Featured Articles

Work on Reconstruction of Electrical Systems at Sendai's Minami-Gamo Sewage Treatment Center Following Great East Japan Earthquake

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OVERVIEW: Many of the sewage treatment facilities sited along the Pacific coast of Tohoku suffered serious damage from the Great East Japan Earthquake. This damage was considerably worse than expected and is taking a long time to recover from. Hitachi has been involved in work on electrical equipment for improving the water quality of treated sewage at the Minami-Gamo Sewage Treatment Center in Sendai City from the period immediately after the earthquake right up to the present day, the final fiscal year of the designated "concentrated reconstruction period" (FY2011 to FY2015). This article describes this involvement and what has been learned from the knowledge and experience gained through this work in terms of how best to enable electrical equipment to cope with disasters.

INTRODUCTION

SENDAI City's Minami-Gamo Sewage Treatment Center located on the Pacific coast suffered devastating damage from the tsunami that followed the Great East Japan Earthquake that struck at 2:46 PM on March 11, 2011 (see Fig. 1)[(1), (2)].

Reconstruction work is still ongoing and is scheduled for completion in March 2016[(3), (4)].

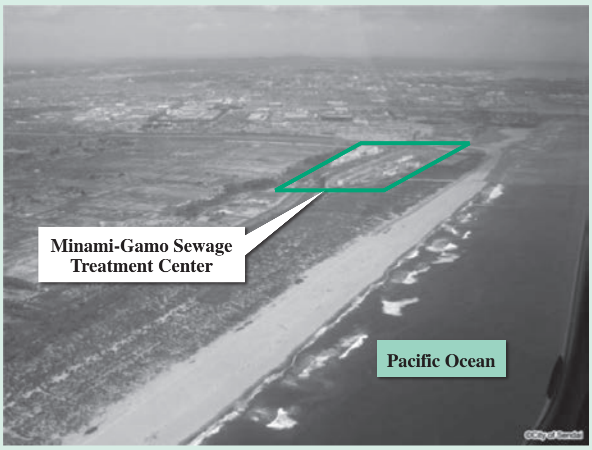


Fig. 1—Aerial View of Minami-Gamo Sewage Treatment Center. The Minami-Gamo Sewage Treatment Center, shown here after the earthquake, is located on the Pacific coast. Among the damage caused by the tsunami was the washing away of the coastal forest.

This article describes the work Hitachi has been undertaking since immediately after the earthquake on assisting with damage assessment surveys of electrical and instrumentation equipment and on restoring these systems. It also describes the Koriyama Monitoring Center, the design of which draws on this experience and seeks to spread the risk in the event of another disaster.

FACILITY OVERVIEW AND DAMAGE SITUATION

With a capacity of 398,900 m^3 per day, the Minami-Gamo Sewage Treatment Center treats approximately 70% of sewage from Sendai City. Treatment is performed using the standard activated sludge method, with the resulting sludge then being concentrated, dried, and incinerated. Most electrical equipment at the facility was supplied by Hitachi.

The maximum height of the tsunami when it struck the coast was about 10.5 m, and about 4.0 m in the vicinity of the Teizan canal that flows through the site. At the water treatment facility located between the coast and canal and the extra-high voltage electrical room located adjacent to the canal, foundation piles, earthwork walls, and buildings were damaged by the impact force of the tsunami and from uprooted trees and other floating debris. This rendered the electrical equipment located outside or on the ground floor or

Fig. 2—Damage Survey in Progress.
Conducting the survey on a site still bearing the scars of the disaster was a difficult task.

basement of buildings unusable due to flooding or to being washed away.

Of the 1,486 items of electrical and instrumentation equipment that had been supplied to the Minami-Gamo Sewage Treatment Center, 966 items (65%) were assessed as being a total loss or partially damaged.

WORK ON MINAMI-GAMO SEWAGE TREATMENT CENTER RECONSTRUCTION

Support for Damage Assessment Surveys

A post-earthquake on-site survey commenced on March 28 in response to a request issued on March 24 by Sendai City and Japan Sewage Works Agency, a public organization. The subsequent assessment report was submitted on April 11. To ensure consistency with other disaster response agencies (local government) in matters such as decision-making procedures and reporting, a second round of surveys commenced on May 9, with a final report submitted on June 6. A total of 504 people were involved in conducting the electrical and instrumentation equipment survey over a 35-day period, with that number rising to around 600, including those involved indirectly in tasks such as finding and collating existing equipment drawings.

Along with the difficulty of obtaining gasoline, food, and drinking water, the survey also faced difficult sanitary challenges with the site still bearing the scars of the recent disaster (see Fig. 2).

Measures Aimed at Progressive Improvement in Quality of Discharged Water

Because it was recognized that the water treatment facility had suffered such severe damage due to the disaster that it would take around five years to fully restore operation, an emergency restoration of operation was undertaken with reference to the content of the Ministry of Land, Infrastructure, Transport and Tourism's "Second Proposals of Technical Committee on Earthquake and Tsunami Countermeasures for Sewerage Systems"(3), with the aim of progressively improving the quality of discharged water (see Fig. 3).

Specifically, prior to full restoration of operation, the plan was to first achieve BOD* of 120 mg/L using sedimentation and disinfection, followed by BOD in the 60- to 15-mg/L range using a combination of biological treatment, sedimentation, and disinfection. The reconstruction of electrical equipment was also scheduled to satisfy this plan.

Work on Sedimentation and Disinfection

Work on installing temporary electrical equipment started on April 21, with a temporary switchboard (electrical control panel supplying equipment that included four automatic dust extraction systems and 36 sludge scraping machines) installed on May 2, a temporary distribution panel on May 9, and a backup high-voltage (6 kV) electrical system on May 12. These enabled operation to restart on May 19.

To process the sludge removed from the simple treatment process, an alternative controller held at the factory was used to restore makeshift operation by replacing the earthquake-damaged HISEC-R600 controller in the sludge processing building. This enabled a resumption of sludge drying using the centrifugal dryers.

Subsequently, automation of the sodium hypochlorite injection system (automatic control using a temporary inlet flow gauge) was achieved during July.

Work on Biological Treatment, Sedimentation, and Disinfection

To commence operation of the interim treatment facility using the contact aeration process, a power system of about 1,500 kVA was needed to provide electric power to equipment such as the blowers that deliver the air for aeration.

As the site was still running on emergency backup power (up to 2,000 kW) at this time, a temporary standard 2,000-kVA generator able to operate continuously (24 hours a day) and outdoor fuel tanks with sufficient capacity for around 72 hours of continuous operation (approx. 33,000 L) were procured. Once these had been registered with the

* Abbreviation of "biochemical oxygen demand." The amount of oxygen required by microbes to breakdown organic material and other pollutants in the water.

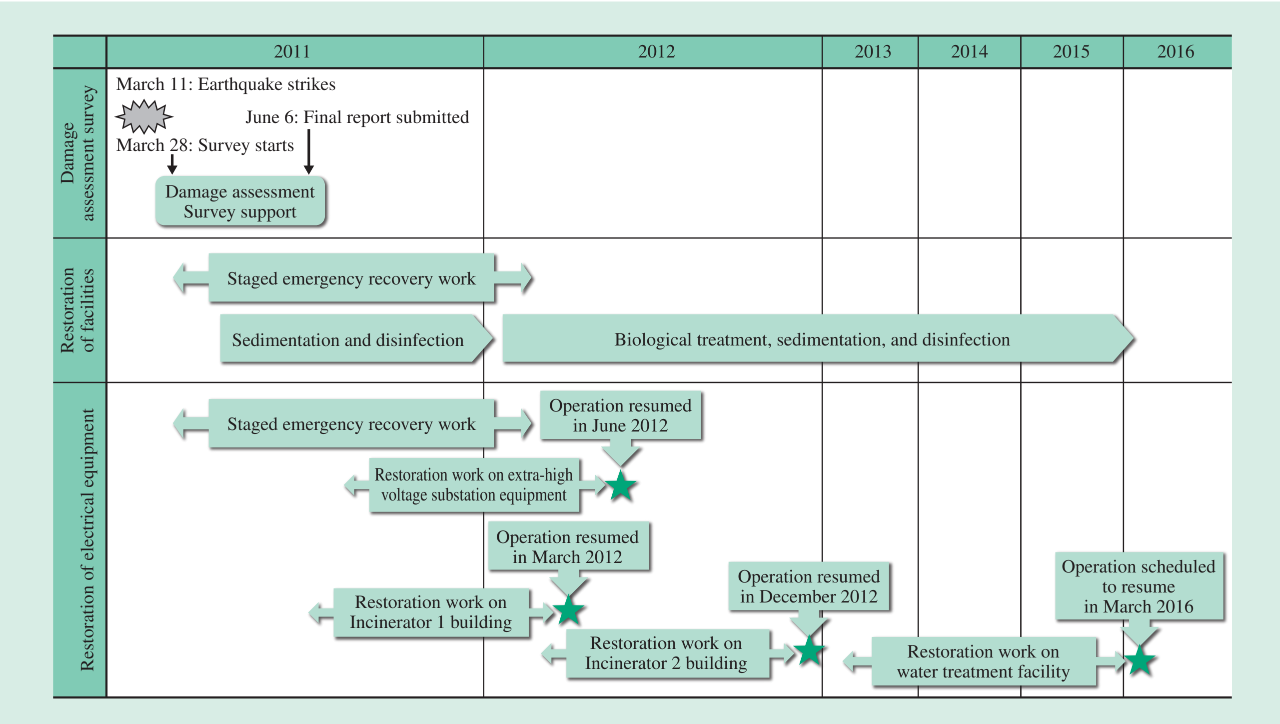


Fig. 3—Work on Minami-Gamo Sewage Treatment Center Reconstruction.
Reconstruction work has been ongoing since the immediate aftermath of the disaster.

authorities and subjected to inspection, operation of the interim treatment facility using the contact aeration process was able to commence in February 2012.

Work on Full Restoration of Extra-high Voltage Substation Equipment

The gas-insulated switches (GISs) that had been located on an outdoor, above-ground compound were deemed irreparable due to the ingress of seawater, so the gas was recovered from the tanks and the units were removed and disposed of on September 20. On the other hand, it was decided to take the transformers that had escaped damage due to water ingress back to the factory for refurbishment, and work commenced on their removal. In April of 2012, the replacement GISs were delivered to the site together with the refurbished transformers that had been cleaned, dismantled, had their radiators replaced, and repainted. After testing, adjustment, and a voluntary pre-operational inspection had been completed, supply of extra-high voltage electric power went live on June 12, more than a year after the earthquake (see Fig. 4).

Work on Full Restoration of Sludge Incinerator

The ground floors and underground floors of the sludge incinerators located on the landward side of the water treatment facility were flooded and suffered water damage.

As was the case with the simplified operation of the water treatment facility, restoring the incinerators used to dispose of the dried sludge was an urgent priority. Demolition of Incinerator 1 commenced in August 2011 and it went back into service in March

GIS: gas-insulated switch

Fig. 4—Fully Restored Extra-high Voltage Substation Equipment (GIS).
By locating structural components on a raised embankment, the restored GISs are located about 10 m above the ground line.

2012 at the same time that the routine operation of the emergency backup generator was restored. Similarly, demolition of Incinerator 2 commenced in February 2012, and following its complete reconstruction, went back into service in December of the same year.

For the reconstruction of the sludge processing building, because the damaged HISEC-R600 controller in the ground-floor low-voltage electrical room was a discontinued product, a system-compatible HISEC-R700 was used instead to avoid any impact on the overall system.

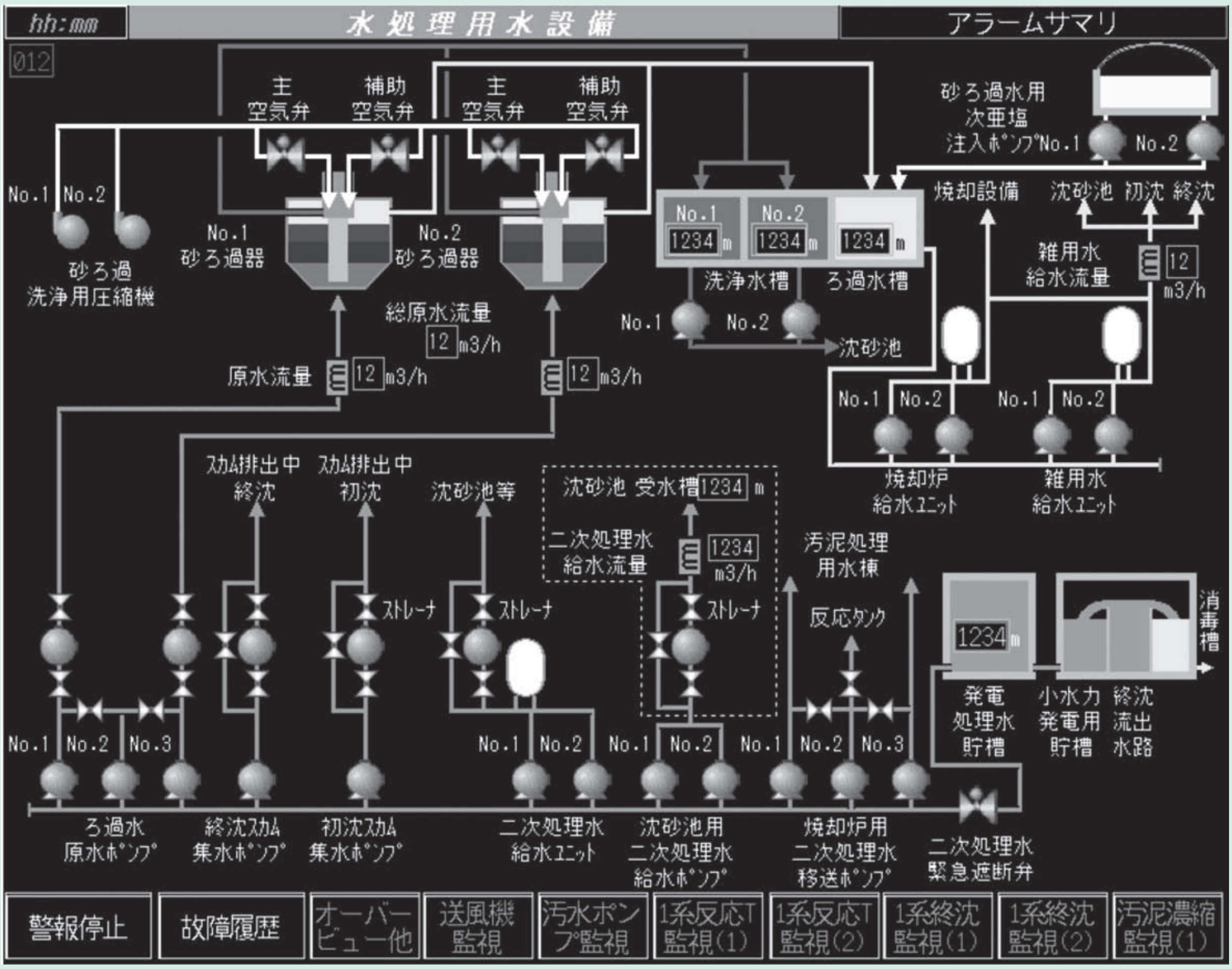
Work on Full Restoration of Water Treatment Facility

The full restoration of the water treatment facility was undertaken using a different process than before, including the use of a deep-layer reaction tank.

Because the associated earthworks and mechanical equipment involved nine projects spread across seven companies, Hitachi coordinated its design, fabrication, and installation activities across the group to coordinate work on the different projects as they proceeded in parallel and to keep them on schedule.

To allow for future functional enhancements, Hitachi took the proactive step of adopting the latest XR1000H controller for the monitoring and control system.

In adopting the latest controller, Hitachi also gave adequate consideration for undertaking this work in ways that maintain compatibility with the existing Hitachi's central monitoring and control system located on the second floor of the administration building where it escaped damage, and the HISEC-R700 controllers used on parts of the site that had already



LCD: liquid crystal display

Fig. 5—Screen for Monitoring Other Equipment (Example).
In addition to the monitoring and operation of equipment controlled by the controller, the LCD touch panels can also be used for process monitoring of other associated equipment.

been restored to operation, such as the extra-high voltage substation equipment and on-site power generation equipment.

One of the features of the monitoring and control system is a function for monitoring other equipment.

In terms of monitoring other equipment, this function provides liquid crystal display (LCD) touch panels on the exterior of the XR1000H controllers located in each electrical room that can be used to monitor other associated equipment as well as to monitor and operate the equipment controlled by the controller. This enables workers to obtain the required information on the spot even if they lack a portable tablet or are not in telephone contact with the central control room (see Fig. 5).

Work is also proceeding on providing energy-saving and energy-generating infrastructure at the new water treatment facility by installing photovoltaic- and microhydro power-generation equipment.

REMOTE MONITORING AND CONTROL SYSTEM FOR SENDAI CITY KORIYAMA MONITORING CENTER

The sewage and storm water pumping stations in Sendai City are divided up into a northern sector (20 stations) and a southern sector (16 stations), with centralized monitoring and control performed at the Rokuchome Monitoring Center.

Based on the experience of the Great East Japan Earthquake, upgrade work on the Koriyama Monitoring Center was completed in FY2014, including a broadband Ethernet link connecting the Rokuchome Monitoring Center and Koriyama Monitoring Center that allows centralized monitoring and control to be performed at both centers. The monitoring and control database for the southern sector pumping stations (server for southern sector clients) was installed at the Koriyama Monitoring

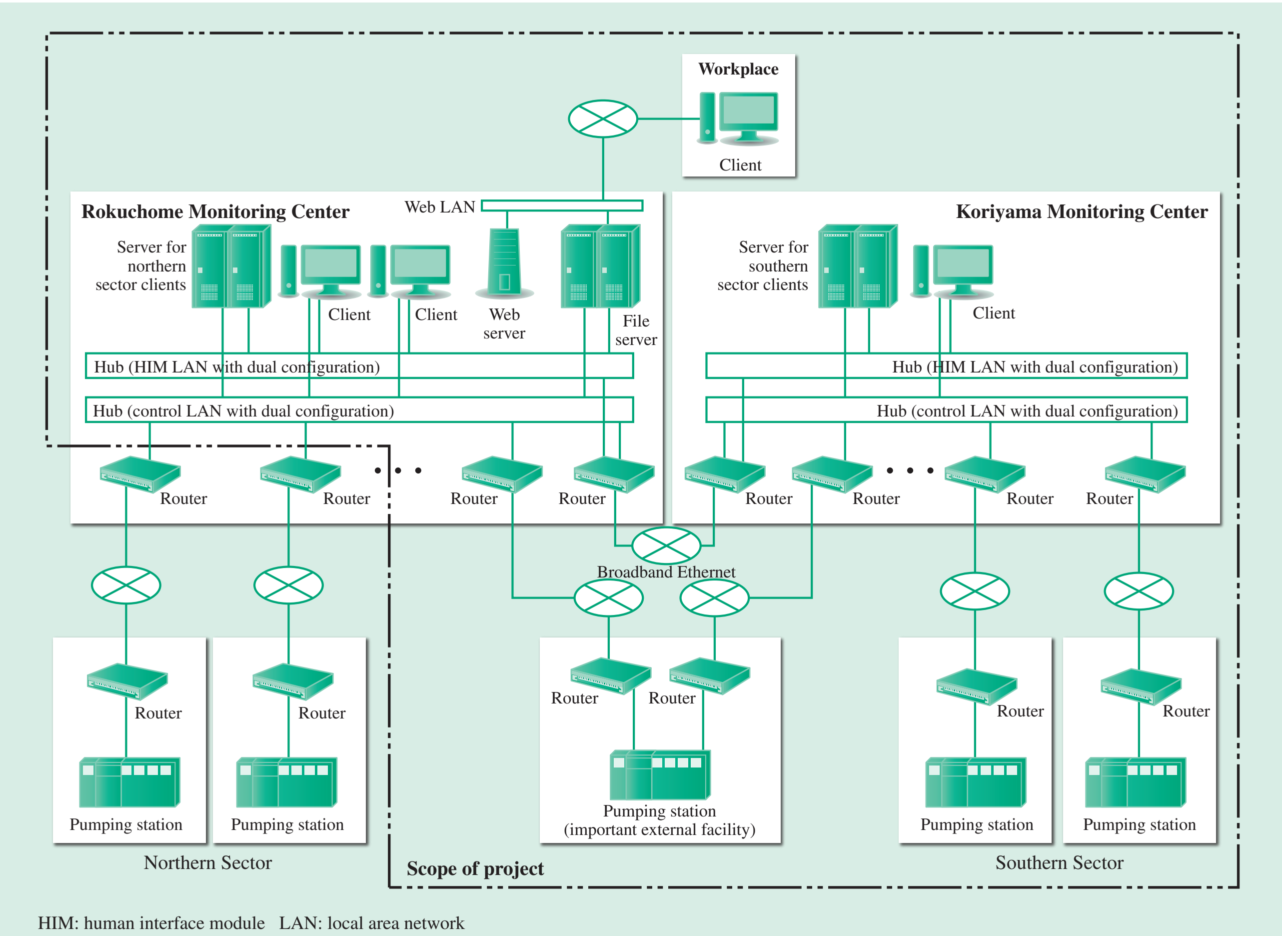


Fig. 6—Remote Monitoring and Control System.
In addition to allowing monitoring and control from both the Rokuchome Monitoring Center and Koriyama Monitoring Center, the broadband Ethernet connection has also enabled the monitoring and control database (client/server) to be installed at both centers to spread the risk.

Center to spread the risk between the different data management facilities (see Fig. 6). Similarly, to improve reliability, a dual system configuration is used for data transmission to the two monitoring centers from three important external facilities.

ELECTRICAL EQUIPMENT ABLE TO COPE WITH DISASTERS

Based on the lessons learned from this experience, Hitachi has considered how to make electrical equipment that is resilient to disasters (minimizing or eliminating damage).

Installation Conditions for Electrical Equipment

(1) Install equipment in a location that is higher than the anticipated level of flooding

With the exception of the water treatment facility located on the shoreline, the electrical equipment installed on the second floor or higher largely escaped flooding damage during the disaster. This means it is a good idea to install substation equipment, electrical distribution systems, direct current power supplies, on-site power generation equipment, central monitoring and control systems, and other such equipment above the level where flooding damage is likely to occur (on a higher floor) (see Fig. 7). In the case of the Minami-Gamo Sewage Treatment Center, equipment was installed above the anticipated level of flooding by using embankments to raise the height by 10.4 m.

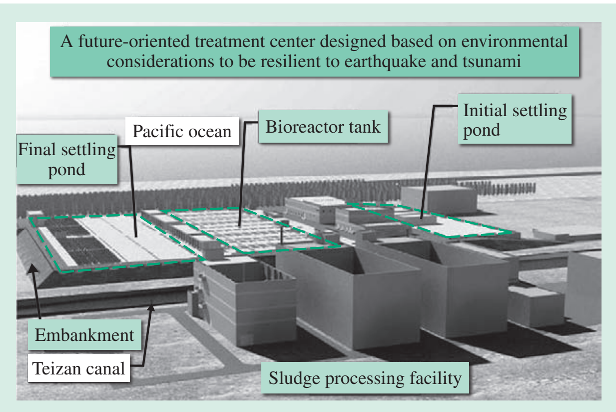


Fig. 7—Construction of Facilities Above Anticipated Maximum Flood Level.
To prevent tsunami damage to structures and avoid loss of equipment and other functions, the facilities were rebuilt on a raised embankment, which in the case of the Sendai City Minami-Gamo Sewage Treatment Center is 10.4 m above ground level.

(2) Dual routing of power and communications

Because electrical equipment forms part of a system, the effects of a failure in one part spread across the entire system. One practice for preventing this has been to use duplicate power and communication cables depending on the importance of the equipment and to provide multiple routes to keep faults to a minimum by being able to keep the system operating using an undamaged route even if some routes are damaged.

Quick Restoration of Electrical Equipment

This section describes how to achieve a quick restoration of operation, with reference to onsite-experience with disaster recovery work. This disaster recovery involved working on earthworks, construction, machinery, and electrical equipment in parallel. Of these, electrical equipment is the last to be specified and the last to commence on-site installation.

The requirements for this work are to shorten design and fabrication schedules and to reduce the amount of on-site work such as installation and commissioning.

(1) Shortening design and fabrication schedules

Along with organizational capabilities for tasks such as procuring labor and sourcing parts, the challenges of undertaking recovery work over a long period of time also include the standardization of design drawings across equipment of the same type.

Examples of this include standardizing the electrical specifications (currents, cable connection procedures, and so on) for scraping machines or the valves used in machinery. Because this enables the adoption of standardized practices after the reconstruction and facilitates maintenance and management, it is necessary to deal with machinery and electrical equipment as a single unit.

(2) Reduce volume of installation, commissioning, and other similar work

Because obtaining technical staff and workers is difficult after a large disaster that affects a wide area, Hitachi believes it is important to cut workloads by reducing the number of electrical parts such as cables that need to be installed.

For example, cabling requirements can be reduced by housing controller input and output devices in an auxiliary relay panel that connects to the controller panel via a communications link (see Fig. 8).

Hitachi also believes that future sites of reconstruction work will need to consider things like incorporating input and output devices into on-site operation panels that have been put together based on

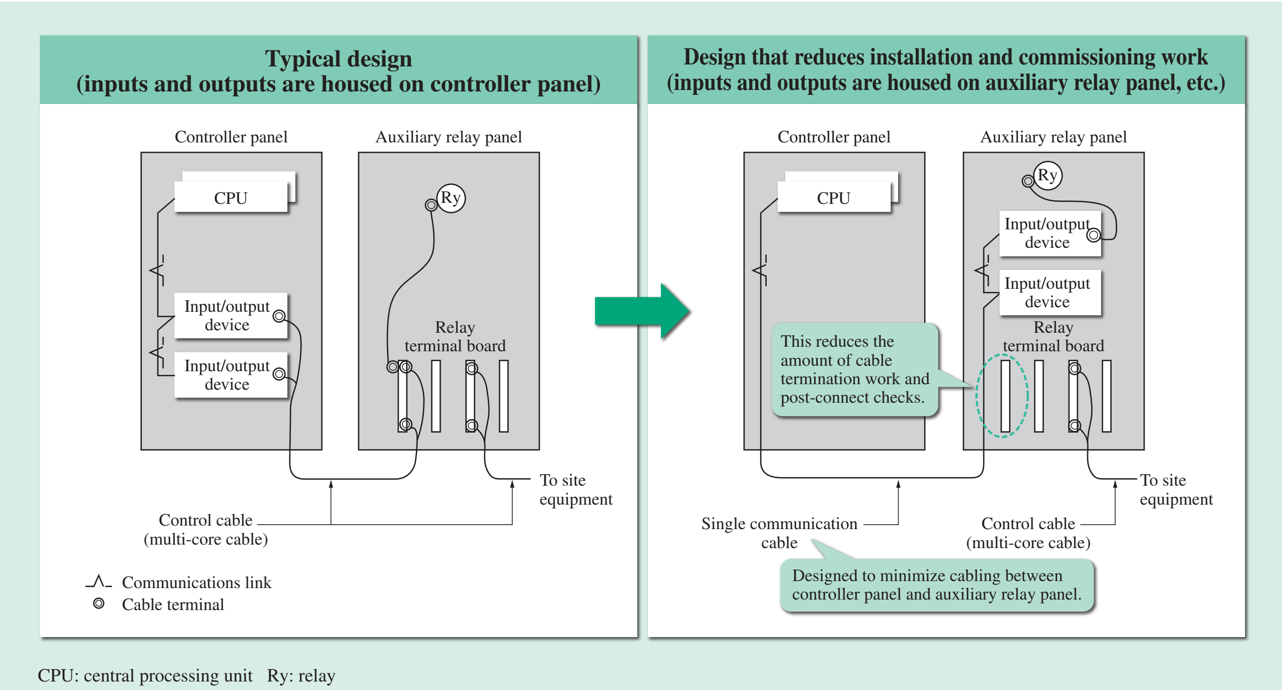


Fig. 8—Reduced Cabling Design.
This is one example of how to enable a quick restoration of operation despite the likely shortage of technical staff after a large disaster affecting a wide area.

engineering considerations, and the use of portable tablets for on-site operation.

CONCLUSIONS

This article has described Hitachi's involvement in reconstruction of the Minami-Gamo Sewage Treatment Center in Sendai City from immediately after the earthquake until the present day.

Hitachi intends to continue to fulfill the expectations placed upon it and provide disaster assistance by utilizing the experience and knowledge gained from this involvement and working with local governments affected by disasters.

Finally, the authors would like to express their sincere thanks to everyone who participated so diligently in the reconstruction work, and to the families who provided them with ongoing support, despite themselves being among the victims of the disaster.

REFERENCES

(1) Planning Committee for Reconstruction of Minami-Gamo Sewage Treatment Center, "Proposal for Reconstruction of Minami-Gamo Sewage Treatment Center in Sendai City" (Sep. 2011) in Japanese.
(2) The Society of Environmental Instrumentation Control and Automation (EICA), "Report of the Great East Japan Earthquake Investigation," (Feb. 2012) in Japanese.
(3) Ministry of Land, Infrastructure, Transport and Tourism, "Second Proposals of Technical Committee on Earthquake and Tsunami Countermeasures for Sewerage Systems, Staged Emergency Recovery Measures (Overview)" (Jun. 2011) in Japanese.
(4) Sendai City, Sendai City Sewage Portal Page, http://www.city.sendai.jp/gesui/1203364_2478.html in Japanese.

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