Reconstruction Support after the Great East Japan Earthquake

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Abstract

As a result of the Great East Japan Earthquake in 2011 (the "Quake") with the epicenter near Tohoku Area Coast in the Pacific Ocean and subsequent tsunami, many plants and factories situated along the Tohoku Region Pacific Coast suffered catastrophic damages and the operation of these facilities became extremely difficult. In this region, there were many suppliers of key parts and materials in support of Japanese industries; therefore, early restoration was desired.

Our Company challenged the early recovery by the expert team of visitor equipment.

1 Preface

Among many restoration jobs, the scale of restoration work for 154kV power receiving facilities of an iron and steel manufacturer was particularly large. Before the Great East Japan Earthquake in 2011 (the "Quake"), this customer manufactured iron and steel products using electric furnaces. This firm produced shaped steel and mechanical parts for construction machines, steel bars and iron wires used for car components, and wire rod used for a steel wire. We manufactured electrical facilities and have maintained them better for a long time.

Regarding the basic system configuration of the customer's electrical facilities, electric power is received at 154kV, stepped down to 22kV by the main transformer, distributed to the respective private substations in the premises, stepped down to 6.3kV at each substation, and then fed to the load machines.

We kept fast and close contact with the customer. The following plans were drafted to realize the earliest and safest recovery of the power system.

(1) The target is for complete restoration one year after the disaster.

(2) At Step I, we will secure power receiving at the extra high voltage substation and temporary power distribution to each factory.

(3) At Step II, electric power will be fed to facilities used in the respective factories.

(4) At Step III, facilities for temporary power transmission will turn to the regular power transmission.

The restoration program was such that the restoration work began on 17 March 2011, power receiving and part of 22kV power distribution was scheduled to be completed on June 30 to clear Step I, then power distribution to 6.3kV substations was scheduled to be completed on July 20 as Step II, and total factory operation start was scheduled in August 2011.

This paper introduces the restoration work (Steps I & II) carried out for the area from extra high voltage facilities to high and low voltage facilities in order to feed electric power to the respective factory facilities in such a short time of less than 4.5 months.

2 Basic Procedures for Restoration

The major factors that damaged the electrical structures were deformation and destruction caused by earthquake deflections and reduction of insulation performance plus contamination due to brine submergence by Tsunami. A great cost and time were anticipated in case all the damaged facilities were to be replaced by new ones. First, we assessed the situation of damage in existing facilities and carried out diagnostic services to examine their functional conditions with the use of various diagnostic tools in order to achieve functional recovery through washing with water and then drying out. In addition, we carried out dry ice blast cleaning to insulators in each substation.

For equipment identified as impossible to reuse, we communicated quickly with our factory to remanufacture it as fast as possible.

3 Actions Taken for Each Facility

3.1 Extra High Voltage Power Receiving Equipment

The power-receiving substation facility has a single circuit to receive power at 154kV. This facility comes in a configuration with a power-receiving circuit-breaker, a power-receiving disconnecting switch, and three main power transformers, each having a primary disconnecting switch and a circuit-breaker.

At the extra high voltage substation (power receiving station), an overhead transmission line from the power company was connected through bushings; however, all metal conductors had been cut by the collapse of the steel tower. Fig. 1 shows an overall view of the destroyed power receiving substation.

It was subsequently revealed that insulation oil had leaked out of the wall penetration type bushings by the effect of insulator fracture and breakage of parts. We concluded that reuse would be impossible in the state it was in without taking any corrective measures.

Of the damage assessed, there were our supplied two 168kV Gas Circuit-Breakers (GCBs), one Vacuum Circuit-Breaker (VCB) and one GCB made by another supplier. At the power receiving station, there was seawater that had flooded up to 1300mm above the floor level. Except for our supplied VCB, control circuits for all the GCBs could not be reused. Fig. 2 shows the operational block of GCB in the damaged state.

For the restoration work, we tried to wash the control circuits of our GCBs with water. After drying out, we performed an operation check test. The equipment seemed to function, but opening and closing time had discrepancies. Since retardant operation of internal protection relays was discovered, we concluded that we should discontinue the use of these circuit-breakers.

The disconnecting switch remained without any particular damage; therefore, we decided to continue to use it. Fig. 3 shows the 168kV VCB.

3.2 Monitoring Facilities

The 154kV and 22kV monitoring facilities were installed inside the power receiving station. These facilities were intended to monitor equipment operation and to also protect electrical systems. Many

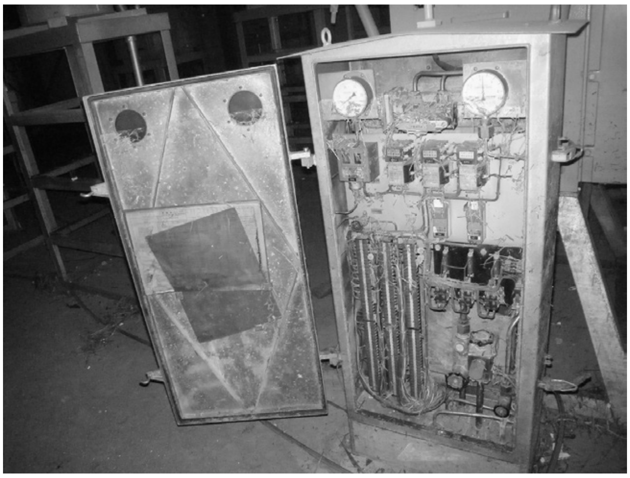

Fig. 2 Operational Block of GCB

Seawater entered the interior of the operator box and driftage is attached.

Fig. 1 Destroyed Power Receiving Substation

The steel tower falls down and incoming bushings are exposed.

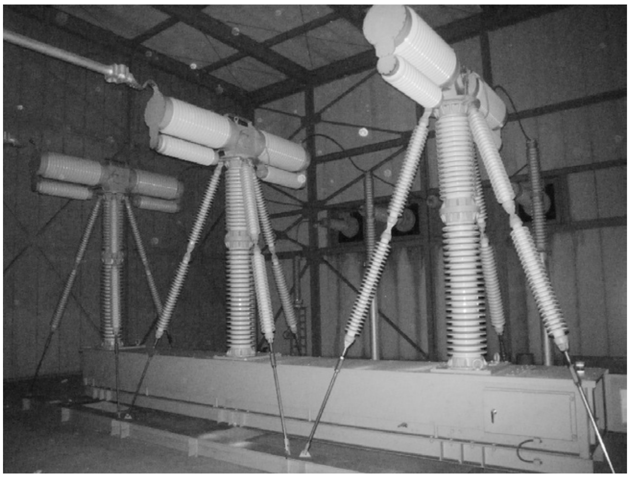

Fig. 3 168kV VCB

The operating mechanism seems to be free from particular damage.

protection relays were concentrated in the operator panel.

Since the monitoring facilities were installed inside the power receiving station, they were submerged in the seawater to 1300mm above the floor level. About half of the devices and instruments were found problematic to continue the operation.

According to final judgment, it was decided that these facilities were to be updated. Since the operational and protective circuits were needed to accomplish the program of Step I (power receiving and temporary power distribution), we carried out the cleaning of the panel interior and decided to tentatively use the protection relays that were not damaged by the disaster so that we could attain temporary restoration in the shortest possible amount of time.

3.3 22kV Switchgear

Fig. 4 shows the 22kV switchgear hit by the flood. Since the 22kV switchgear was installed inside the power receiving station, 50% of the switchgear was submerged in the seawater and this made it impossible to continue to use this product. To accomplish the program of Step I, we decided to use some of the units therein for temporary power transmission at 22kV. Since it was difficult to restore the control circuit for the VCBs within the restoration schedule of Step I, these VCBs were temporarily restored as a disconnecting switch to be used until the delivery of new products. **Fig. 5** shows the interior of 22kV switchgear damaged.

3.4 6.3kV Switchgear

Switchgears for 14 sets of 6.3kV substations installed in seven places in the premises of this factory were submerged in the seawater up to 50% to 90% of the switchgear height. Since devices and instruments allocated inside these switchgears suffered from degradation of insulation performance, we concluded that they could not be reused.

3.5 Oil-Immersed Transformers

Most of the extra high and high voltage oil-immersed transformers were submerged in seawater. We checked the conditions of damage in external appearance and analyzed insulation oil to determine the adequacy of reuse. **Fig. 6** shows the destroyed transformer.

The sampled insulation oil was carried by our Materials and Environmental Performance Analysis

Fig. 4 22kV Switchgear

Seeing from contamination, intrusion of seawater was clear.

Fig. 5 22kV Switchgear Interior

The VCB installed inside the switchgear cannot be operated because there is an intrusion of seawater.

Fig. 6 Destroyed Transformer

The transformer is seriously damaged due to collision with driftage.

Center. The gas-in-oil analysis and insulation oil characteristic test were carried out in a short time. For gas-in-oil analysis, conditions of deterioration and presence of any abnormality were examined according to the quantity and combination of types of flammable gases detected in oil. For the insulation oil characteristic test, insulation breakdown voltage and quantity of water in oil were measured to examine the level of deterioration in the insulation oil.

The target transformers were 24 units in all, from a 50MVA large-capacity transformer to small capacities of 200kVA. Except for three units damaged by rubble, flammable gases and water components contained in insulation oil were found kept within the standard control values and the exterior and bushings were washed with water as a remedial measure. We therefore concluded that reuse was possible.

3.6 DC Power Facilities

Each DC power facility is a combination of storage battery banks and their chargers installed to feed the operational and control power to the central substation and respective subsidiary substations.

All the six sets of DC power facilities in operation then had been submerged in the seawater and were found unfit for reuse. We therefore manufactured new replacement units and delivered them in a very short timeframe.

3.7 Cable Diagnosis

For 6.3kV trunk cables, their terminals were cleansed to remove saline components. After that, we measured the insulation resistance to determine the level of adequacy for reuse.

For 38 CV cables, we used a megger at an applied voltage of 10,000V. We perceived reduction of insulation resistance in 17 cables out of 38; therefore, we concluded that these cables should be renewed.

For low-voltage main cables of about 200 circuits, insulation resistance was measured at an applied voltage of 500V. As a result, the cables were found to have insulation resistance above the control level and we decided to reuse them.

3.8 3-Phase Induction Type Electric Motor

Motors for cooling water pumps used in the customer's factory had been submerged in the seawater. They were brought into our plant for the purpose of desalination. This treatment was carried out for 22 units with capacities ranging from 22kW to 220kW.

Motors were disassembled and their stators and rotors were cleaned with steam to remove foreign substances. After that, they were treated for desalination. Still more, they were steam cleaned again for drying in a vacuum dry kiln. They were then put into insulation remedial treatments and dried again in the vacuum dry kiln. These processes were performed for insulation reinforcement.

3.9 Dry Ice Blast Cleaning for Insulators

The dry ice blast cleaning method was applied to primary and secondary insulators of transformers and extra high voltage power receiving panels submerged in the seawater. Through this cleaning, surface contaminants (ion components, etc.) detrimental the electrical performance characteristics could be decreased or removed for all insulators. By efficiently cleaning parts that are difficult to be reached and for those that are time-consuming and labor-intensive, the labor burden could be substantially relieved; this contributed to the shortening of the restoration schedule.

4 Postscript

Supported by the smooth cooperation with the customer, we could contribute to the restoration of the customer's facilities drawing on our long-standing maintenance and diagnosis techniques. This fact also gave us a great pleasure as we were able to help restore the damaged site. **Figs. 7** and **8** show views of the restoration after the completion of Step Ⅲ. We could accomplish large-scale restoration services in a short amount of time; such an

Fig. 7 **Restored Power Receiving Substation**

The picture shows the restoration from the damaged scene of **Fig. 1**.

Fig. 8 **Restored Field Monitoring Panel**

The renovation of panels is completed and this marks total restoration.

achievement really stems from a close network and teamwork among Meiden Group, other related parties, and the customer.

We think that our society as a whole should learn great lessons from the disaster and should use them for the prevention of another disaster in the future. We wish for no further occurrences as a result of a similar natural disaster. We deeply appreciate the people of this recovery project for their cooperation. Going forward, we will continue to develop more useful diagnostic technologies and offer beneficial services to our customers.