Lessons Learned from The Great East Japan Earthquake and Tsunami ~ Restoration and Reconstruction of Power Facilities ~

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Major Facilities (Consolidated basis) (as of March 31, 2016)

- **Power Stations (Total)**: 259, 18,812 MW
  - **Hydro**: 226, 2,538 MW
  - **Thermal** (including internal combustion): 13, 12,725 MW
  - **Renewable**: 18, 276 MW
  - **Nuclear**: 2, 3,274 MW

- **Transmission Facilities**
  - **Line Length**: 15,212 km
  - **Circuit Length**: 24,794 km
  - **Supports**: 58,229

- **Substations**: 627, 75,211 MVA

- **Distribution Facilities**
  - **Line Length**: 146,550 km
  - **Circuit Length**: 583,091 km
  - **Supports**: 3,088,541

Tohoku Electric Power
The 9.0-magnitude Great East Japan Earthquake hit the wide area of northeast coast of the main island of Japan on March 11, 2011. It was the most powerful earthquake ever recorded to have hit Japan, and the fourth most powerful earthquake in the world since modern record-keeping began in 1900.

The subsequent gigantic tsunami caused devastating damages across the coast in the Tohoku region, where Tohoku Electric Power Co., Inc. supplies electricity.
Damages of Facilities ~ Nuclear Power Station ~

<table>
<thead>
<tr>
<th>Location</th>
<th>Status</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higashidori</td>
<td>In regular maintenance: 1 unit (in stoppage)</td>
<td></td>
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<tr>
<td>Onagawa</td>
<td>In operation: 2 units</td>
<td></td>
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<tr>
<td>Onagawa</td>
<td>In regular maintenance: 1 unit (in starting process)</td>
<td>* All three units safely cold shutdown.</td>
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Onagawa Nuclear Power Station

A heavy oil tank for unit 1. (Collapsed)

Accessory of reactor building for unit 2. (Sea water flooding.)

Tsunami Height
Approx. 13 m (**)

Ground level
Approx. 13.8 m (*)
above the O.P. (***)

The height of the ground was determined to be 14.8m taking into consideration the records of tsunami in the past. The tsunami did NOT exceed the height of the ground.

(* Considering subsidence of 1m due to the earthquake,  ** Trace of tsunami: Maximum 13.8m  *** Onagawa NPS datum plane for construction, -0.74m below standard mean sea level of Tokyo Bay)
One out of 5 transmission line circuits continued power transmission. Six out of 8 emergency diesel generators were integral.
Max. 364 residents who suffered from the tsunami took shelter in a facility of Onagawa Nuclear Power Station for max. about three months.

We served food and blankets for them, and transported expecting mothers and those who needed medical treatment to hospitals in Sendai city using our helicopter.

The activity was highly evaluated and the station was awarded by WANO.

IAEA Expert Team investigated the Onagawa NPS in summer 2012, and published a report.

“It was concluded that the facilities of the Onagawa NPS remain “remarkably undamaged” given the magnitude, distance and duration of ground shaking.”

(IAEA Mission to ONAGAWA nuclear Power Station to examine the Performance of Systems, Structures and Components Following the Great East Japan Earthquake and Tsunami, 30 July - 11 August 2012, IAEA MISSION REPORT)
For enhancing safety, various countermeasures are being taken including seismic reinforcement, building about 15m-height seawall, securing emergency power supply, and enhancement of cooling and containment functions.
Haramachi Thermal Power Station with a capacity of 2,000 MW was devastatingly damaged by the about 18m-height tsunami.

Thanks to the strenuous reconstruction effort on 24-hour basis, it resumed full operation in April 2013, which greatly improved the stability of power supply in the Tohoku region. As the damage was quite severe, it took as long as two years to resume the full operation.

The damages of thermal power stations decreased our generation capability greatly. In order to meet the power demand particularly in summer and winter

◆ Full operation of the undamaged power stations along the coast of The Sea of Japan.
◆ Purchase of power from other utilities in case of need.
◆ Asking customers to save energy.

We have achieved stable power supply without power interruption.
A great amount of debris destroyed substation structures and apparatuses. Some substations were submerged and some were nearly swept away by the tsunami.

A number of substation apparatuses such as transformers, disconnectors, and lightning arresters were broken by vibration.

Totally 75 substations were damaged.
Transmission towers were collapsed or tilted by massive debris, such as wave-dissipating concrete blocks and broken rails of railway, attacking them.

Jumper support long-rod insulators were broken by massive vibration.

Cable accessories, such as terminations and oil-filled tanks, were destroyed by the debris of the tsunami.

Totally 46 towers were damaged.
Some areas were nearly swept away and no poles and wires could be seen.

A great number of poles, wires, and accessories such as pole transformers were collapsed or broken.

Totally about 36,000 poles were damaged.
We set up temporary facilities for early restoration of power supply.

We restored power supply using vehicle-mounted transformers and cubicles.

Temporary apparatuses were used for restoration.

Satellite communication systems were set up where telecommunication systems were destroyed.

We built temporary substations near the damaged substations within three weeks after starting construction.
Toward early restoration ~Being all united, filled with a sense of mission.~

We reconstructed destroyed facilities for early restoration of power supply.

Workers were constructing a temporary tower, while they were still having fears of aftershocks.

Restoration work was carried out with the help of other utilities and many subcontractors willing to provide help.

We rebuilt distribution lines before debris had been cleared. The debris made restoration works very hard.

Once debris was cleared, the restoration work became highly efficient.
The earthquake caused a huge blackout in the wide area of the Tohoku region. The number of affected customers were maximum 4.66 million.

Nearly 80% of the customers were restored within 3 days after the earthquake.

The early restoration not only provided local residents with a sense of security, but also contributed to prompting the restoration works of other infrastructures.
Countermeasures

Against Tsunami
◆ Move substation to higher place where even larger tsunami CANNOT reach
◆ Elevate the ground and floor levels on which power apparatuses are placed
◆ Reinforce the strength of building
◆ Remove a portion of wall so that tsunami can passes through the building without damaging it.

For early restoration

We developed and installed air-transportable vehicle-mounted LV generator “ToMoS (Tohoku Mobile Speedy)”, which can be transported in a helicopter owned by the Japan Self-Defense Forces. The vehicle makes it possible to supply power to islands and to areas where access roads are cut off.

| Vehicle | Engine: gasoline, 660 cc  
Seating capacity: 2 |
|---------|-----------------------------|
| Generator | 100V/200V, 
13kVA/15kVA (50Hz/60Hz) |
| Weight | 492 kg (including diesel fuel (40 l.) |
| Continuous operation time | 10 hours with 75 % load |
Countermeasures

Against strong vibration
Applying flexible materials to substation apparatuses and transmission lines

- Polymer bushings of 154/66kV transformer
- 154kV Polymer cable terminations
- 154kV Polymer lightning arresters
- 275kV Polymer jumper support insulator

Tohoku Electric Power
We have been expanding the introduction of renewables being connected to our power grid.

Renewables connected to our power system

- **Solar**: 2.45 GW
- **Wind**: 0.8 GW

as of March, 2016

*The Great East Japan Earthquake*
Efforts for Achieving Sustainability

Field Test of Hydrogen manufacturing and the use of hydrogen for stabilization of power grid

<table>
<thead>
<tr>
<th>Hydrogen Manufacturing Rate</th>
<th>about 5Nm³/h</th>
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<tr>
<td>Hydrogen Tank Capacity</td>
<td>about 200 Nm³ (corresponding to about 300kWh when discharged)</td>
</tr>
<tr>
<td>PV</td>
<td>Output: about 50kW</td>
</tr>
</tbody>
</table>
| Fuel and Li-ion Batteries   | Fuel: less than 10kW  
Li-ion: about 60kWh |

Participation in Smart Community Project

“Smart Community” being field-tested by Ishinomaki City, and Toshiba (in collaboration)

“Smart Community” being field-tested by Ohira Village, Toyota Motor, and Toyota Motor East (in collaboration)
Ending

“Rebuilding of TOHOKU advances with Electricity”

Thank you