

Large Scale Blackout in Hokkaido Caused by the Earthquake on 6th September

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Hokkaido, Japanese Electricity Supply, and the Earthquake on 6th September

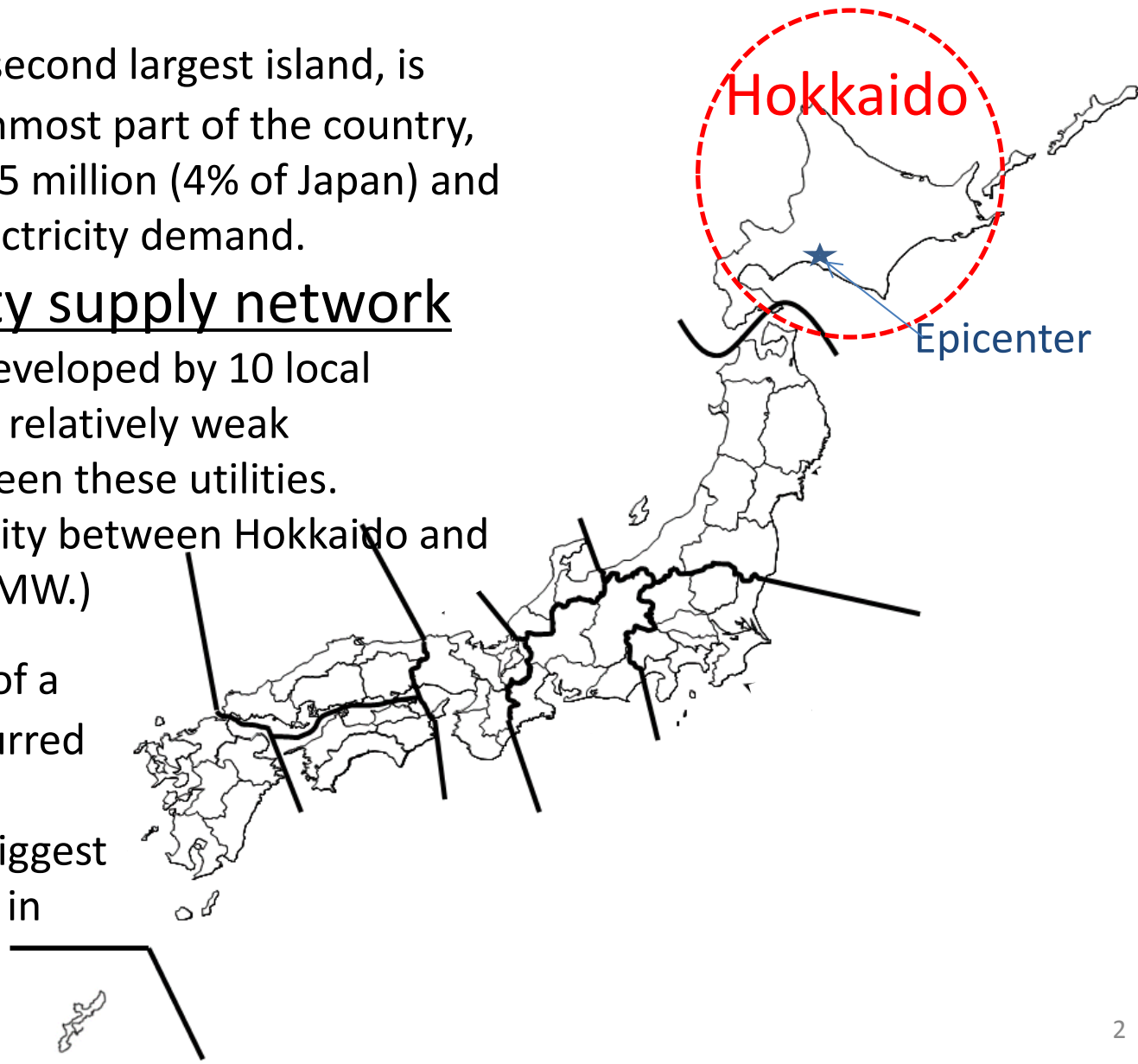
- Hokkaido, Japan's second largest island, is located in the northernmost part of the country, with a population of 5.5 million (4% of Japan) and 5.3 GW of the peak electricity demand.

- Japan's electricity supply network

has historically been developed by 10 local dominant utilities with relatively weak interconnections between these utilities.

(Interconnecting capacity between Hokkaido and the main island is 600 MW.)

- An earthquake of a magnitude of 6.7 occurred at 03:08 AM on 6th September with the biggest tremor ever observed in Hokkaido's history.



First Utility-area-wide Blackout in Japan

- Power plants and transmission lines near the epicenter were damaged by the strong tremor, which led to area-wide frequency fluctuation and the whole area being blacked out 17 minutes after the earthquake.
- First utility-area-wide blackout in Japan which involved 3 million households served by the Hokkaido Electric Company (HEPCO).
- The recovery of power supply to the whole area took 45 hours. Due to supply shortage, industries and households were requested to reduce their electricity demands for two weeks.



The Investigation Committee for Reviewing the Blackout

- On 10th September, the Minister of Economy, Trade & Industry ordered an investigation into the cause of the blackout and the appropriateness of the recovery process.
- On 25th October, the Investigating Committee issued an interim report composed of the following points:
 1. From the earthquake to the blackout
 2. Recovery from the blackout
 3. Measures to prevent a recurrence

1. Earthquake to Blackout (Frequency fluctuation) (03:08 to 03:25 AM)

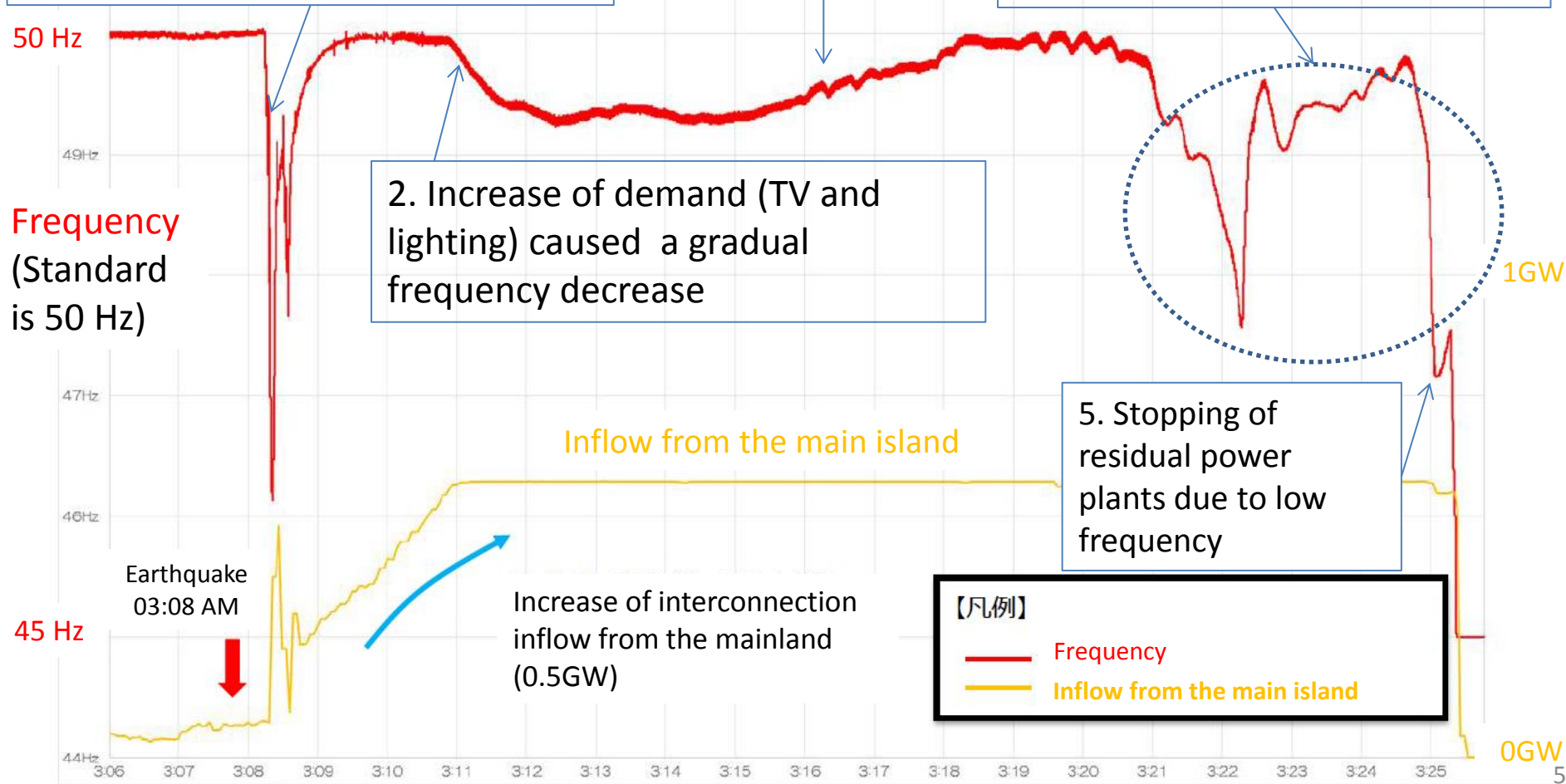
1. Initial outage of power plants (totally 1.8GW; coal-fire 1.2GW, wind 0.2GW, hydro 0.4GW) and load rejection (1.3GW)

3. Increased output from undamaged power plants

4. A decrease in output of a power plant (0.3GW) & loss of frequency control measures led to severe fluctuation

2. Increase of demand (TV and lighting) caused a gradual frequency decrease

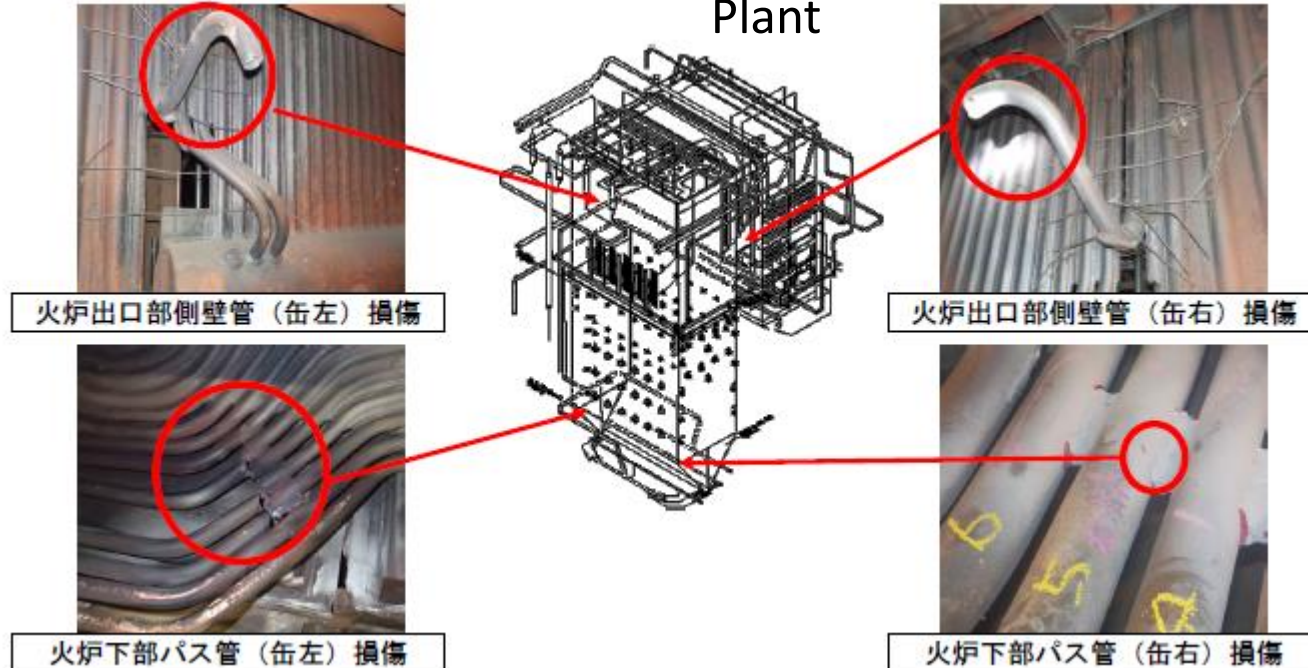
5. Stopping of residual power plants due to low frequency



Coal-fire Power Plant Near the Epicenter

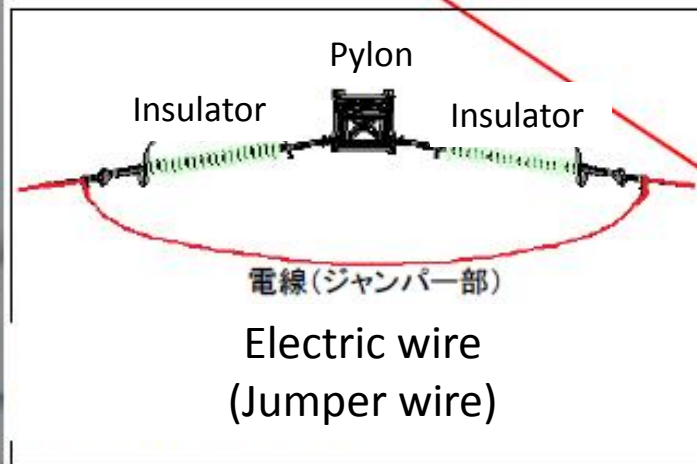
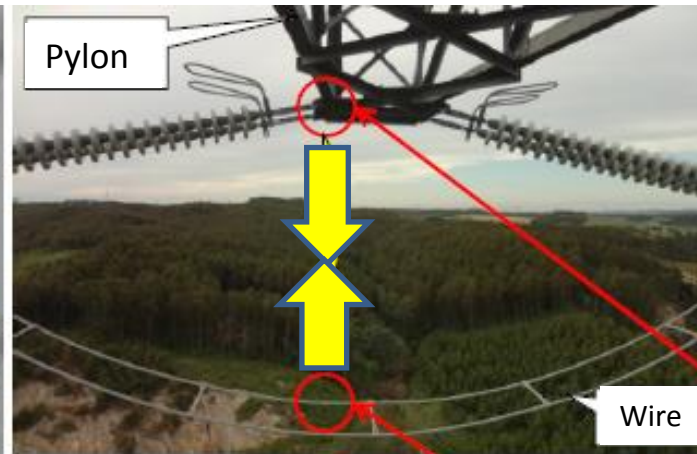
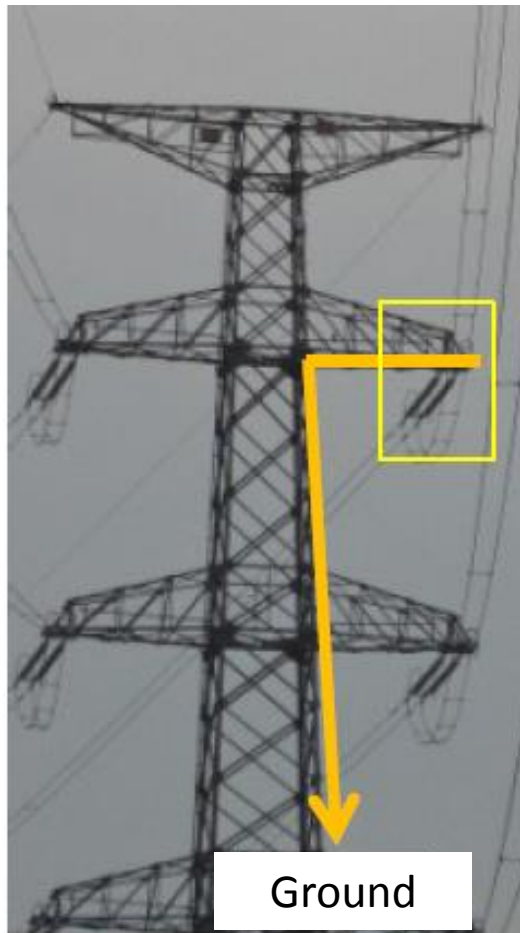
- At the moment of the earthquake, three reactors at the Tomato-Atsuma coal fire power plant were supplying 1.5 GW, which was nearly half of Hokkaido's electricity demand.
- Due to the strong tremor, all three reactors stopped working.

Damage in the boiler pipes of the 2nd reactor at the Tomato-Atsuma Power Plant

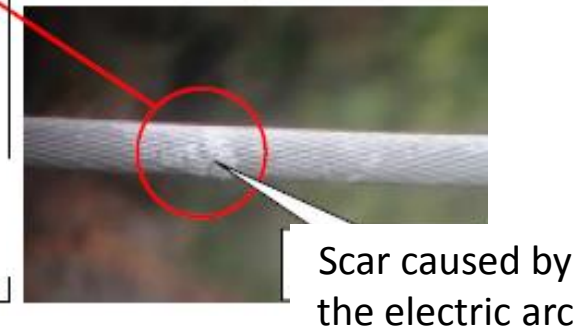


Transmission Trouble and Stopping of Hydro Power

- Four transmission routes connecting eastern Hokkaido to the demand center were temporarily cut off by a ground fault.



It is estimated that the short circuit happened between an electric wire and a pylon due to the strong tremor.



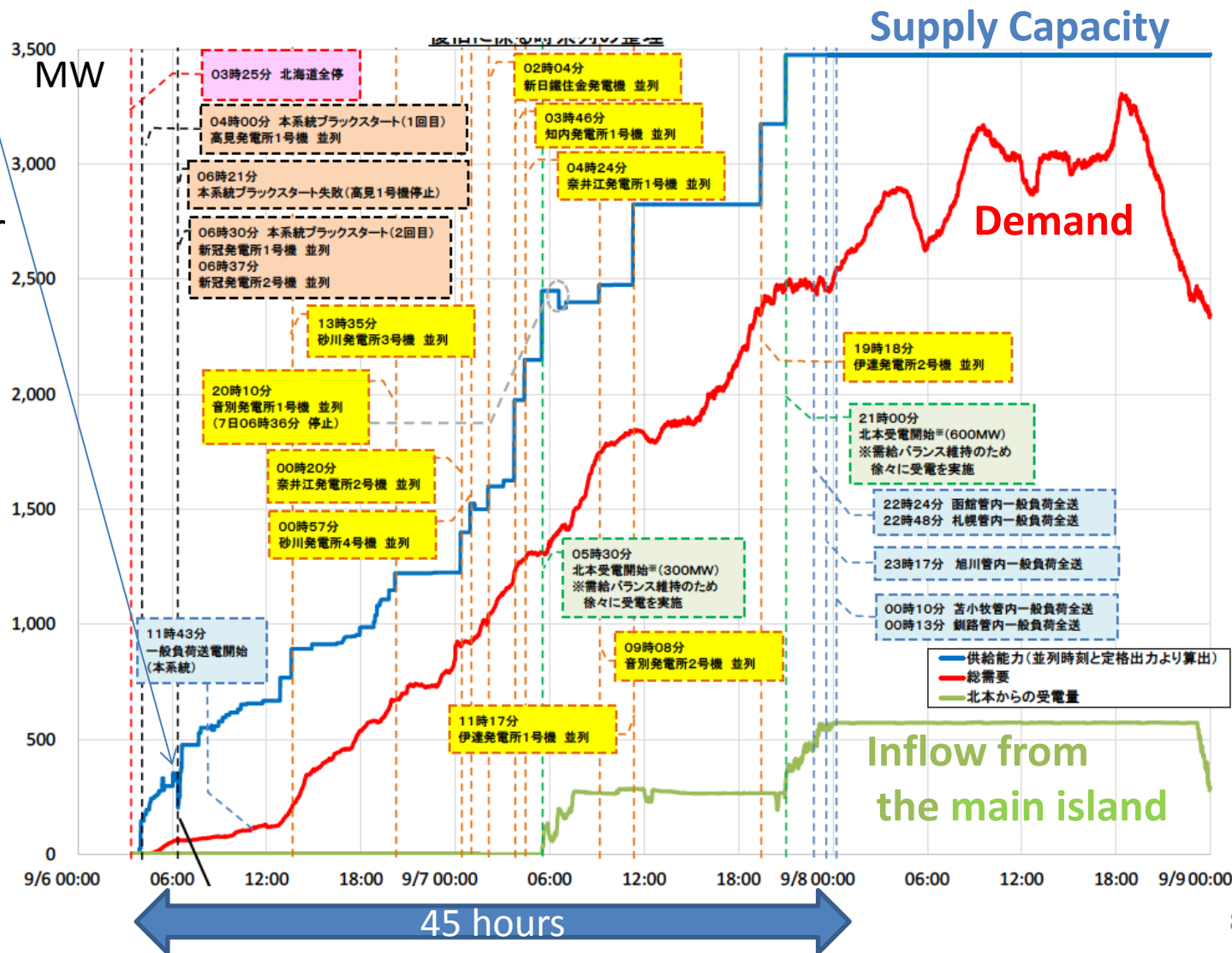
- Temporary transmission cut caused a frequency spike in eastern Hokkaido and undamaged hydro power plants (0.4 GW) were stopped by OFR.

2. Recovery from the Blackout (45 hours)

- During the recovery process, HEPCO followed the procedural manual for black-starts which prescribes the gradual starting of power plants.

- First black-start attempt (04:00)** failed because the shunt reactor in a substation stopped due to an abnormal current.

- Second black-start attempt (06:30)** used auxiliary transformers to avoid the same accident.



Summary of Interim report

1. From the earthquake to the blackout

- Combined factors of three reactors outages (N-3) and four transmission line cuts (N-4) led to a frequency fluctuation.
- Interconnection to the main island initially worked, but not sufficiently to cover the loss of major fire and hydro power plants.

2. Recovery from the blackout

- While following the procedural manual, the first black-start attempt failed.
- With the second attempt, recovery was successful, but still took 45 hours to resupply the whole area.

3. Short-term measures to prevent recurrence

- Revision of the upper limit of load rejection (+350MW).
- Keeping a pump storage power plant (dormant at the time of the earthquake) on standby status to be prepared for the same level of supply disruption. etc.

Mid- to Long-term Challenges

The Japanese government will assess the necessity of both operational measures and investment.

<Operational measures>

- Upgrading the UFR (Under Frequency Relay) rules on Hokkaido.
- Upgrading rules for releasing VRE generators from the grid.
- Revising the frequency control mechanism on Hokkaido (including governor-free generators and AFC).

<Capacity investment measures>

- Investment to utilize and expand the capacity interconnection line to the main island.