. The thyristor rectifier unit works to suppress overload. For example, if a load of 150% or more continues for 2 hours or more, the DC voltage is reduced so that the output current becomes 100% or less. It also reduces the DC voltage so that the output current does not exceed 300%. Even if the DC voltage is reduced, the power supply can be continued by getting the power supply from adjacent substation up to the amount that the thyristor rectifier unit cannot output. In the case of a diode rectifier unit, the DC voltage cannot be controlled, so if the overload continues, a serious failure such as an increase in the element temperature will occur. The diode rectifier unit will then stop, as will the power supply. This thyristor rectifier unit is equipped with a function to suppress an overload by utilizing the ability to control the DC voltage. It reduces the risk of stopping the power supply.



**Fig. 3 Overload Capacity**

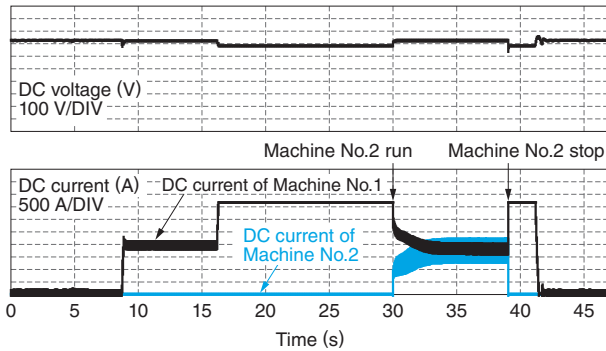
Specifications of overload capacity are shown. After a continuous application of a 100% load, a 150% load can be maintained for two hours and a 300% load for one minute.

thyristor is turned on. Even for equipment that has already introduced a diode rectifier unit, by operating in the diode mode, it is possible to operate to maintain a load balance with the adjacent substation.

#### 3.4 Parallel Operation Function

When thyristor rectifier units that control DC voltage are connected in parallel, the current becomes unbalanced due to the difference in DC voltage output by the thyristor rectifier unit, and it is not possible to supply power for the number of parallel units.

This newly developed thyristor rectifier unit is equipped with a function to control the balance of DC current during parallel operation. Fig. 4 shows



**Fig. 4 Parallel Operation Test Waveforms**

Parallel operation test waveforms are shown. In the state that Machine No.1 is operated, Machine No.2 is started for parallel running. This diagram indicates that a stable load balance is secured in such a situation.

the parallel operation test waveforms during the shop test. It demonstrated that the second unit was operated 30 seconds after the load of 3600 A was carried by one unit, and the balance was achieved at 1800 A a few seconds later. From this waveform, it was confirmed that the balance control was stable and it was functioning well. In addition, we confirmed that when the second unit was stopped and one unit was operated at around 38 seconds. The total load was instantly switched to one rectifier unit and it was possible to respond to sudden load fluctuations.

We can make proposals to fit the customer's application, such as increasing power to power running (a fast run driving mode or balanced speed mode on an uphill slope) or operating in parallel only during rush hours of the timetable.

### 3.5 Human Machine Interface (HMI)

This thyristor rectifier unit is equipped with a touch panel. By touching the screen of the color Liquid Crystal Display (LCD), it can start or stop the equipment and can make various settings. In addi-

**Table 2 HMI Specifications**

Major specifications of the HMI are shown.

Item	Specifications
Operation button	Run and Stop operation of thyristor rectifier unit Fault recovery operation
Operation logs	Run and Stop
Error log	Various error logs
Telemetry	AC voltage DC voltage, DC current DC power
Settings	Command values of DC voltage Phase angle

tion, this monitor can perform equipment status monitoring and the unit can record the operation logs, and measure the voltage and current. In the unlikely event of a failure, the operator can rush to the site and check the equipment status and failure items. **Table 2** shows the HMI specifications.

## 4 Postscript

The renewal work of Shin-Sapporo Substation and Nango Substation proceeded in a limited short period of time at night when traction power outages were possible. Even under the limited installation space, the renewal work was successfully completed, and these substations provide stable power supply to Tozai Line. Going forward, we would like to continue to contribute to Sapporo Transportation Bureau by our substations since this is a product that represents our technological capabilities.

Finally, we would like to express our deepest gratitude to all the people concerned for their guidance and cooperation in the development, production, and installation of this product.

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