Heat-Pipe-Cooled Silicon Rectifiers for DC Railways

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Abstract

At a DC traction substation for railways, rectifiers are installed for the purpose of converting AC power to DC power. In conventional lines in Japan, most of our work is in the renewal of aged facilities. In these cases, the demand for compact and lightweight rectifiers is increasing.

We manufacture heat-pipe-cooled silicon rectifiers for DC traction substations for railways. The heat-pipe-cooled silicon rectifier is an environment-friendly product. It uses purified water as a coolant. While effectively using this feature, we substantially reviewed the overall structure design of this product. We developed a compact and lightweight rectifier unit which is favorable for renovation projects for existing facilities.

1 Preface

Formerly at a DC traction substation for railways, rotary rectifiers or mercury rectifiers were used for the conversion from AC to DC power, however today, silicon diode rectifiers are mostly used. For a cooling system, the forced air cooling type, oil-cooling type (oil-immersed), or self-cooled ebullient cooling type with the use of Freon coolant was formerly used. Recently, the heat-pipe self-cooled type is mostly used, as it is a more eco-friendly model.

Since the beginning of 2000, we have been manufacturing heat-pipe-cooled silicon rectifiers for DC traction substations in railways. Ten years have passed since the completion of initial development and we consider it is time to review the design of this product to fit current needs. In the Japanese market, most of our work is in the renewal of the aged facilities. In renovation work, there is a growing demand for more compact and lightweight rectifier model. This paper introduces the newly developed heat-pipe-cooled silicon rectifier featuring a compact and lightweight design.

2 Ratings and Construction

Table 1 shows major specifications of rectifiers. Fig. 1 shows an example of a rectifier and transformer layout. The rated DC voltage is 1500V

Table 1 Major Specifications of Rectifiers

Typical ratings and specifications are shown.

Rated DC voltage	1500V
Rated capacity	3000kW・4000kW
Duty class	Class D (100% continuous, 150% for 2h, 300% for 1 min) Class E (100% continuous, 120% for 2h, 300% for 1 min)
Input frequency	50/60Hz
Connection system	Double 3-phase bridge connection
Cooling system	Evaporative cooling self-cooled type
Voltage regulation	5%・6%・8%
Applicable standard	JEC-2410-2010

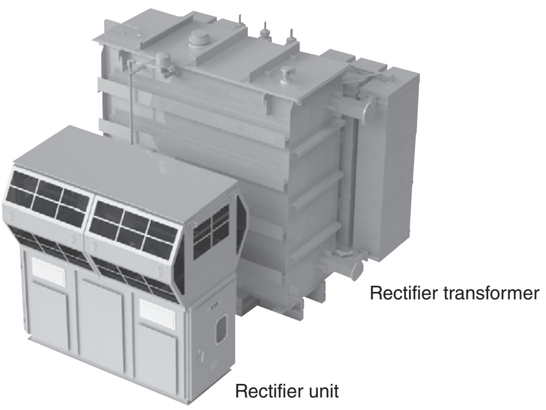

Fig. 1 Example of Rectifier and Transformer Layout

The rectifier transformer and rectifiers are connected through ducts so that the overall installation space can be reduced to a minimum.

and the rated capacity is applicable to 4000kW or lower. The DC voltage regulation is applicable up to 5%.

The rectifier unit comes in a construction with an extruded upper part. Heat pipe fins are accommodated in this upper section. The basic construction is common to indoor and outdoor equipment. The heat pipe fins located in the upper part of the equipment are provided with a mechanism with effective rainwater measures. It is able to avoid a negative impact even in the case of a strong wind and rain drops directly hitting it. The lower part of equipment is used to accommodate the main circuit, monitoring device, and maintenance block.

The surface of the equipment side is equipped with a duct connection port to which the straight bus duct from the rectifier transformer is connected. Since such a mechanism is adopted, the rectifiers, rectifier transformer, and all subsidiary devices and units can be installed minimal installation space. This feature is useful when a planned installation space for equipment is limited, like in renewal work of existing facilities.

To enable cable connections with the rectifier transformer, a special structure is adopted so that cables from the outside can be led into the equipment through its lower section.

Fig. 2 shows the connection diagram. For the reduction of harmonic currents flowing out to the utility power network system, a 12-pulse rectification system is adopted. The connection mode is a double 3-phase bridge connection system (parallel 12-pulses).

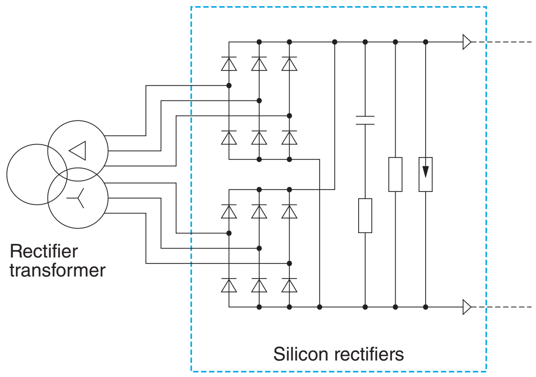

Fig. 2 **Connection Diagram**

An outlined connection diagram of the main circuit for rectifiers is shown.

3 Features

3.1 Compact and Lightweight Design

We carefully reviewed the design of internal circuiting arrangements to drastically minimize external dimensions. Total mass is also substantially reduced. Compared with our conventional outdoor 4000kW unit (W3380 × D1680mm, 3950kg), the installation space (projected area) is reduced by 36% and the total mass by 44% (W2400 × D1500mm, 2200kg). Fig. 3 shows a comparison of installation space and mass. Fig. 4 shows a comparison of installation space between a conventional and newly developed model.

3.2 Prevention of Electric Shocks

Insulation materials made of aluminum nitride with high heat conductive characteristics are arranged between silicon rectifier elements and heat pipes. By such an arrangement, heat pipes can be treated as a non-charged part and there is no danger of electric shock, even if a service technician touches the fins.

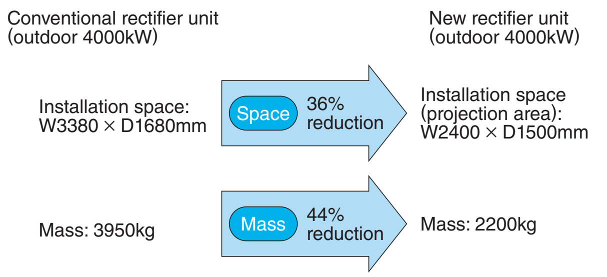

Fig. 3 **Comparison of Installation Space and Mass**

Comparison is shown with conventional equipment based on an outdoor 4000kW unit.

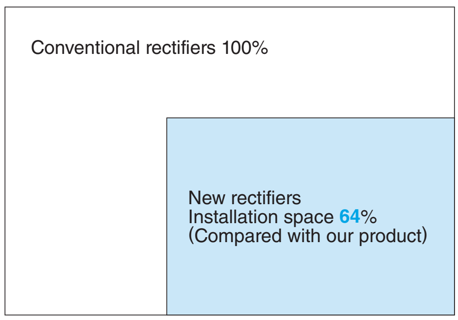

Fig. 4 **Reduction of Installation Space**

A comparison is shown between our conventional and new model. This is an outdoor 4000kW unit.

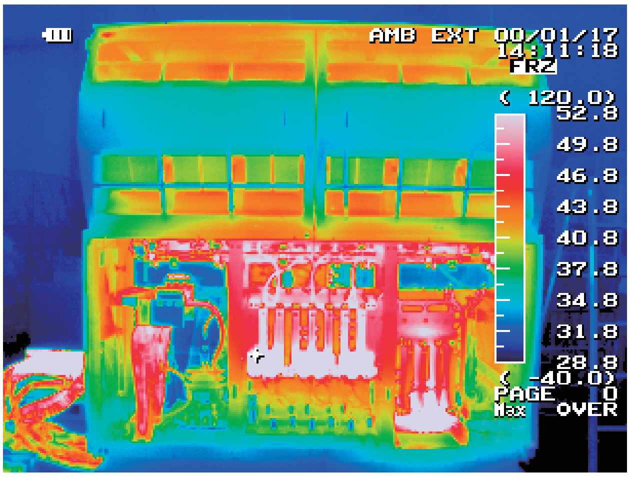

Fig. 5 Example of Analytical Result from Temperature Rise Test

Hot spots were confirmed through the temperature rise test.

3.3 Low Environmental Burden

Purified water is used as a coolant to be sealed in the heat pipes. Even if the equipment is abandoned or destroyed, there is no danger of negative impact upon the surrounding environment. This is an eco-friendly product.

3.4 Improvement of Environmental Resistance Due to the Adoption of Sealed Construction

The main circuit is accommodated in a sealed construction. Such a structure is effective in preventing deterioration from dust and debris. Even though the sealed construction is adopted, equipment is designed to not overheat any part exceeding the permissible heat level inside the equipment. For this purpose, internal parts and main circuit conductors are distributed to secure an optimal layout. The effect of this layout design was confirmed at the time of temperature rise test. Fig. 5 shows an example of an analytical result from temperature rise test.

4 Postscript

For this time frame, our target range was rated outputs of 4000kW or lower. Going forward, we will work on the development of large capacities (6000kW) and special ratings (Class S). In so doing, we would like to meet a wider variety of our customer's demands.

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