Replacement Work of Power Receiving and Distribution Facilities in an Underwater Tunnel

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Abstract

The Kanmon Tunnel is an underwater roadway tunnel and carries National Highway Route 2. It was opened in 1958. It is a two-lane, two-way tunnel. It connects Honshu and Kyushu with a total distance of 3460 meters. It is an important tunnel for vehicle traffic and physical distribution. About 30,000 cars pass through it every day. Presently, there are four ventilation shafts for the tunnel. There are electric rooms at the top of each shaft, high voltage connection cables laid between power receiving and distribution facilities and ventilation shafts. Since these cables and electrical facilities have aged, we replaced old units with new ones in three years. For this replacement work, we drew up a replacement work plan with consideration of safety. There was an issue with drainage of spring water inside tunnel, approximately 4800t a day, in order not to allow adverse influence on important functions of the tunnel. We completed this project successfully.

1 Preface

For this replacement work, aged electrical facilities and high voltage connecting cables were replaced by taking three years to complete. These facilities were installed in each electric room at the top of ventilation shaft. There are four ventilation shafts in the tunnel.

The Kanmon Tunnel has four shafts situated in Mukuno, Shimonoseki, Moji, and Kojo. The electric room is located at the top of each shaft. The Shimonoseki-side Shaft receives electric power from The Chugoku Electric Power Co., Inc. and the Moji-side Shaft from Kyushu Electric Power Co., Inc. Each shaft receives power at 6.6kV. It is used mainly for lighting in the tunnel, ventilation and exhaust fans, and water drainage pumps. Power source for tunnel lighting for inbound lane is different from that for outbound lane. Lighting for the inbound lane that goes toward Shimonoseki uses the power from The Chugoku Electric Power Co., Inc. while that for the outbound lane that goes toward Kitakyushu gains power from Kyushu Electric Power Co., Inc. Each power is supplied from the transformer panel for lighting and a panel is installed for each traffic lane.

This paper introduces the replacement work of power receiving and distribution facilities and inter-shaft transfer cables into new ones.

2 Outline of Replacement Work

For the Kanmon Tunnel, aged facilities such as power receiving and distribution facilities and dust collectors were replaced with new ones. This replacement work was carried out in parallel to construction work for ventilation facilities. We oversaw the replacement work of the following power receiving and distribution facilities.

(1) One complete set of replacement power receiving and distribution facilities for the respective shafts in four locations

(2) One complete set of replacement exhaust power panels and ventilation power panels

(3) Extension of electric room functions for toll booths located in Moji and Shimonoseki

(4) One complete set of replacement pumping room transformers on Shimonoseki Pithead

(5) Replacement of high voltage cables between shafts and tollgate areas

High voltage cables: Approx. 14,540 meters

Fig. 1 shows a view of Moji-side gateway of the Kanmon Tunnel. Fig. 2 shows the ventilation facility before renewal at the Kojo-side Shaft.

Fig. 1 Moji-Side Gateway of the Kanmon Tunnel

Moji-side gateway is shown.

Fig. 2 Ventilation Facility before Replacement at the Kojo-Side Shaft

Three units on the left are blowers and three units on the right are air-exhaust ventilators.

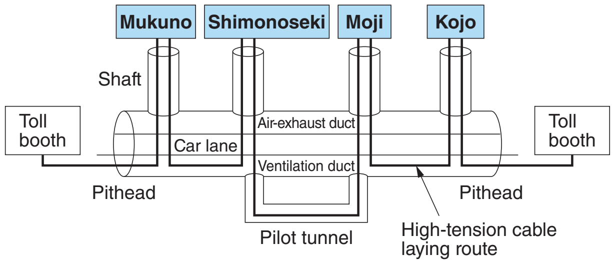


Fig. 3 Cable Routes in the Tunnel

Since the pithead section of the cable routes is faced towards the car lane side, cabling work was carried out while traffic was closed. Cable routes in the tunnel are located along the ventilation ducts and pilot tunnel under the car lane.

Fig. 4 Cable Drum Carry-in for Cable Laying in the Tunnel

The sidewalk elevator has a maximum loading capacity of 3000kg for 40 passengers. This elevator was also used for transportation of the cable drums. It was made unavailable for ordinary passengers from 10PM to 6AM next day. Cable drums were carried in during the nighttime while the elevator was not open to general passengers.

2.1 Method of Cable Laying

Fig. 3 shows the cable routes in the tunnel. Cables are laid through the ventilation ducts under the car lanes, from the underground electric line at the pithead to the shaft top electricity room about 90 meters high. Prior to the start of this work, we drew up a work plan considering the right method of cable carry-in of cables to the underground site and how to secure safe working conditions.

Fig. 4 shows a view of a cable drum carry-in for cable laying in the tunnel. For cables to be laid between shafts, cable drums were carried with the aid of an elevator (Max. 40 passengers and load capacity 3000kg) used to carry pedestrians on the sidewalk. At that time, the cable drums were split into groups to fit the maximum permissible size of the elevator.

Fig. 5 shows a view of cable laying work at the pithead of the tunnel. For the section from the vicinity of the pithead to the space under car lanes, cables are laid from the car lane side. Consequently, it was necessary to take regulatory measures for one-side alternate traffic. Cables, however, could be laid safely because this work was carried out at the same time as when small-scale tunnel inspection and repair work (by another project) was carried out by stopping all traffic for 60 days.

3 Switchover Procedures

For this replacement work project, switchover from aged facilities to new ones was carried out for the facilities of power receiving and distribution, ventilation, and lighting. Switchover work was car-

Fig. 5 Cable Laying Work at the Pithead of the Tunnel

In the original plan, cable laying work was expected to be conducted by blocking one side in the nighttime. Later, this plan was changed as the work would be conducted during the time of small-scale inspection and repair work. During this period, two lanes were completely blocked for 60 days. As a result, cable laying work could be carried out safely in the daytime. Cables were carried into ventilation ducts under the car lanes and these came through air vents.

ried out at each shaft. Switchover procedures are outlined below regarding the ventilation and lighting facilities at Moji Shaft.

3.1 Replacement Work of the Ventilation Facilities

(1) Step 1

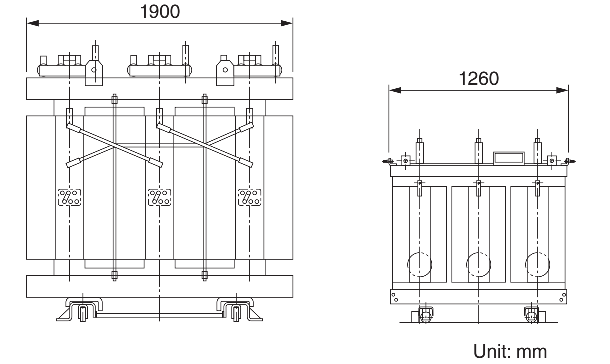
First, a space was secured to install a newly produced switchboard in the same existing electric room. Usually, three blowers and three air-exhaust ventilators were operated for ventilation inside the tunnel. During the replacement work period, however, only one air-exhaust ventilator was operated during the replacement work for smoke exhaustion in the event of a fire inside the tunnel. The other five fan units remaining were removed. At the same time, various power boards on the electric room side were also removed. As a result, a sufficient installation space was secured for the renewed power boards.

(2) Step 2

By separate work, an air-exhaust ventilator was newly installed. Using this machine, a combined test with newly installed boards was carried out. The remaining air-exhaust ventilator (1 unit) was finally removed. At the same time, exhaust power boards on the electric room side were also removed to secure a space to install blower power boards.

(3) Step 3

After the installation of blower power boards, a combined test with the installed blowers was carried out to completion.

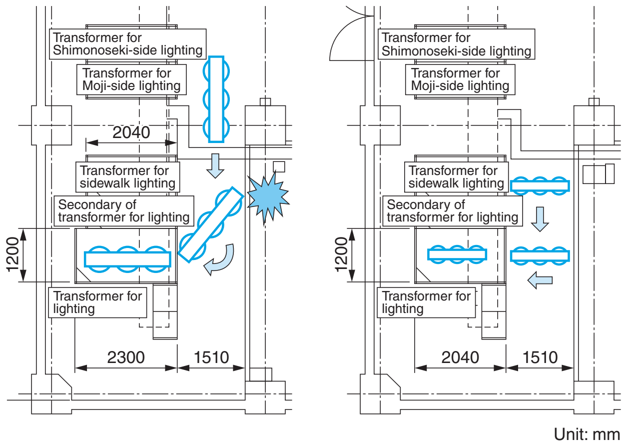


(a) With tap-changer (200kVA 6.6kV-6.6kV/3.3kV)

(b) Without tap-changer (200kVA 6.6kV-3.3kV)

Fig. 6 Comparison of Transformer Sizes

Sizes are compared between (a) initial plan: a tap-changing transformer with 6.6kV primary and 6.6kV/3.3kV secondary and (b) subsequently changed plan: another transformer with 6.6kV primary and 6.6kV secondary. Sizes of the tap-changing transformer turned out to be far larger than initially thought.



(a) Initial plan

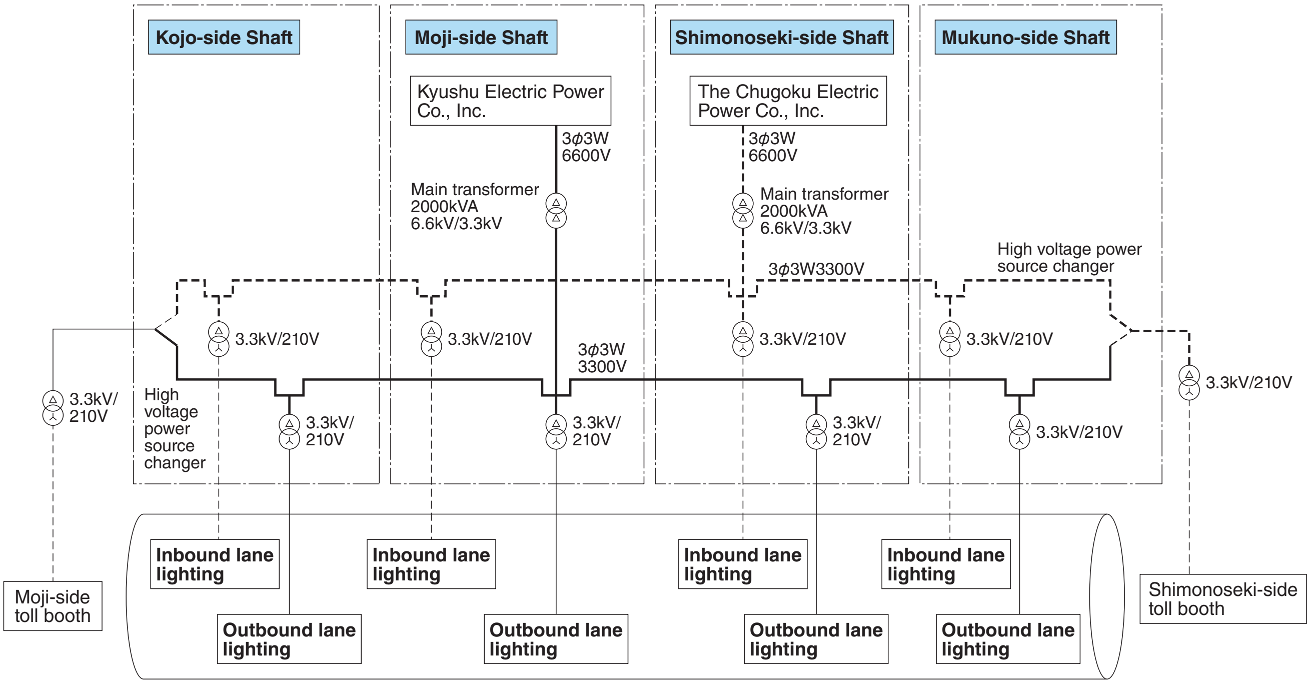
(b) Reviewed plan

Fig. 7 Comparison of Electric Room Layout and Transformer Carry-in

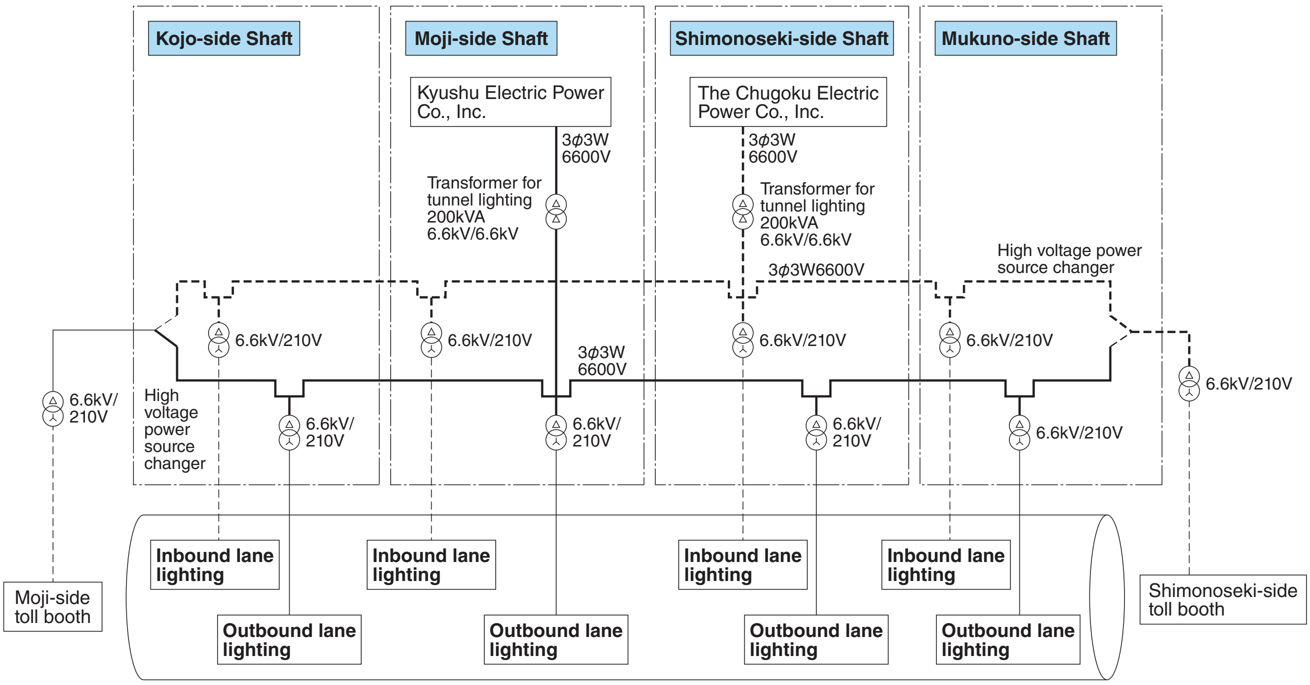
When a panel size is 2300mm in depth and transformer length is 1900mm, it became clear that putting the transformer inside the panel was difficult. As such, this plan was revised.

3.2 Replacement Work of Lighting Facilities

The transformers for tunnel and sidewalk have a primary voltage at 3.3kV. Our working plan was that this primary voltage of 3.3kV will be unified into the 6.6kV system after all the facilities for four shafts have been completely renewed. Switchover work to the 6.6kV system must be done in a limited time at night. To shorten changeover time, we had planned to use a tap-changing transformer where the 3.3kV/6.6kV tap changer is located on its secondary side. This tap-changing transformer was, however, too big to be incorporated in the power board of the electric room. As such, with consultation with the contact ordering party, the aforementioned transformer was modified into two transformers, one for 6.6kV and the other for 3.3kV. Since each transformer was small, it was easy to carry out for installation in a narrow electric room. **Fig. 6** shows a comparison of transformer sizes, **Fig. 7** shows a comparison of an electric room layout and transformer carry-in, and **Fig. 8** shows a single-line connection diagram of the lighting power source before and after the system switchover.



(a) Before renewal



(b) After replacement work

Fig. 8 Single-Line Connection Diagram of Lighting Power Source

A single-line connection diagram of tunnel lighting power source is shown. The 2000kVA main transformer had been replaced to a 200kVA transformer for tunnel lighting. The lighting system receives a power at a 3.3kV system. By this time, it was changed to commonly receive the power at 6.6kV. A single-line connection diagram of tunnel lighting power source is shown. The 2000kVA main transformer had been replaced to a 200kVA transformer for tunnel lighting. The lighting system receives a power at a 3.3kV system. By this time, it was changed to commonly receive the power at 6.6kV.

(1) Step 1

All lighting in the inbound lane was blocked in order to carry out voltage changeover. The respective lighting transformers of the four shafts were connected to the secondary circuit of the lighting transformer at the Shimonoseki Shaft. All transformer tap-changing actions were, therefore, taken simultaneously. Tap-changing of transformers for the tollgate was also carried out at that time. Since tollgates cannot permit a service interruption, a temporary generator was used to maintain operation of the tollgates while tap-changing was carried out.

(2) Step 2

All lighting in the outbound lane was shut down in order to carry out voltage changeover. In the same manner as for the inbound lane, changeover actions were taken in four places at the same time. After the completion of changeover for four shafts and two tollgates, the 6.6kV system became available. Since it was necessary to perform voltage changeover work in six dispersed locations overnight, it was the most essential factor to make a detailed work plan and to establish good communication among project joining companies and related project members.

4 Postscript

An order for this project was received in January 2014. The project was finished in April 2017 without any accidents or injuries. It took three years and three months and required the cumulative total number of 6500 people.

Since this tunnel work had to be carried out while ordinary vehicles and pedestrians were passing through, a dangerous power outage caused as a result of work errors might have led to traffic accidents in car lanes and/or confinement of passengers in an elevator car. In order to avoid such accidents, facility switchover procedures and location of operating switches on power boards were previously examined together with the representatives of the contract ordering party. In this manner, work was promoted. We always confirmed the work was free from unusual phenomena and possible errors and kept good communication with the individuals in the Control Center during system switchover work.

Lastly, we express our sincere gratitude to the project-related personnel at West Nippon Expressway Company Limited for their kind guidance and cooperation during the performance of the project: from the commencement to completion.