The Investigation Committee on the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake

Final Report

(Text)

December 19, 2018

The Investigation Committee on the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake

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Introduction

With the 2018 Hokkaido Eastern Iburi Earthquake that occurred at 3:07 on September 6, 2018, a major blackout (hereinafter referred to as "blackout") occurred all over Hokkaido area, which was the first time in Japan after the establishment of the 9 electric power companies in 1951 (10 electric power companies in 1972).

Along with this, on Sep 11, 2018, Hiroshige Seko, the Minister of Economy, Trade and Industry issued an order to Hokkaido Electric Power Company and Organization for Cross-Regional Coordination of Transmission Operators, Japan (hereinafter referred to as “OCCTO”) to investigate the cause of the major blackout.

Following this order, OCCTO established "the Investigation Committee on the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake" (hereinafter referred to as "the Investigation Committee"), to ensure that highly transparent and impartial investigations are performed involving third parties based on objective data from a neutral /fair position. In addition, the Investigation Committee carried out investigations to respond to the consultation topics determined by OCCTO.

Based on the fact that some report was required by October 2018 as indicated in the Advisory Committee for Natural Resources and Energy, Electricity and Gas Industry Committee, Electricity and Gas Basic Policy Subcommittee (Hereinafter referred to as "Strategic Policy Subcommittee on Electricity and Gas"), and as the Investigation Committee had almost completed the understating of actual facts and identification of problems through their investigation operations, it was decided to compile and publish the interim report, and OCCTO published and submitted it to the Minister of Economy, Trade and Industry on October 25[1]. In addition, on the same day, the interim report was discussed in the second meeting of the Working Group on Electricity Resilience, which was established under Strategic Policy Subcommittee on Electricity and Gas, and the Consumer Product Safety Subcommittee under Industrial Structure Council and Electric Power Safety Subcommittee under Industrial Safety, for discussing the issues and measures in building highly resilient power infrastructure and systems.

The interim report included the facts found in the investigation thus far on the sequence of events from the occurrence of the earthquake to the blackout, and the sequence of events from the blackout to securing a certain level of supply (about 3,000MW), discussions and

[1] In addition, the investigation committee compiled an interim report (supplementary edition) (references) on October 31, 2018 and on the very same day OCCTO submitted it to the Minister of Economy, Trade and Industry, and also made it available to the public.

recommendations of recurrence prevention measures from a technical perspective based on aforementioned facts that had partially been confirmed through simulations.

Note that as recurrence prevention measures, considerations and recommendations were incorporated considering that it was the responsibility of the Investigation Committee to investigate not only on the measures to be implemented at an early point 2018/19, but also to investigate on the mid-to-long term measures as much as possible in order to enable the Government to start investigations on mid-to-long term measures early based on this event, and present it in the interim report.

In addition, even for the matters taken up in the interim report, the elucidation of related facts was not complete, and specific evaluation at that time was difficult. For such matters, it was decided to report the results in the final report after elucidating the related facts.

Meanwhile, in parallel with the investigations by the Investigation Committee, discussions required for the consolidation of facts related to the series of disasters since the summer of 2018, such as heavy downpour in July 2018, typhoon no. 21 and typhoon no. 24 during 2018, Hokkaido Eastern Iburi Earthquake in 2018, etc., were conducted by the Working Group on Electricity Resilience for reporting and discussing overall inspection results of power infrastructure and for identifying problems, and specific decisions were made on the measures to be taken in the future. Thus, the interim report was prepared on November 27, 2018 and was made available to the public.

Overall inspection was conducted by the Working Group on Electricity Resilience on 2 items, “the entire network” and “individual facilities such as thermal power generation facilities”.

Overall inspection of “the entire network” was conducted based on the recently occurred events and the interim report of the Investigation Committee. In specific, as risk investigation on the occurrence of blackout due to the tripping of the largest site, investigations were conducted on:
1) Would there be blackouts due to frequency drop even in the case of tripping of the largest site during the most severe scenarios, and are necessary measures taken for operations, etc.?
2) Are there places where there are possibilities of blackout due to frequency drop similar to the current event (functional shutdown of the largest power supply site, important substation, etc.) because of N-4 transmission line accident in critical transmission lines?
Note that in the Hokkaido area, it is recommended to take response measures based on the interim report of the Investigation Committee and the discussions in the second meeting of Working Group on Electricity Resilience.

As a result of investigation for the tripping of the largest site, in preparation for the tripping of Tomato-atsuma Power Plant, which is the largest site currently in operation in Hokkaido area, it was recommended that operations be carried out at present (winter 2018/19) based on the interim report of the Investigation Committee as investigations, including the methods of specific operations, have been completed. In addition, for the final report, the plan is to investigate based on the simulations of cases where the Tomato-atsuma Power Plant has tripped after commercial operations of the new Hokkaido-Honshu HVDC Link and Ishikariwan-shinko Power Plant in Feb-Mar 2019, and the case where Tomari Power Plant, which is currently in long-term shutdown, trips after the resuming operations. Also, it has been decided to take the necessary measures based on the investigation results.

As a result of investigations for the N-4 transmission line accident, during the investigations and discussions by the Investigation Committee and second Working Group on Electricity Resilience based on the N-4 accident in the voltage range of 275 kV or lower, Hokkaido Electric Power Company decided that it is necessary to investigate appropriate recurrence prevention measures in dense areas of transmission lines in the vicinity of important substations. Also, it was evaluated that “Blackout will not occur” by taking necessary measures even for the transmissions lines near other power plants in the area.

In addition, considering the impact of the series of disasters since the summer of 2018 on people's lives and economic activities, as an initiative of the entire government, emergency inspections were conducted throughout Japan, so that important infrastructures which support human life such as electric power can maintain its function in face of all disasters. On Nov 27, in the second conference by the Ministerial Council on Emergency Inspection of Critical Infrastructures, the results of emergency inspections and measures taken by the government were compiled and made available to public. The contents of the interim report by the Working Group on Electricity Resilience has been incorporated in the results of emergency inspections and measures taken by the government.

After the interim report, the Investigation Committee has carried out further investigation including analysis using detailed simulations, to investigate on the effectiveness of mid-to-long term measures. The interim report of the Working Group on Electricity Resilience and the government's response measures were compiled. Not only from the viewpoint of the blackout in Hokkaido, but also from the viewpoint of improvement of a nationwide and even wider electricity resilience, both government and OCCTO are transitioning to a state where discussions are being carried out so as to obtain specific conclusions on “medium term measures”, which starts immediately after compilation, by next spring. In addition to the above fact, as the investigation on the problems to be solved and the investigation on the effectiveness of mid-to-long term measures have been completed, it was decided to compile and publish the final report.

The final report shall be based on the interim report, and shall be a revised version with the addition of further investigation results by the Investigation Committee, study results on the investigation results and measures by the Government, etc.

In addition, the final report shall contain the facts found in the investigation so far from the occurrence of this earthquake to blackout, and from blackout to securing a certain level of supply (about 3,000 MW), confirmations through simulation based on aforesaid facts, and mainly, the consideration and recommendation on measures to prevent recurrence from technical point of view.

Regarding the recurrence prevention measures, in addition to measures to be implemented at an early point for winter 2018/19 as proposed in the interim report, considerations and recommendations were incorporated considering the fact that it was also the responsibility of the Investigation Committee to re-investigate the mid-to-long term measures proposed in the interim report based on the simulation results and specify it in the final report.

Regarding the mid-to-long term measures proposed in the final report of the Investigation Committee, as further investigations are being carried out by the Government and OCCTO to obtain specific conclusions by next spring on the “medium term measures” proposed in the interim report of Working Group on Electricity Resilience, it is strongly recommended to incorporate the same appropriately.

Section 1 Purpose and approach of investigation

1. Establishment of the Investigation Committee

"The Investigation Committee on the Major Blackout by the 2018 Hokkaido Eastern Iburi Earthquake" was set up at the 169th OCCTO Board of Directors Meeting based on Provisions of Article 41-1 defined in OCCTO's Articles of Organization, to investigate on the following matters.

The consultation topics at the OCCTO Board of Directors Meeting during the establishment of the Investigation Committee were as follows:

[1] Analysis of the cause of the major blackout affecting the entire Hokkaido area (from the occurrence of the earthquake at 3:07 am to the major blackout at 3:25 am on September 6)
[2] Technical investigations (black start generator operation , etc.) regarding the process (September 6 and 7) until securing a certain level of power supply (approx. 3,000 MW) after the major blackout
[3] Consideration of recurrence prevention measures, etc. (including blackout scale control measures) to be taken in the Hokkaido area, etc.

2. Objective of the investigation

The objective of the Investigation Committee is to identify the series of events in light of the blackout due to loss of power supply from the grid in an entire area which has not been experienced and to investigate the cause and recurrence prevention measures to be considered as lessons learned. However, investigation of the cause is not intended to pursue liability responsibility.

3. Composition of the Investigation Committee

Following are the members:

Chairman

・Akihiko Yokoyama (Professor, Department of Advanced Energy Graduate School of Frontier Sciences, University of Tokyo)

Members

・Toshio Inoue (Director, System Engineering Research Laboratory, Central Research Institute of Electric Power Industry)

・Yumiko Iwafune (Project Professor of the Institute of Industrial Science, University of Tokyo)

・Takao Tsuji (Associate Professor of the Faculty of Engineering, Yokohama National University)

Observers

・Electric Power Safety Division, Ministry of Economy, Trade and Industry

・Electricity Infrastructure Division, Agency for Natural Resources and Energy

・The Federation of Electric Power Companies of Japan

・Hokkaido Electric Power Co. Ltd.
(Hereinafter referred to as "Hokkaido Electric Power Company")

Secretariat OCCTO

4. Points of notice during investigation

The Investigation Committee shall keep the following in mind to ensure transparency and to carry out an appropriate investigation:

- In order to carry out investigation with more accurate data, the actual data of Hokkaido Electric Power Company shall be used for investigation. There may be time lag or loss due to communication in the data transferred from the Load Dispatching Center of Hokkaido Electric Power Company to OCCTO, and so this shall not be used as data for investigation. However, this shall be used to check if the actual data of Hokkaido Electric Power Company is appropriate.
- The data shall not only be shown as a graph, but real data shall be published as well to ensure transparency. However, as there may be discrepancies in the data due to time lag and transmission loss because of the place from where data is obtained, the source of data shall be clearly stated.
- Investigation shall involve not only facts with high certainty that can be confirmed with data, but also events which require explanation using certain estimations and assumptions. For this reason, it shall be ensured that facts and assumptions are not mixed.
- Though the Investigation Committee shall carry out discussions using expert findings, it shall work to promote understanding for the general public by including explanations in technical terms, etc.

5. Investigation Committee’s activities

Since the first Investigation Committee meeting on September 21, 2018, the Investigation Committee has held meetings four times and is doing its investigations.

The Investigation Committee, through the Secretariat, received materials submitted by related companies and related organizations, and analyzed them.

6. Subject of investigation by the Investigation Committee

The Investigation Committee aims to comprehensively investigate the reason for the major blackout accompanying the 2018 Hokkaido Eastern Iburi Earthquake and its background. Matters that are not directly related to the blackout investigation, such as the series of processes of investment decisions and construction of large-scale power sources are outside the scope of investigation.[2]

However, the Investigation Committee, being in a position to answer the public’s questions, has conducted a broad investigation on matters believed to be related to the cause of blackout, and also on matters which were considered to be in its background. For example, it covers the concept of facility formation standards etc. as well. In addition, regarding the recurrence prevention measures for the prevention of major blackout, the Investigation Committee is mainly carrying out investigations not only involving all the generators in the power plant tripping at the same time, but also assuming even more severe cases such as high-output operating conditions of renewable energy, etc.

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[2] The Working Group on Electricity Resilience investigated and evaluated the background of the formation of facilities of Hokkaido Electric Power Company (investment decision and construction of important power generation and transmission facilities) and assessed it as “There is no inappropriateness or unreasonable delay that will increase the risk of blackout in facilities formation and investment decision of facilities of Hokkaido Electric Power Company, which includes the investment for reinforcement of Hokkaido-Honshu HVDC Link, investments for Ishikariwan-Shinko Power Plant and construction of Tomato-atsuma power plant” in the interim report. Regarding this point, another opinion by the Working Group on Electricity Resilience was “The formation of and investment in facilities of Hokkaido Electric Power Company can be evaluated as necessary measures against blackout, considering that there was a possibility that power shortage in some areas might be prolonged due to insufficient supply after blackout recovery. However, though we won’t call the measures inappropriate, we are doubtful that they can be evaluated as appropriate”.

7. Relationship between final report and interim report

The interim report compiled on October 25, 2018 contained maximum details on related facts identified in the investigation so far, and evaluations based on them. Considerations and recommendations on mid-to-long term measures were also incorporated as much as possible, not only for the early implementation of measures for winter 2018/19, but also for enabling the Government to start investigations of mid-to-long term measures based on this event as soon as possible.

Meanwhile, the analysis by detailed simulation for elucidating the related facts from the occurrence of the earthquake to blackout was not completed at the interim report stage, and in order to investigate the effectiveness of mid-to-long term measures, further investigation including analysis by detailed simulation was required.

Therefore, the Investigation Committee conducted further investigation after the interim report and compiled the final report. The final report is based on the interim report, and is a revised version with the addition of further investigation results by the Investigation Committee, study results on the investigation results and measures by the government, etc.

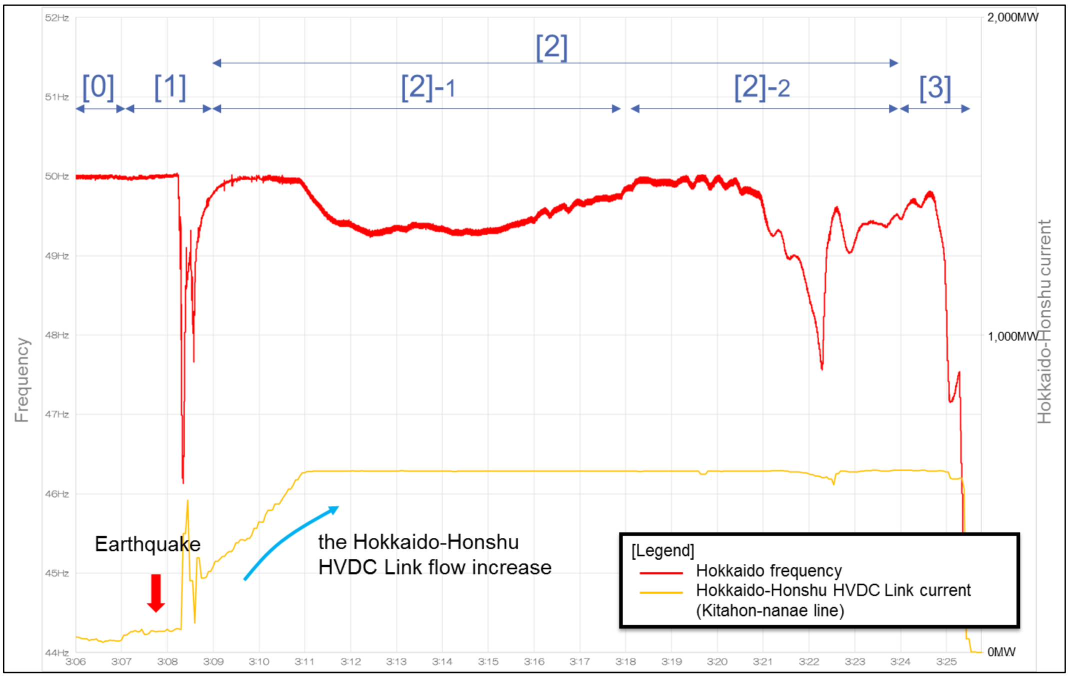
Section 2 Details of Sequence of Events from the Occurrence of the Earthquake to the Blackout

1. Method of clarifying the events

Regarding the blackout that occurred in the regional service area of Hokkaido Electric Power Company due to 2018 Hokkaido Eastern Iburi Earthquake, the investigation has clearly specified each and every event that occurred taking into account the grid status from the occurrence of the earthquake to the blackout, operations based on the commands from Load Dispatching Center, operational status of devices operating automatically in the grid, and the consequence of status changes caused by all of the above.

For this reason, the events from the occurrence of the earthquake to blackout were sorted by OCCTO (refer to Fig. 2-1) based on objective facts, by organizing the events that occurred within the grid in a time series on the basis of the frequency which can decode the supply-demand balance of the entire grid, and by checking the data which explains and complements the events such as increase or decrease of output by each generator, activations of under frequency relay (UFR)[3], etc.

Fig. 2-1 Frequency and power flow fluctuations of Hokkaido-Honshu HVDC Link to blackout



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3 Under Frequency Relay (UFR) – A device that presets the under frequency value and its duration in advance and automatically shuts down the load and generator in accordance with the operating conditions. The term shall mean the same hereafter.

However, not all evidence exists for these events, so they were sorted using the following approach, facts were identified, and the ending expressions of sentences in the final report were written in different styles.

Facts that are identified without a doubt and having clear records and consequences
⇒ *Ending Expression : "~is (was)", "~is being (was being)"*

Facts with high probability including guesses from the data
⇒ *Ending Expression : "~is believed to be"*

Events for which data is not available, for which consequences cannot be fully explained, which are based on listening, which are not clear at present but have a possibility, and whose possibility cannot be denied:
⇒ *Ending Expression: "there is a possibility that~"*

2.Important data used in investigation

The data related to the grid status on the day of the earthquake and shown in Table 2-2 was received from Hokkaido Electric Power Company, and the related facts were checked.

However, as the data transmission and processing time is included in the time stamp of the data from the Load Dispatching Center and the grid control stations, delay of about several seconds was also noted and confirmed.

Table 2-2 Types of data items used in investigation

Title	Data Interval	Details
Frequency	20 msec	Frequency of all Hokkaido grids (Hz)
Voltage*	3 sec	Substation bus voltage (kV) of 275 kV grid
Generator output*	3 sec	Instructed value of each generator (MW), Effective power (MW)
Current flow in transmission lines*	3 sec	Effective power (MW)
Status change log*	1 sec	Recorded data on the change in the status of substation equipment

*only the data necessary for investigation is used

3. Grid status immediately before the occurrence of the earthquake

Regarding the status of the grid immediately before the occurrence of the earthquake, the following facts were confirmed on the shutdown state of the generators (refer to Fig. 2-3 and Fig. 2-4).

- Since some thermal power plants had been shut down due to lower demand during late night, and since they require some time to restart, the operation plan to meet the demand curve of the following day was
  ・start Sunagawa Units 3/4 and Naie Unit 2 respectively,
  ・keep Date Unit 1 and Onbetsu Units 1/2 shut down
- Thermal power plants were operated in merit order. For this, Tomato-atsuma was operated with high output, and other thermal power generators operated with minimum output.
- The total demand of Hokkaido area (at the generating end) is 3,087 MW. The supply capacity of the operating power plants is specified below:
  Naie Unit 1 (Coal, rated output 175MW) – 61MW
  Date Unit 2 (Heavy oil, rated output 350MW) - 76MW
  Tomato-atsuma Unit 1 (Coal, rated output 350MW) - 338MW
  Tomato-atsuma Unit 2 (Coal, rated output 600MW) - 556MW
  Tomato-atsuma Unit 4 (Coal, rated output 700MW) - 598MW
  Shiriuchi Unit 1 (Heavy oil, rated output 350MW) - 96MW
  Niikappu Units 1/2, Takami Unit 1, Nukabira Unit 1, Ashoro Units 1/2 (Hydro, rated output 361MW in total) - 69MW
  Miscellaneous hydro (Excluding Niikappu Units 1/2, Takami Units 1/2, Nukabira Units 1/2, Ashoro Units 1/2, Kyogoku Units 1/2) - 711MW in total
  Major wind (rated output 319MW in total) - 166MW
  Other power generators - 344MW in total
  Hokkaido-Honshu HVDC Link (600MW (Maximum power interconnected on the Hokkaido side 570MW) - 72MW
- Meanwhile, Sunagawa Unit 3 (Coal, rated output 125MW) was scheduled for parallel in at 11 a.m. on Sep 6, Sunagawa Unit 4 (Coal, rated output 125MW) was scheduled for parallel in at 2 p.m. on Sep 6, and Naie Unit 2 (Coal, rated output 175MW) was scheduled for parallel in at 5:30 a.m. on Sep 6.
- In addition, Tomakomai Unit 1 (Heavy crude oil/ natural gas, rated output 250MW) was under planned outage, Tomakomai-kyodo (Heavy oil, rated output 250MW) was under

planned outage, Date Unit 1 (Heavy oil, rated output 350MW) was under balance stop, Onbetsu Units 1/2 (Gas oil, rated output 148MW) was under balance stop, Kyogoku Units 1/2, Takami Unit 2, Nukabira Unit 2 (Hydro, rated output 521MW in total) were under planned outage.

Fig. 2-3 Grid status immediately before the earthquake (power transmission grid status)

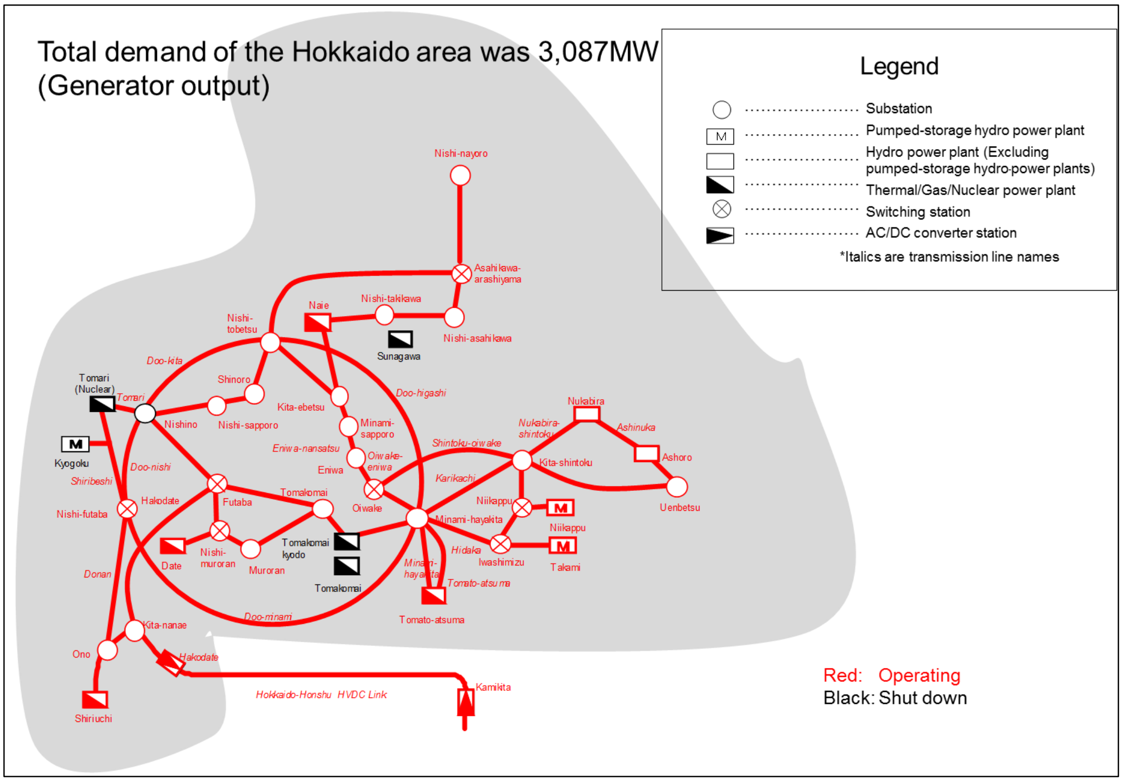


Fig. 2-4 Grid status immediately before the earthquake (Operational status of generators)

Supply capacity				Rated (MW)	Output (MW)	Operation plan
Thermal	Sunagawa	Unit 3	Coal	125	0	Parallel in scheduled at 11:00
		Unit 4		125	0	Parallel in scheduled at 14:00
	Naie	Unit 1	Coal	175	61	In operation
		Unit 2		175	0	Parallel in scheduled at 5:30
	Tomakomai	Unit 1	Heavy crude oil/ natural gas	250	0	Planned Outage *1
	Tomakomai kyodo	Unit 3	Heavy oil	250	0	Planned Outage
	Date	Unit 1	Heavy oil	350	0	Balance stop *2
		Unit 2		350	76	In operation
	Tomato-atsuma	Unit 1	Coal	350	338	In operation
		Unit 2		600	556	In operation
		Unit 4		700	598	In operation
	Shiriuchi	Unit 1	Heavy oil	350	96	In operation
		Unit 2		350	0	Planned Outage
	Onbetsu	Units 1/2	Gas oil	148	0	Balance stop
Hydro *3	Niikappu Units 1/2, Takami Unit 1, Nukabira Unit 1, Ashoro Units 1/2			361	69	In operation
	Kyogoku Units 1/2, Takami Unit 2, Nukabira Unit 2			521	0	Planned Outage
	Other hydro			–	711	In operation
Major wind powers*3				319	166	In operation
Other *4				–	344	In operation
Hokkaido-Honshu HVDC Link (Maximum power reception on the Hokkaido side)				600 (Approx. 570)	72	In operation
Demand				–	3087	

(Supplemental note for the table)
*1: "Planned Outage" refers to when the generator is shut down for regular inspection, etc.
*2: "Balance stop" refers to when the generator operation is shut down due to demand-supply balance
*3: Hydro/wind power generators for which the Load Dispatching Center is receiving telemeter (remote measurement) information
*4: "Other" is for the off grid power obtained by subtracting the sum of the thermal/hydro/major wind/ Hokkaido-Honshu HVDC Link from the demand

4.Immediately after the earthquake [1] (Occurrence of the earthquake to Frequency recovery) (From 3:08 to 3:09 on September 6))

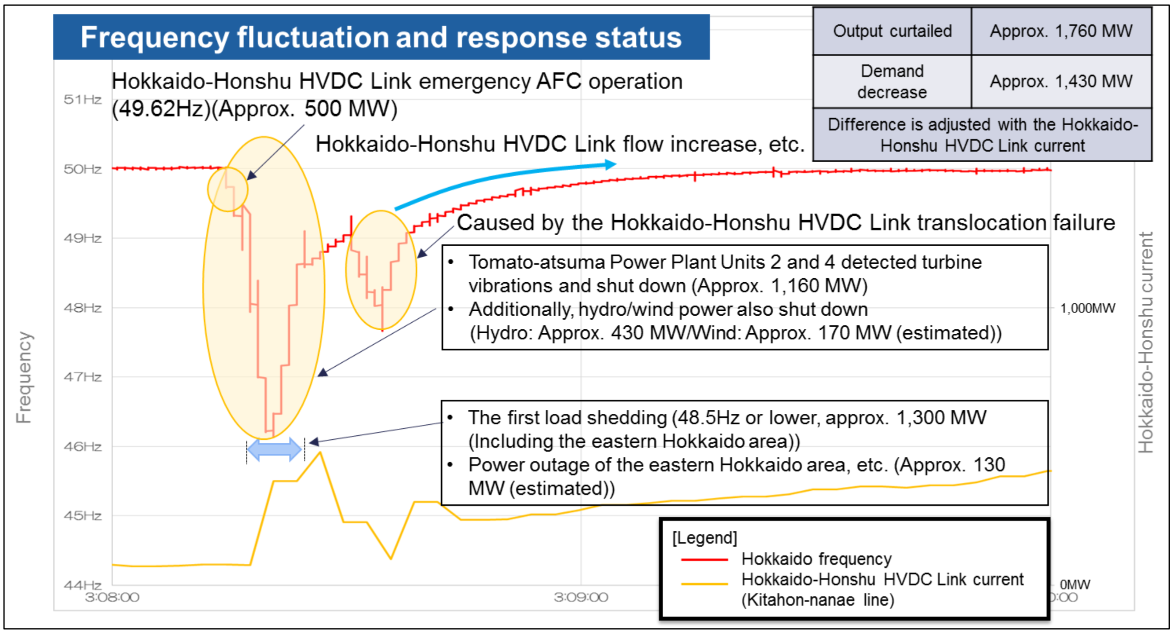
(1) Grid status immediately after the earthquake [1] (From 3:08 to 3:09 on September 6))

Regarding the grid status immediately after the earthquake [1] (From 3:08 to 3:09 on September 6)), the following facts were confirmed about overview of the frequency fluctuations and the response status:

- Tomato-atsuma Units 2/ 4 shut down due to detection of turbine vibrations, resulting frequency drop. As a result, emergency power transfer (operating at 49.62 Hz) from the Hokkaido-Honshu HVDC Link, load shedding by the under frequency relay (UFR) (demand: ▲1,300 MW) were activated, and wind power was shut down (output : ▲ 170 MW in total) (refer to Fig. 2-5).

- In addition, the Karikachi trunk line and two other lines shut down due to ground fault, resulting in power outage in eastern Hokkaido area (load: ▲ Approx. 130 MW), and hydro power shut down (Power generation: ▲ 370 MW). About 430 MW of hydro power had shut down in entire Hokkaido, including other transmission line accidents. As a result of the above events, the frequency drop stopped at 46.13 Hz, switching towards recovery, and balanced temporarily to 50 Hz due to the AFC function of Hokkaido-Honshu HVDC Link.

Fig. 2-5 Frequency fluctuations and response status (From 3:08 to 3:09 on September 6)



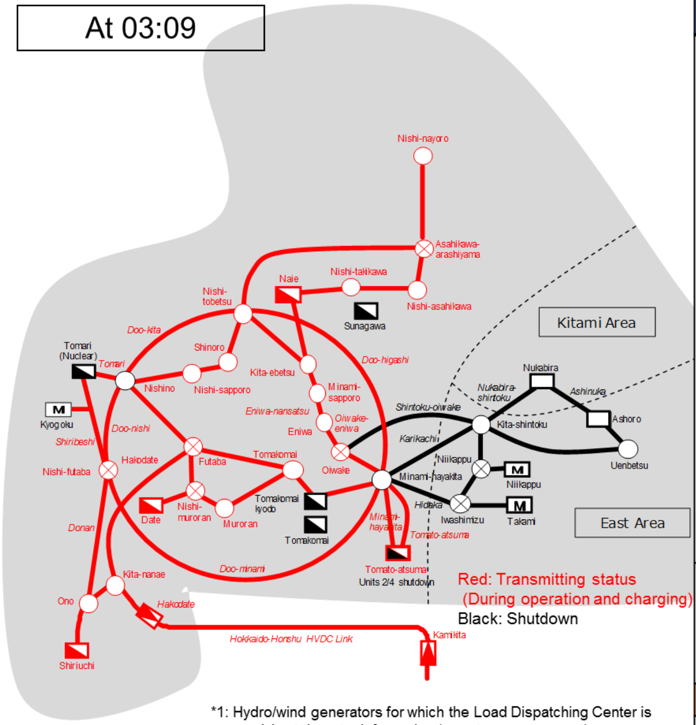
Regarding the grid status immediately after the earthquake [1] (Occurrence of earthquake to frequency recovery) (From 3:08 to 3:09 on September 6), the facts in Fig. 2-6 were confirmed in relation to individual events of frequency changes and response status. As shown in Fig. 2-6, several events occurred in parallel within the short period between event 1 and event 8, and the timings of activations have been mainly estimated from settings and telemeter recordings and arranged accordingly. For this reason, the impact on frequency by the actual operations and order of operations does not depend on this order.

Fig. 2-6 Events for which fact finding was carried out by the Investigation Committee [1]

Individual events
1.Frequency suddenly dropped due to the shutdown of Tomato-atsuma Units 2/4 (Power generation: ▲1,160 MW: Turbine vibrations detected) **<Matters for confirmation>** The shutdown of Tomato-atsuma Units 2/4 was confirmed using the telemeter (remote measurement) records. Regarding the output of Tomato-atsuma Unit 1, the value of power generation terminal output and transmission line current (Minami-hayakita line + Tomato-atsuma line) had deviated by about 2 times from 3:08, and the measurement of the said generator was suspected to be abnormal. So, the transmission line current value was used. Enquire with Hokkaido Electric Power Company, on the requirements for the shutdown of Tomato-atsuma Units 2/4. Also, confirm during the enquiry that Tomato-atsuma Unit 1 does not have the automatic shutdown functionality. **<Fact findings>** The frequency drop was due to the shutdown of Tomato-atsuma Units 2/4. This can be explained adequately from the records and is being identified as a fact without a doubt.
2.Power was received urgently from Hokkaido-Honshu HVDC Link **<Matters for confirmation>** Regarding operational frequency, operational time and power received, a back check was performed on the recordings of the telemeter (remote measurement) with the data provided by Electric Power Development Co., Ltd., which manages the Hokkaido-Honshu HVDC Link. It was confirmed that the automatic frequency control device (AFC) of Hokkaido-Honshu HVDC Link was operating at 49.62 Hz. **<Fact findings>** It can be identified as a fact without a doubt from records that the Hokkaido-Honshu HVDC Link was operational.
3.Load shedding was activated due to the frequency drop (demand: ▲ 1,300 MW) **<Matters for confirmation>** The Under Frequency Relay (UFR) was activated due to the extremely high loss of supply capacity against the size of demand. It was confirmed from Hokkaido Electric Power Company that the Under Frequency Relay (UFR) settings are being specified with time limit of 48.5Hz from 0.1 sec to 21 seconds and of 48.0Hz from 0.1 sec to 6 seconds. The load shedding capacity of UFR was checked using the load on the substation. Also, interviews confirmed that some of the load (60MW) was re-transmitted (automatic) due to the mistake in settings. **<Fact findings>** It can be identified as a fact without a doubt that along with the frequency drop, the AFC of Hokkaido-Honshu HVDC Link starts operating, after which the time limit of UFR starts, followed by load shedding activation, and thus a total of 1300 MW of load shedding is activated.
4.Wind power shut down due to the frequency drop (Power generation: wind power ▲ 170MW in total) **<Matters for confirmation>** The shut downs of wind power were confirmed through telemeter (remote measurement) records. However, the figure was sum of the wind power connected only to the extra-high voltage grid collected, and provided from Hokkaido Electric Power Company; Wind powers connected to the high voltage grid were not included. **<Fact findings>** It can be identified as a fact without a doubt from records that wind power, which had been generating output at 170MW immediately in total before the earthquake, shut down.
5. Due to the accident in the Karikachi trunk line, Shintoku-oiwake line, and Hidaka trunk line, there was power outage in eastern Hokkaido area and Kitami area (demand: ▲ about 130MW), and hydro power shut down (Power generation: Hydro power▲ 370MW in total (430MW in entire Hokkaido including other transmission line accident etc.)) **<Matters for confirmation>** It was confirmed that the shutdown was caused by the transmission line accidents of Karikachi trunk line, Shintoku-oiwake line, Hidaka trunk line. As a result of patrolling, similar arc marks have been confirmed in all the shut down lines, and the cause for this is considered to be the ground fault due to the contact of jumper wire with the line hardware. The frequency of eastern Hokkaido area and Kitami area rose due to the transmission line accident. Along with this, the generator shut down, and power outage occurred in eastern Hokkaido area and Kitami area. The fact that the demand of 130MW (estimated from transmission line current) suffered a power outage after the UFR activation was confirmed with a telemeter (remote measurement). It was also confirmed using a telemeter that hydro power of 430MW in total shut down in entire Hokkaido. **<Fact findings>** It can be identified as a fact without a doubt through Load Dispatching Center, oscillograph recordings and arc marks, that there was a ground fault in each transmission line. Also, it can be identified as a fact without a doubt that eastern Hokkaido area became an isolated grid due to the transmission line accident and hydro power shut down due to the frequency rise.
6. Frequency drop stopped at 46.13Hz and switched to recovery **<Matters for confirmation>** Most of the hydro power plants activate a relay at 46.0Hz and it is also necessary to accurately confirm up to how much the frequency dropped. For this reason, a check was conducted using the Load Dispatching Center data recorded in units of 20 milliseconds (0.02 sec), and it was confirmed that the lower limit was set to 46.13Hz. **<Fact findings>** It can be identified from the records as a fact without a doubt that the lower limit of the frequency was 46.13 Hz.
7. The Load Dispatching Center has dispatched early start-up to the hydro and thermal power generators which were in balance stop **<Matters for confirmation>** The fact that commands were sent from the Load Dispatching Center for hastening the start-up of Naie Unit 2 which was scheduled for parallel in at 5:30, and for the start-up of Date Unit 1, Sunagawa Unit 3/4, and hydro power generators which had been shut down, was confirmed from the recordings of commands from the Load Dispatching Center. Also, an attempt was made to start-up within the limited time, but the blackout occurred while only a few units had started up. Also, though start-up commands were sent for the hydro power generators, which were in balance stop, the frequency recovered temporarily, and the start-up commands were cancelled automatically. **<Fact findings>** It can be identified without a doubt from the command logs of the Load Dispatching Center that start-up commands were sent from the Load Dispatching Center to thermal and hydro power generators which were in balance stop.

8. Frequency was temporarily balanced at 50 Hz by the AFC function of Hokkaido-Honshu HVDC Link
<Matters for confirmation>
As the grids in Hokkaido were unstable, the conversion from DC to AC (commutation) of the power received from Hokkaido-Honshu HVDC Link was not possible for several seconds. But, as it returned to normal operation quickly and became sufficient to support the demand size, it gradually increased from 70MW to 570MW (+ About 500MW), which is the maximum capacity of received power in Hokkaido. The correlation between the maximum power received with Hokkaido-Honshu HVDC Link and the time required for frequency stabilization could be checked.
<Fact findings>
It can be identified as a fact without a doubt that at least the Hokkaido-Honshu HVDC Link was in a state of balancing the supply and demand.

Fig. 2-7 Grid status immediately after the occurrence of the earthquake (at 3:09 on September 6) (Operational shutdown status of generators)



Supply capacity				Rated (MW)	Output (MW)
Thermal	Sunagawa	Unit 3	Coal	125	0
		Unit 4		125	0
	Naie	Unit 1	Coal	175	58
		Unit 2		175	0
	Tomakomai	Unit 1	Heavy crude oil / natural gas	250	0
	Tomakomai-kyodo	Unit 3	Heavy oil	250	0
	Date	Unit 1	Heavy oil	350	0
		Unit 2		350	76
	Tomato-atsuma	Unit 1	Coal	350	294 (estimated)
		Unit 2		600	0
		Unit 4		700	0
	Shiriuchi	Unit 1	Heavy oil	350	103
		Unit 2		350	0
	Onbetsu	Units 1/2	Gas oil	148	0
Hydro *1	Niikappu Units 1/2, Takami Unit 1, Nukabira Unit 1, Ashoro Units 1/2			361	0
	Kyogoku Units 1/ 2, Takami Unit 2, Nukabira Unit 2			521	0
	Other hydro			–	343
Major wind powers*1				319	1
Other				–	Unknown *2
Power transfer (Hokkaido-Honshu interconnection link)				600	270 (Increasing)

*1: Hydro/wind generators for which the Load Dispatching Center is receiving telemeter information (remote measurement)
*2 It cannot be calculated since accurate demand at this point is not known (However, it was confirmed that 110 MW power supply remained)

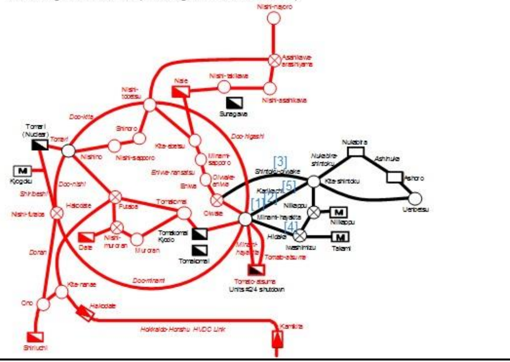
(2) Status of eastern Hokkaido area

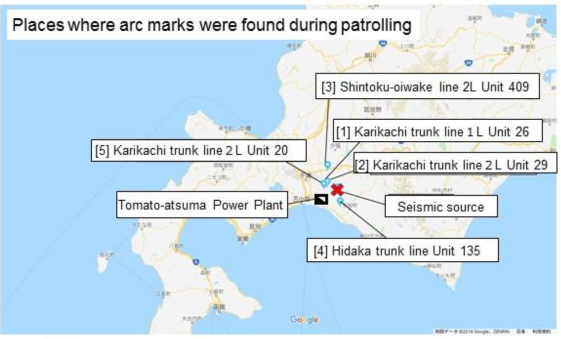
Overview of the transmission line accident (4 lines) which led to the isolation of eastern Hokkaido area is as shown in Fig. 2-8. From arc marks left at the transmission tower at the accident location, recordings of Load Dispatching Center and oscillograph, it was confirmed that there was a ground fault in all transmission lines (successful re-closure of circuits after about 1 minute).

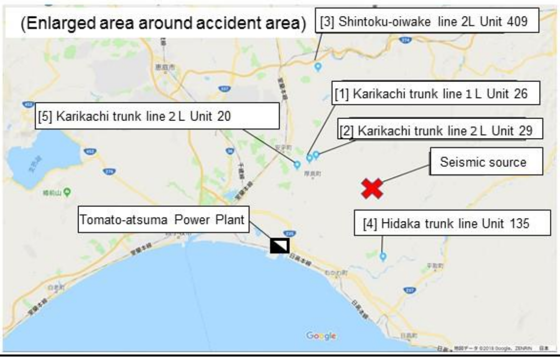
Fig. 2-8 Status of eastern Hokkaido area

Line [*1] (Order of accident)	Accident		
	Time [*3]	Phase	Tower No.
[1] Karikachi trunk line 1 L	3:08:17	Phase-1 ground fault	Unit 26
[2] Karikachi trunk line 2 L[*2]	3:08:17	Phase-1 ground fault	Unit 29
[3] Shintoku-oiwake line 2 L	3:08:19	Phase-2 ground fault	Unit 409
[4] Hidaka trunk line	3:08:21	Phase-1 ground fault	Unit 135
[5] Karikachi trunk line 2 L	3:08:25	Phase-1 ground fault	Unit 20

*1 Shintoku-oiwake line L1 is under operational shutdown
*2 High speed re-closure "good" (re-closing in 0.6 seconds)
*3 Confirmed using oscillograph (with GPS time synchronization)
(However, since Hidaka trunk line is not equipped with GPS function, the recordings of Load Dispatching Center were used)





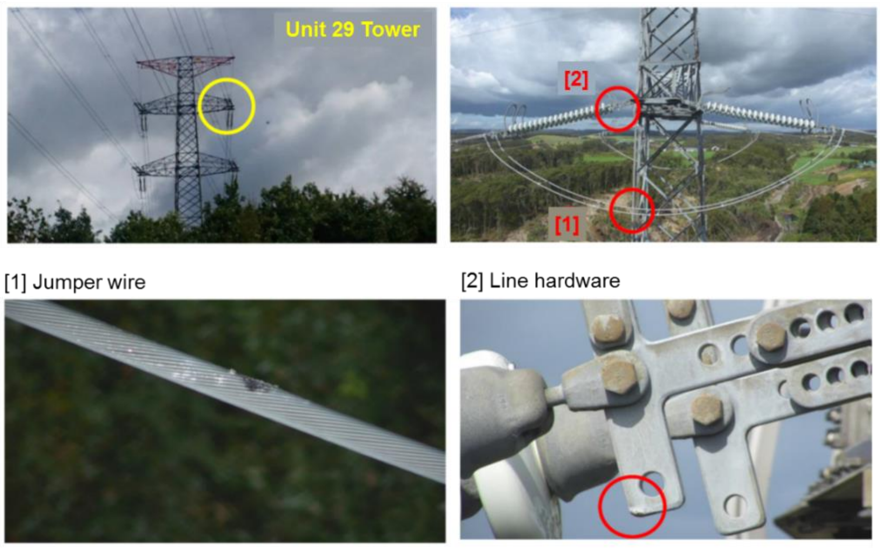


Regarding the transmission line accident, upon patrolling, arc marks were seen in all lines as shown in Fig. 2-9, and its reason was found to be the ground fault which occurred due to the contact of jumper wire and line hardware.

Fig. 2-9 Status of transmission line accident in eastern Hokkaido area

<Typical examples: Karikachi trunk line 2L single phase ground fault accident>

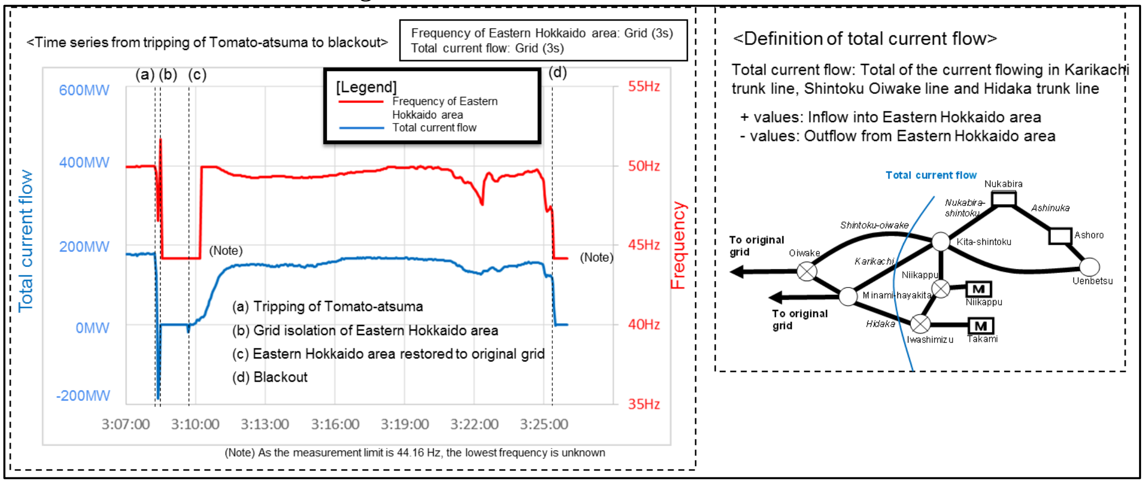
[Place of accident]
Tower Unit 29 - Blue Phase (Upper line) Arc marks were seen on jumper wire and overhead wire hardware



The status of eastern Hokkaido area along with the transmission line accident at that time is as seen in Fig 2-10 and Fig. 2-11. Based on this, the time series from the tripping of Tomato-atsuma Units 2/4 until the isolation of eastern Hokkaido area (from 3:08 to 3:09 on September 6) is believed to be as follows:

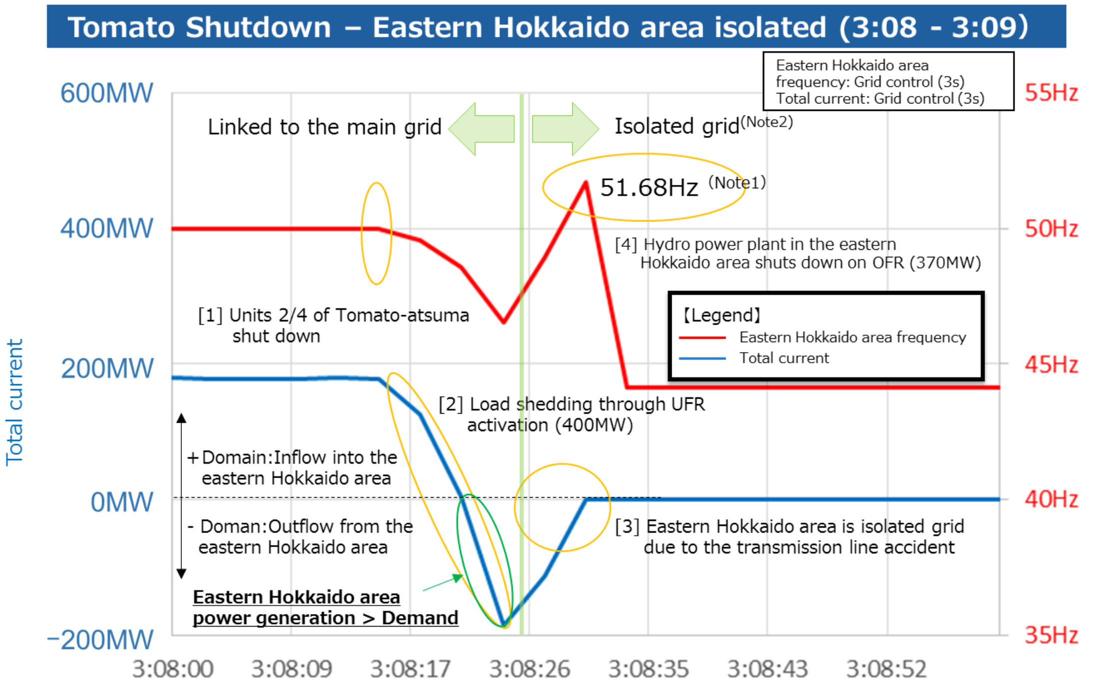
(i) Tomato-atsuma Units 2/4 tripped → frequency of the entire grid drops
(ii) Load shedding by UFR activation → power generation > demand in eastern Hokkaido area
(iii) Eastern Hokkaido area gets isolated and becomes an island grid due to the transmission line accident (Karikachi trunk line, Shintoku-oiwake line, Hidaka trunk line).
⇒ Frequency of eastern Hokkaido area rises
(iv) Hydro power generator of eastern Hokkaido area shut down (OFR[4] activation) due to the frequency rise
⇒ Frequency of eastern Hokkaido area drops
⇒ Complete blackout in eastern Hokkaido area for a short time

Fig. 2-10 Status of eastern Hokkaido area



4 OFR: Over Frequency Relay. When the supply capacity is excessive and the frequency becomes equal to or more than a certain value for a certain period of time, the OFR operates, disconnecting the generator from the grid.

Fig. 2-11 Status of eastern Hokkaido area

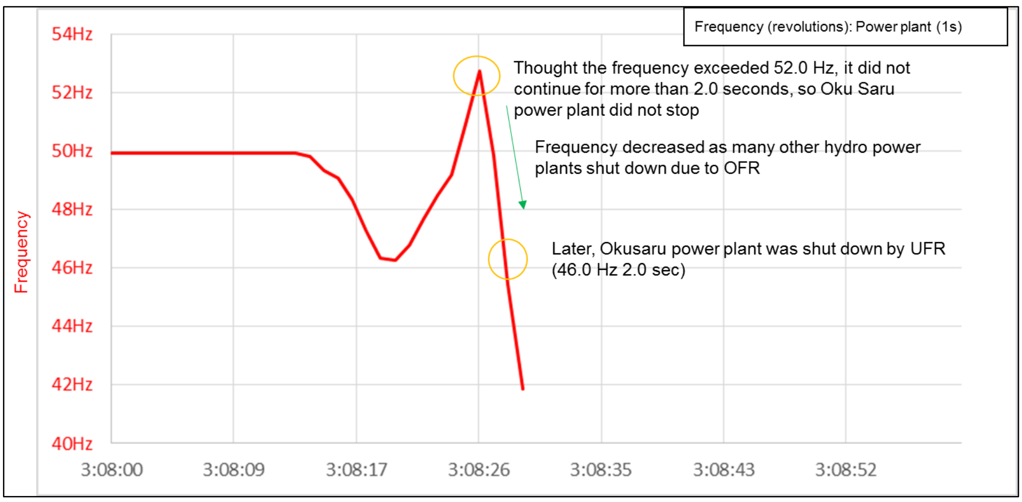


(Note 1) Although the measured value was 51.68Hz, we assume that it was at least 52.0Hz for at least 0.5 seconds due to the facts that the measurement was made every 3 seconds and that the OFR (operating value: 52.0Hz 0.5 seconds) of the hydro power plant was working. However, the hydro power plant whose OFR operating value was 52.0Hz 2.0 seconds did not shut down. (Refer to the next sheet)

(Note 2) Due to the fact that the measurement was taken every 3 seconds and due to delayed transmission, etc., we have not been able to chronologically synchronize the eastern Hokkaido area frequency and the total current.

Regarding the frequency rise of the eastern Hokkaido area which became an isolated grid, it is believed that the frequency (the value obtained by converting the number of rotations of the generator into frequency) from the hydro power plant (Okusaru Power Plant) where OFR is not activated, exceeded 52.0 Hz (See Fig 2-12).

Fig. 2-12 Status of frequency in eastern Hokkaido area



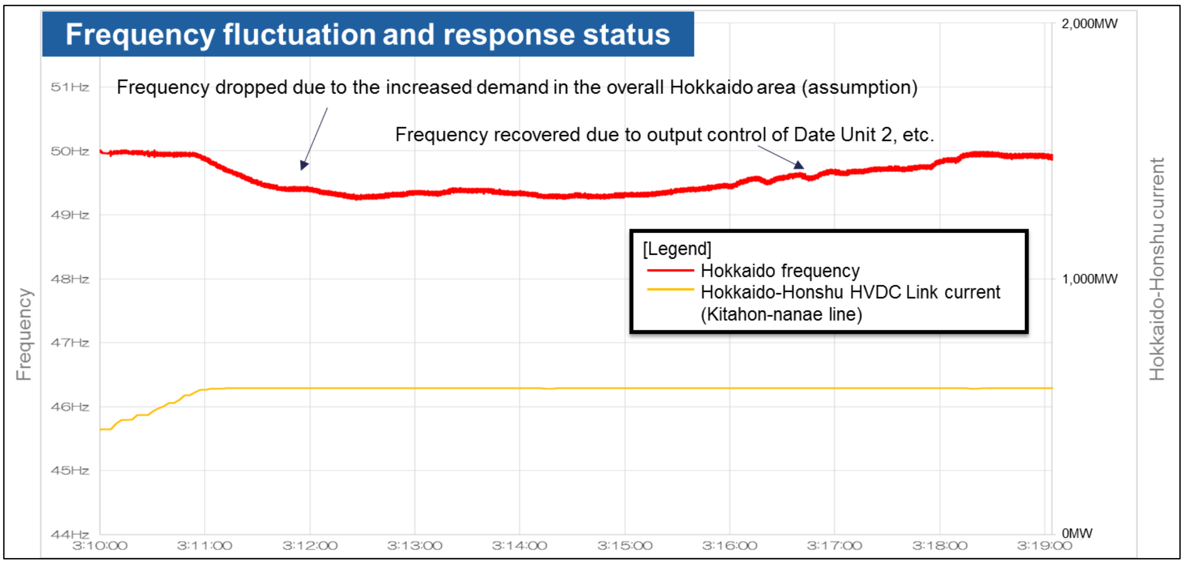
5.Immediately after the earthquake [2] (restoration of distribution line to second load shedding) (from 3:09 to 3:24 on September 6)

(1) Immediately after the earthquake [2]-1 (recovery of frequency to output decrease of Tomato-atsuma Unit 1) (From 3:09 to 3:19 on September 6)

Regarding the grid status immediately after the earthquake [2]-1 (recovery of frequency to output decrease of Tomato-atsuma Unit 1) (from 3:09 to 3:19 on September 6), the Investigation Committee confirmed the following facts (refer to Fig. 2-13) in relation to the overview of frequency fluctuations and response status:

- After the recovery of frequency, frequency gradually dropped due to demand increase (it is presumed that was not caused only by lighting and television watching used for information gathering, but one of the reasons was the load increase due to the grid voltage rise after load shedding).[5]
- The Load Dispatching Center instructed and controlled the thermal power generators for the output increase, and the frequency started to recover.

Fig. 2-13 Frequency fluctuations and response status (From 3:09 to 3:19 on September 6)



Regarding the grid status immediately after the earthquake [2]-1 (recovery of frequency to output decrease of Tomato-atsuma Unit 1) (from 3:09 to 3:19 on September 6), the facts in Fig. 2-14 were confirmed in relation to the individual events of frequency fluctuations and response status.

[5] Due to the reduced grid size caused by the earthquake, the impact of demand fluctuations on frequency increased.

Fig. 2-14 Events for which fact finding was carried out by the Investigation Committee [2]

Individual events
9. Power was restored to the Eastern Hokkaido area by the restoration from accidents (automatic re-closing) of Karikachi trunk line, Shintoku-oiwake line, Hidaka trunk line, etc. **<Matters for confirmation>** It was confirmed using the state change recordings (recordings on the operational state of power equipment) from Load Dispatching Center that the automatic re-closing (connecting the transmission line again) after the accident was a success. As a result, the demand (presumed as pure demand as the hydro power of Kitami area and eastern Hokkaido area was shut down) of about 130 MW from the transmission line current flow returned to the grid. Note that the level up to which the demand recovered can only be speculated. **<Fact findings>** It can be recognized as a fact without a doubt from the recordings that re-closure was success. Also, regarding the recovery of demand, the facts from the presence of actual current flow until the demand increase can be identified as a fact without a doubt.
10. Frequency gradually dropped due to demand increase **<Matters for confirmation>** As the demand for power is not being calculated, the output of the power plant is considered as demand if the frequency is stable. Therefore, it is reasonable to consider that demand has increased in the event when frequency drops. As a result of presuming the demand, the demand seems to be increasing even after the power increase from Hokkaido-Honshu HVDC Link. It is believed that the demand may have increased soon after the occurrence of late-night earthquake due the voltage rise, in addition to the power demand increase for room lighting, for information collection through TV, etc. **<Fact findings>** In general, it can be presumed that the demand for power increased after the occurrence of late-night earthquake. In addition, it can be presumed that the effect of increased demand might be due to voltage rise. Although this can explain the cause for frequency drop, there is no actually measured data, so it can be recognized that the frequency may have dropped due to demand increase.
11. The output of thermal power increased because of the instructions from the Load Dispatching Center **<Matters for confirmation>** While checking the recordings of instructions at the Load Dispatching Center, it was found that Date Unit 2 was instructed to increase the output, and for Naie Unit 1, instructions were given from the Load Dispatching Center to the site. Regarding Shiriuchi Unit 1, as it is out of control of the Load Dispatching Center, it was checked and confirmed that the output could not be increased due to boiler instability. Instructions for increasing output were given to all the power sources which can adjust the increased output. **<Fact findings>** From the recordings of the Load Dispatching Center and telemeter recordings, the increase in thermal power output due to the instructions from the Load Dispatching Center can be recognized as a fact without a doubt.

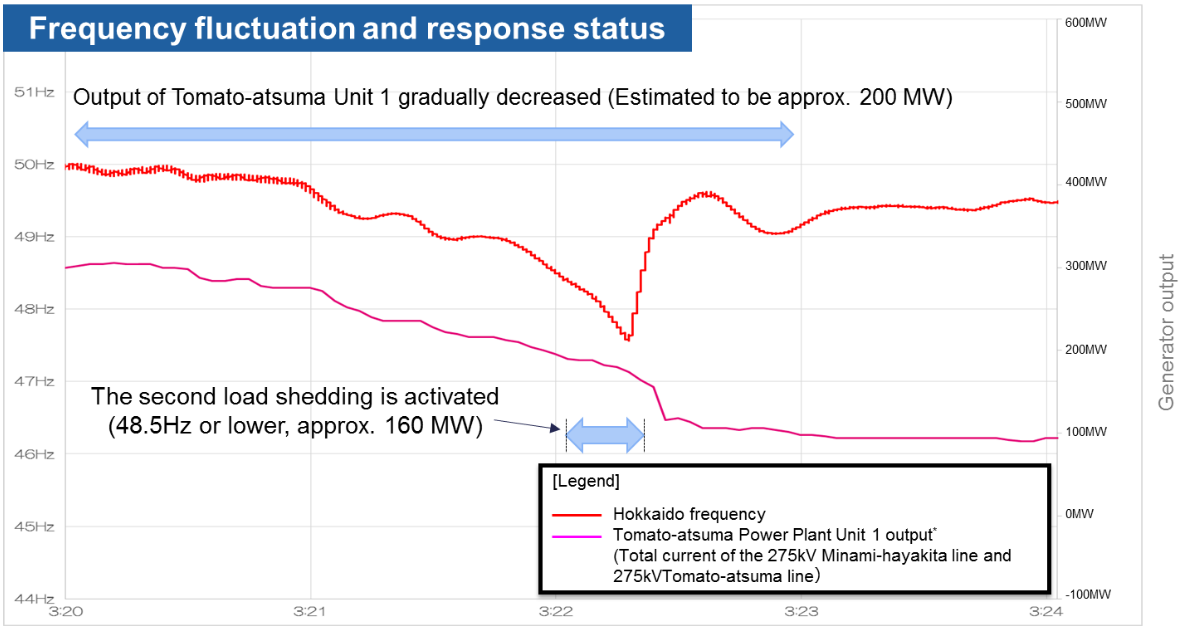
(2) Immediately after the earthquake [2]-2 (output decrease of Tomato-atsuma Unit 1 to second load shedding) (From 3:20 to 3:24 on September 6)

Regarding the grid status immediately after the earthquake [2]-2 (output decrease of Tomato-atsuma Unit 1 to second load shedding) (From 3:20 to 3:24 on September 6), the Investigation Committee confirmed the following facts (refer to Fig. 2-15) in relation to the overview of frequency fluctuations and response status:

- Frequency decreased as the output of Tomato-atsuma Unit 1 did not stabilize and output decreased gradually (Power generation: presumed to be ▲200 MW).
- As the duration was short during the first frequency drop, there were some UFRs which were not activated. Aforesaid UFRs activated during the second frequency drop as they fell in their operational range and load shedding was activated (Demand: ▲160 MW).

As a result, although the frequency tended towards recovery, stability could not be maintained.

Fig. 2-15 Frequency fluctuations and response status (From 3:20 to 3:24 on September 6)



* The transmission line current (Minamihayakita line + Tomato-atsuma line) value was almost twice as much as the generating-end output of Tomato 1G, starting around 3:08. Since it may have been caused by measurement abnormality of the generator, we used the transmission line current value.

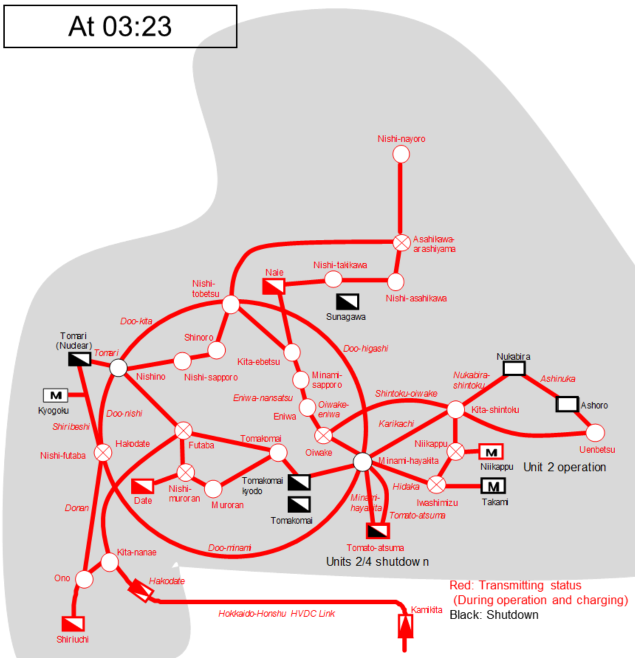
Regarding the grid status immediately after the earthquake [2]-2 (output decrease of Tomato-atsuma Unit 1 to second load shedding) (From 3:20 to 3:24 on September 6), the facts in Fig. 2-16 were confirmed in relation to the individual events of frequency fluctuations and response status.

Fig. 2-16 Events for which fact finding was carried out by the Investigation Committee [3]

Individual events
12. The output **of Tomato-atsuma Unit 1 decreased (Power generation: Presumed to be ▲200 MW 3:20 to 3:23)** **<Matters for confirmation>** The output decrease of Tomato-atsuma Unit 1 was confirmed with the telemeter of the Load Dispatching Center. Due to the impact of the earthquake, the boiler tubes got damaged and in addition, the deaerator water level controller, which is part of the feed water system to the drum, also malfunctioned. As a result, capacity of water supplied to the drum decreased and the drum water level drastically decreased. At this time, the operators shut down the coal pulverizer and suppressed the capacity of steam sent to the steam turbine, as shutdown prevention measures for generators. This lowered the output. **<Fact findings>** From the recordings, the decrease in output at Tomato-atsuma Unit 1 can be recognized as a fact without a doubt.
13. Load shedding was activated due to frequency drop (Demand: ▲ 160 MW) **<Matters for confirmation>** It was confirmed that the relays were activated in accordance with the settings even during the second load shedding by Under Frequency Relay. It was confirmed that the load shedding capacity was 160 MW, and it increased to about 49.5 Hz. **<Fact findings>** From the recordings, the load shedding by UFR can be recognized as a fact without a doubt.

Fig. 2-17 Grid status immediately after the earthquake [2]-2 (As of 3:23 on September 6)

(Generator operations shut down)



Supply capacity				Rated (MW)	Output (MW)
Thermal	Sunagawa	Unit 3	Coal	125	0
		Unit 4		125	0
	Naie	Unit 1	Coal	175	64
		Unit 2		175	0
	Tomakomai	Unit 1	Heavy crude oil / natural gas	250	0
	Tomakomai-kyodo	Unit 3	Heavy oil	250	0
	Date	Unit 1	Heavy oil	350	0
		Unit 2		350	135
	Tomato-atsuma	Unit 1	Coal	350	94 (estimated)
		Unit 2		600	0
		Unit 4		700	0
	Shiriuchi	Unit 1	Heavy oil	350	119
		Unit 2		350	0
	Onbetsu	Units 1/2	Gas oil	148	0
Hydro *1	Niikappu Unit 1, Takami Unit 1, Nukabira Unit 1, Ashoro Units 1/2		Niikappu Unit 2	361	1
	Kyogoku Units 1/2, Takami Unit 2, Nukabira Unit 2			521	0
	Other hydro			–	339
Main wind powers*1				319	2
Other				–	Unknown*2
Power transfer (Hokkaido-Honshu interconnection link)				600	574

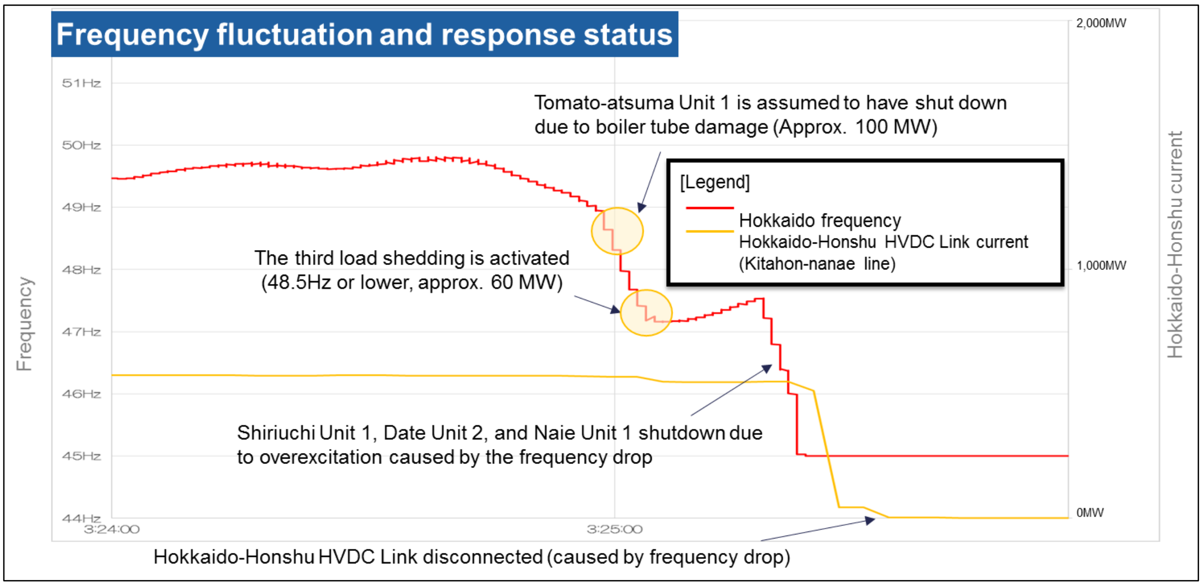
*1: Hydro/wind generators for which the Load Dispatching Center is receiving telemeter information (remote measurement)
*2: It can not be calculated as accurate demand at this point is not known (However, it was confirmed that 110 MW power supply remained)

6.From the second load shedding to blackout (From 3:24 to 3:25 on September 6)

Regarding the grid status from the second load shedding to blackout (From 3:24 to 3:25 on September 6), the Investigation Committee confirmed the following facts (refer to Fig. 2-18) in relation to the overview of frequency fluctuations and response status:

- Frequency dropped again as Tomato-atsuma Unit 1 shut down.
- After the first UFR load shedding, a part of load was accidentally restored. With this frequency drop, load shedding (demand: ▲60 MW) was automatically activated again, but the remaining capacity of the shedding was not sufficient to recover the frequency.
- Due to the frequency drop, other thermal power and hydro power plants shut down to protect their equipment, and in addition the Hokkaido-Honshu HVDC Link became unavailable.
- Supply capacity was lost due to the above events, eventually leading to blackout.

Fig. 2-18 Frequency fluctuations and Response status (From 3:24 to 3:25 on September 6)

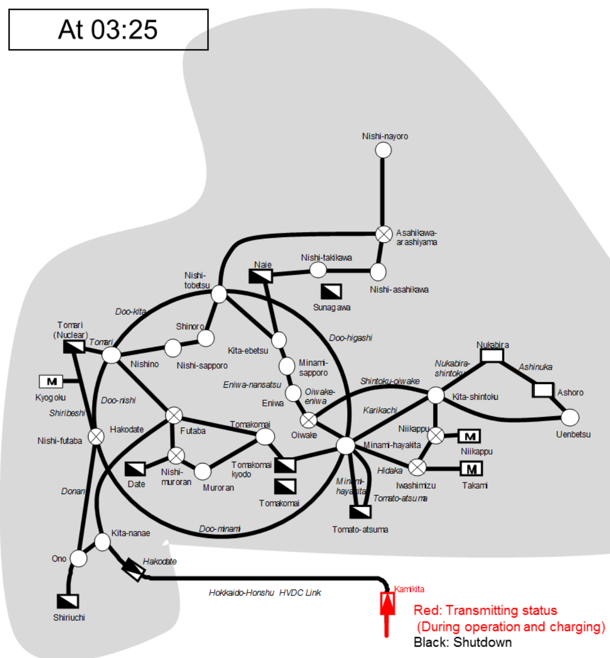


Regarding the grid status from the second load shedding to blackout (From 3:24 to 3:25 on September 6), the facts in Fig. 2-19 were confirmed in relation to the individual events of frequency fluctuations and response status.

Fig. 2-19 Events for which fact finding was carried out by the Investigation Committee [4]

Individual events
14. Frequency dropped again as Tomato-atsuma Unit 1 shut down (Power generation: presumed ▲100 MW 3:24 to 3:25) **<Matters for confirmation>** It was confirmed from the state change recordings that Tomato-atsuma Unit 1 shut down at 3:25. Through interview with Hokkaido Electric Power Company, the reason for the shutdown was confirmed to be the decrease in the water level inside the drum. **<Fact findings>** From the recordings, the shutdown of Tomato-atsuma Unit 1 can be recognized as a fact with almost no doubt.
15. Load shedding was activated due to frequency drop (Demand: ▲ 60 MW) **<Matters for confirmation>** It was confirmed that the third UFR load shedding was automatically activated, and that all the remaining relays were activated. The volume required for frequency recovery was not available, and it reached the limit for load shedding. Note that it was confirmed that a part of load had shed once was restored, but shed again. **<Fact findings>** Even from the operational recordings it can be recognized as a fact with almost no doubt.
16. Shiriuchi Unit 1, Date Unit 2, Naie Unit 1 shut down (Power generation: ▲ 340 MW) **<Matters for confirmation>** It was confirmed from the state change recordings that the Units were in a state of over-excitation, but this over-excitation occurred due to the system frequency drop, leading to the shutdown of these 3 thermal power plant units. **<Fact findings>** From the operational recordings it can be recognized with almost no doubt that aforesaid 3 thermal power plant Units shut down due to the frequency drop.
17. Due to the frequency drop the hydro power plants (mainly 46 Hz or lower) shut down and the Hokkaido-Honshu HVDC Link became unavailable **<Matters for confirmation>** Hydro power plants shut down due to the activation of UFR and the power in the area ran out, so it is believed that the Hokkaido-Honshu HVDC Link also shut down. Regarding events 16 and 17, the order of the previous and later events is not necessarily the same as the timestamp order. **<Fact findings>** From the operational recordings, the shutdown of 3 thermal power units can be recognized as a fact with almost no doubt. However, there is lack of enough evidence to state that the order of shutdown was that of 3 thermal power plants, hydro power plants, and then the Hokkaido-Honshu HVDC Link, so we shall only state that this was possibly the order.
18. Blackout occurred in Hokkaido area.

Fig.2-20 Grid status until blackout ③ (3:25 on September 6) (Generator operational status etc.)



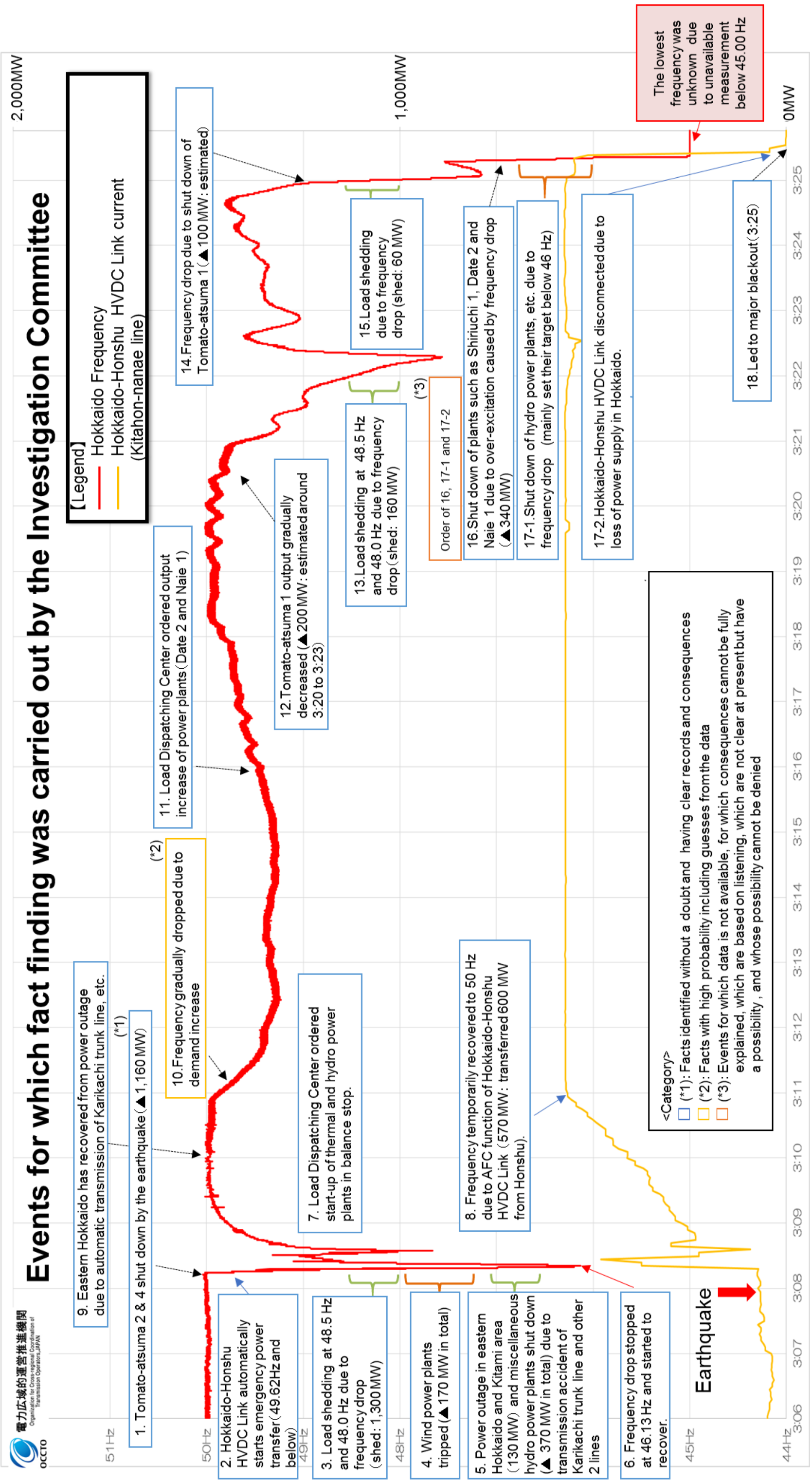
*: Hydro/wind generators for which the Load Dispatching Center is receiving telemeter information (remote measurement)

Supply capacity				Rated (MW)	Output (MW)
Thermal	Sunagawa	Unit 3	Coal	125	0
		Unit 4		125	0
	Naie	Unit 1	Coal	175	0
		Unit 2		175	0
	Tomakomai	Unit 1	Heavy crude oil / natural gas	250	0
	Tomakomai-kyodo	Unit 3	Heavy oil	250	0
	Date	Unit 1	Heavy oil	350	0
		Unit 2		350	0
	Tomato-atsuma	Unit 1	Coal	350	0
		Unit 2		600	0
		Unit 4		700	0
	Shiriuchi	Unit 1	Heavy oil	350	0
		Unit 2		350	0
	Onbetsu	Units 1/2	Gas oil	148	0
Hydro*	Niikappu Units 1/2, Takami Unit 1 Nukabira Unit 1, Ashoro Units 1/2			361	0
	Kyogoku Units 1/2, Takami Unit 2 Nukabira Unit 2			521	0
	Other hydro			–	0
Main wind powers*				319	0
Other				–	0
Power transfer (Hokkaido-Honshu interconnection link)				600	0

7. Recognized events and the status of response

(1) Recognized events

The events described from Sections 2.1 to 2.6, for which fact finding was carried out by the Investigation Committee, have been collectively described in Fig. 2-21.



(2) Response with governor-free operations and AFC function

Two functions are designed in order to maintain and control the frequency for the normal supply-demand fluctuations; the governor-free (GF) function (automatic regulator of the output for each generator respectively, by means of a speed governor installed in the turbine), and the AFC function (regulator of the outputs for generators unitarily, through the automatic control signals from the Load Dispatching Center).

Capacity Hokkaido Electric Power usually ensure the control capacity of

- The governor-free (GF) operation capacity: which is 2% (mainly secured by thermal power) of the area demand (at the sending end) and
- The AFC operation capacity: which is 2% (secured by hydro power) of the area demand (at the sending end)

At the time of immediately before the earthquake, the operational capacities of GF capacity and AFC capacity were as Fig. 2-22 and the above-mentioned sufficient capacities in usual capacity had been ensured.

Fig. 2-22 The operational capacities of GF capacity and AFC capacity immediately before the earthquake

<Main GF capacity *1: Thermal power>

	Max. (MW)	Output (MW)	GF capacity (MW)	Remarks
Naie Unit 1	175	61	–	Dispatching Power Control
Shiriuchi Unit 1	**350**	**96**	**35**	**GF＋** Dispatching Power Control
Date Unit 2	350	76	–	Dispatching Power Control
Tomato-atsuma Unit 1	**350**	**338**	**10.5**	**GF＋** Dispatching Power Control
Tomato-atsuma Unit 2	**600**	**556**	**44**	**GF＋** Dispatching Power Control
Tomato-atsuma Unit 4	700	598	–	Dispatching Power Control
Total	**2700**	**1725**	**89.5**	
Area demand %	–	–	**Approx. 2.9%**	**Area demand 3087MW*2**

<AFC capacity: Hydro power>

	Max. (MW)	Output (MW)	Raised reserve capacity (MW)	Remarks
Shimoniikappu	**13**	**10**	**3**	・The running hydro power plants other than the left were operating at a constant output, in order to adust the voltage of the local system or to prevent water overflow by the typhoon of several days before.
Shizunai Unit 1	**23**	**20**	**3**	
Shizunai Unit 2	**23.7**	**20**	**4**	
Takami	**98**	**25**	**73**	
Taisetsu	**15**	**15**	**0**	
Total	**172.7**	**90**	**83**	
Area demand %	–	–	**Approx. 2.7%**	**Area demand 3087MW**

*1 The effect of GF can be expected even in AFC hydro power or some part of the hydro power
*2 In order to compare with the output of power generation, it is calculated from the power generation end for convenience sake

Since the main generators shut down due to the earthquake,

- The GF generators remained were Shiriuchi Unit 1, which was unstable at that time, Tomato- atsuma Unit 1 and some hydro power plants.

- The AFC generators had "Zero" reserve capacity, it means no regulating capacity was secured.

As a result, it became difficult to maintain a stable frequency when the AFC reserve capacity of the Hokkaido-Honshu HVDC Link was lost after the first load shedding.

Fig. 2-23 The operational capacities of GF capacity and AFC capacity immediately after the earthquake

<GF capacity: Mainly thermal power>

	Max. (MW)	Output (MW)	GF capacity (MW)	Remarks
Naie Unit 1	175	58	–	Generator unstable
Shiriuchi Unit 1	**350**	**103**	**(35)**	
Date Unit 2	350	76	–	
Tomato-atsuma Unit 1	**350**	**294 (Estimated)**	**(10.5)**	
Tomato-atsuma Unit 2	**600**	**0**	**–**	Generator shut down
Tomato-atsuma Unit 4	700	0	–	
Total	**2700**	**531**	**(45.5)**	
Area demand %	**–**	**–**	**(2.5%)**	**Estimated area demand 1800MW***

<AFC capacity: Mainly hydro power>

	Max. (MW)	Output (MW)	Raised reserve capacity (MW)	Remarks
Shimoniikappu	**13**	**0**	**–**	**Generator shut down**
Shizunai Unit 1	**23**	**0**	**–**	
Shizunai Unit 2	**23.7**	**0**	**–**	
Takami	**98**	**0**	**–**	
Taisetsu	**15**	**0**	**0**	**Fall in generator output**
Total	**172.7**	**0**	**0**	
Area demand %	**–**	**–**	**0%**	**Estimated area demand 1800MW***

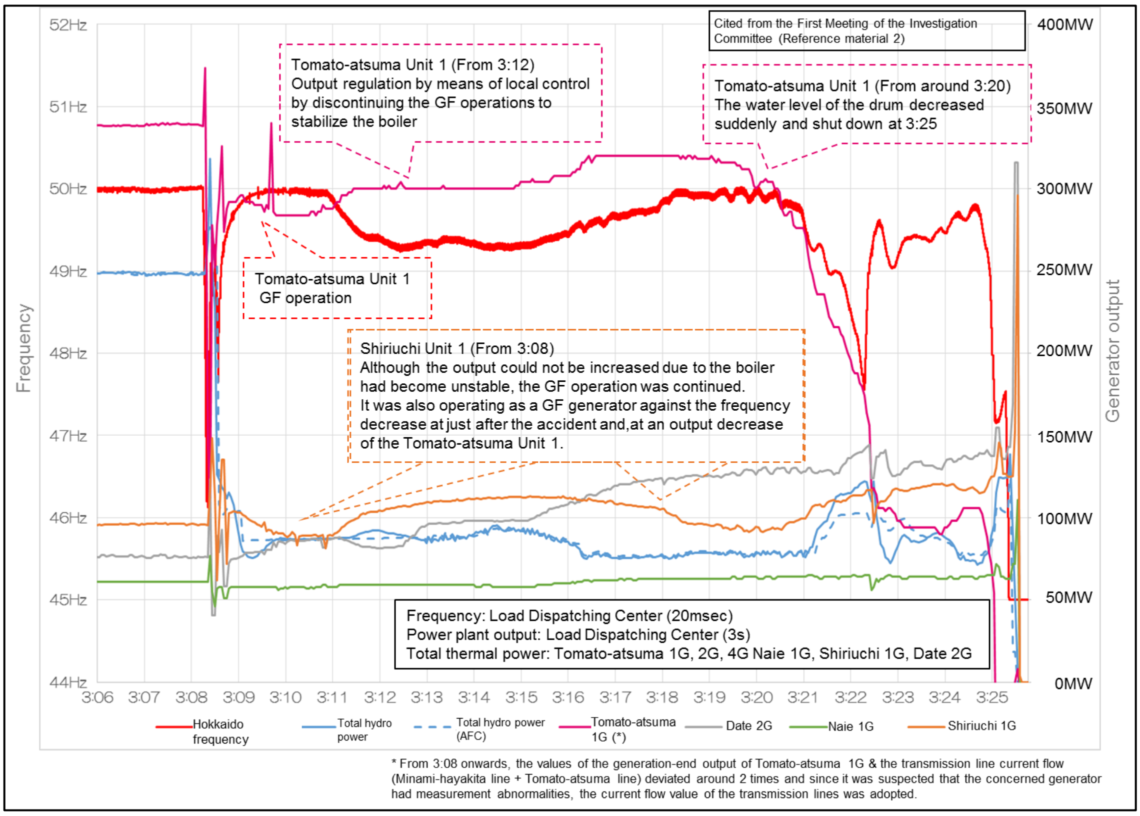
* Estimated from the previous 3087MW - load shedding (1300MW)

Subsequently, regarding the GF generator outputs,

- The GF operation of Tomato-atsuma Unit 1 was suspended from 3:12 on September 6 because the output changed suddenly and the boiler became unstable.
- The GF operation of Shiriuchi Unit 1 was continued while maintaining the output, although the output could not be increased because the boiler had become unstable.

As a result, it is believed that Shiriuchi Unit 1was operated (as a GF generator) generally according to the frequency fluctuation.

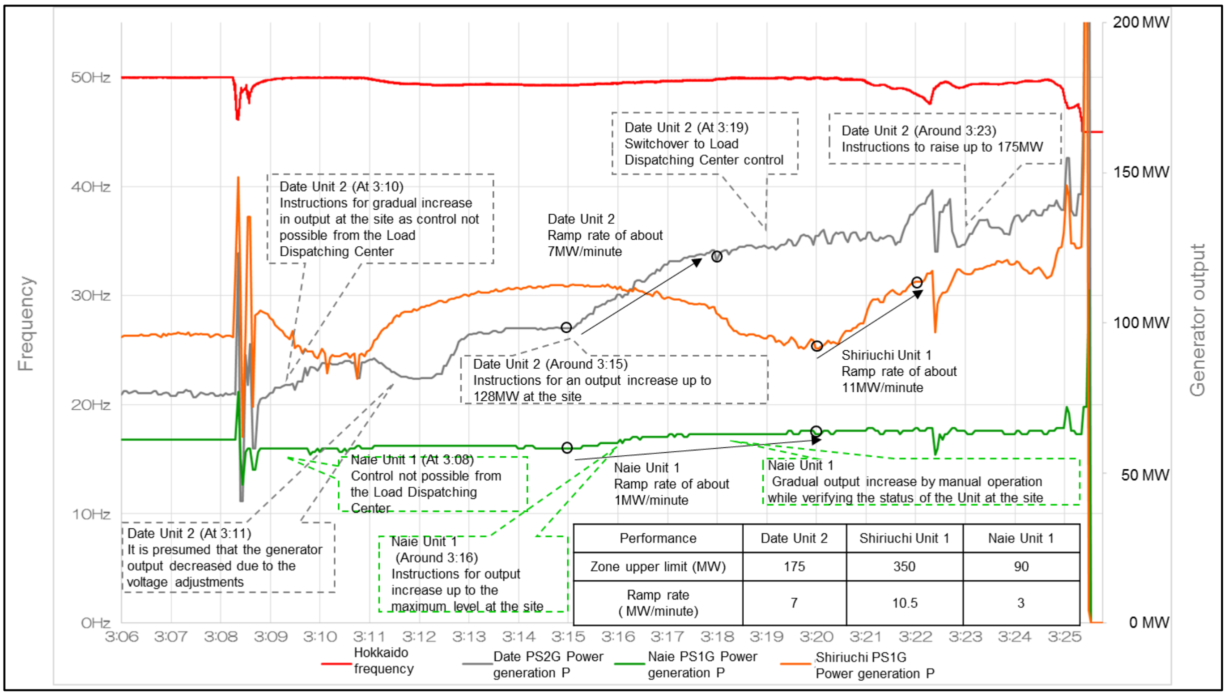
Fig. 2-24 Status of GF operated thermal power



The status of thermal power plants other than the GF generators after the occurrence of the earthquake is as follows (Refer to Fig. 2-25):

- Date Unit 2 output was increased sequentially while verifying the status at local site and the Load Dispatching Center.
- Since the Load Dispatching Center could not control Naie Unit 1, so the local site operators were instructed to raise the output of the unit, and the output was gradually increased through manual operations while verifying the status of the unit at the local site with the slower ramp rate.

Fig. 2-25 Status of other thermal generators

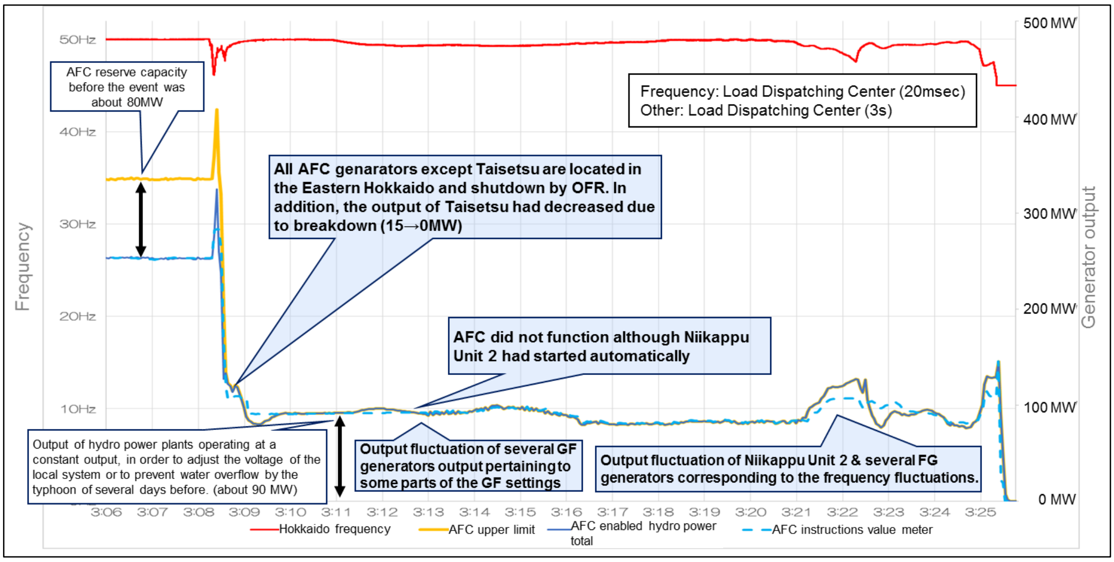


The status of hydro power plants which could be controlled by AFC from the Load Dispatching Center after the occurrence of the earthquake is as follows, and it was not possible to increase their outputs promptly (Refer to Fig. 2-26):

- The AFC operational capacity (80 MW) which had been ensured in advance became "Zero" after the earthquake.
- Following a frequency drop, instructions to operate hydroelectric power plants which could be controlled including which are scheduled not to operate in unit commitment planning of "Increasing output by 49.5Hz or lower, starting up with 49.0Hz or lower" were issued automatically from the Load Dispatching Center to the various Grid Control Centers, but with the recovery of the frequency, these instructions automatically stood cancelled.
- Although, Niikappu Unit 2 started automatically, it did not function well as an AFC generator since the lack of the necessary information due to the impact of the power outage in the eastern Hokkaido area.

As mentioned above, as regards the status of frequency maintenance, the frequency which recovered temporarily up to 50Hz immediately after the earthquake, began to drop due to the demand increase from 3:11 onwards, and to counter this, although the output of thermal power plants in parallel was increased, the stability of frequency could not be maintained. It is believed that this is due to the fact that the ramp rate of thermal power is slower than that of hydro power and hence the entire automatic frequency control (AFC) function which depended on hydro power was lost by the aforementioned shut down of hydro power plants.

Fig. 2-26 Status of hydro power generators

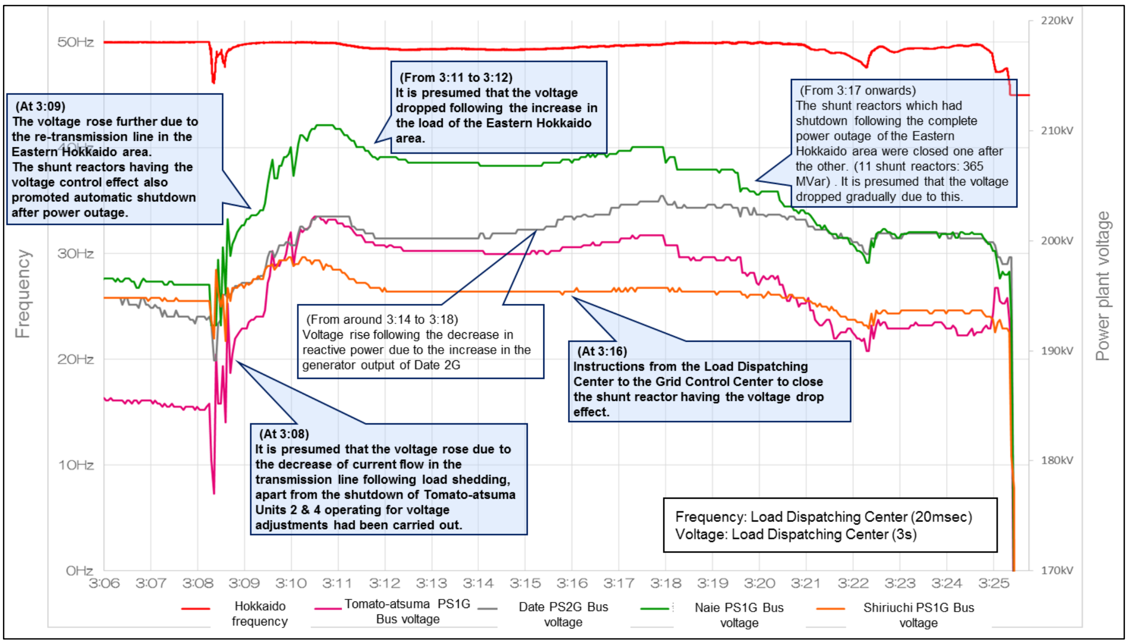


(3) Response with grid voltage (power plant voltage) operation

The voltages at the various power plants after the occurrence of the earthquake are as follows (Refer to Fig. 2-27):

- Besides the shutdown of generators at Tomato-atsuma operating for voltage adjustments, the voltage rose due to load shedding and the re-transmission in the eastern Hokkaido area etc. (The shunt reactor which has the voltage suppression effect shut down automatically with power outage in the eastern Hokkaido area).
- It is presumed that the voltage suppressed gradually due to the reclosing of the shunt reactor from the Grid Control Center etc. (The Grid Control Center is presumed to have concentrated mainly on the voltage adjustments because the frequency had temporarily recovered).
- It can be evaluated that suppressing the grid voltage by means of closing the shunt reactor etc. was the appropriate measure for the over-voltage control of equipment as also an appropriate measure from the view point of frequency maintenance since a rise in the grid voltage increases the load which in turn is a cause for a further frequency drop.

Fig. 2-27 Status of voltages at the power plants



The reactive power and the grid voltage at various power plants after the earthquake are as follows (Refer to Fig. 2-28 and Fig. 2-29):

- It is shown that the reactive power was being adjusted to suppress the rise in the bus voltage of the power plants immediately after the earthquake.
- Subsequent to this, the voltage suppressed due to the reclosing of the shunt reactors by the Grid Control Center, the reactive power is believed to have been reduced.

Fig. 2-28 Status of generator reactive power

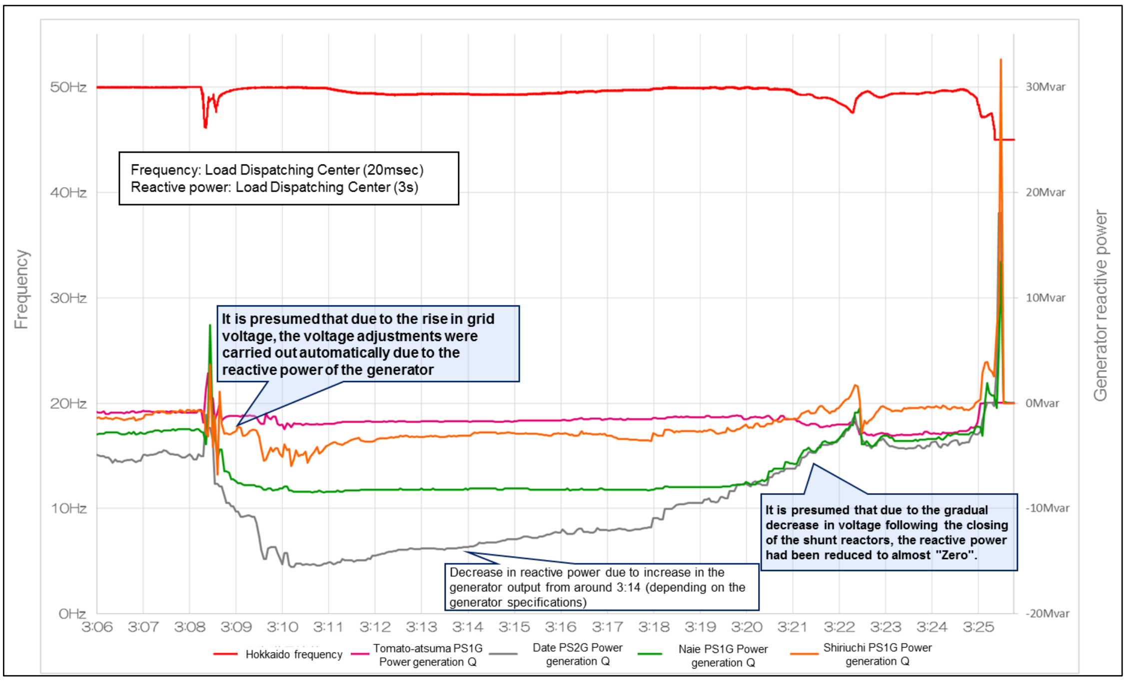
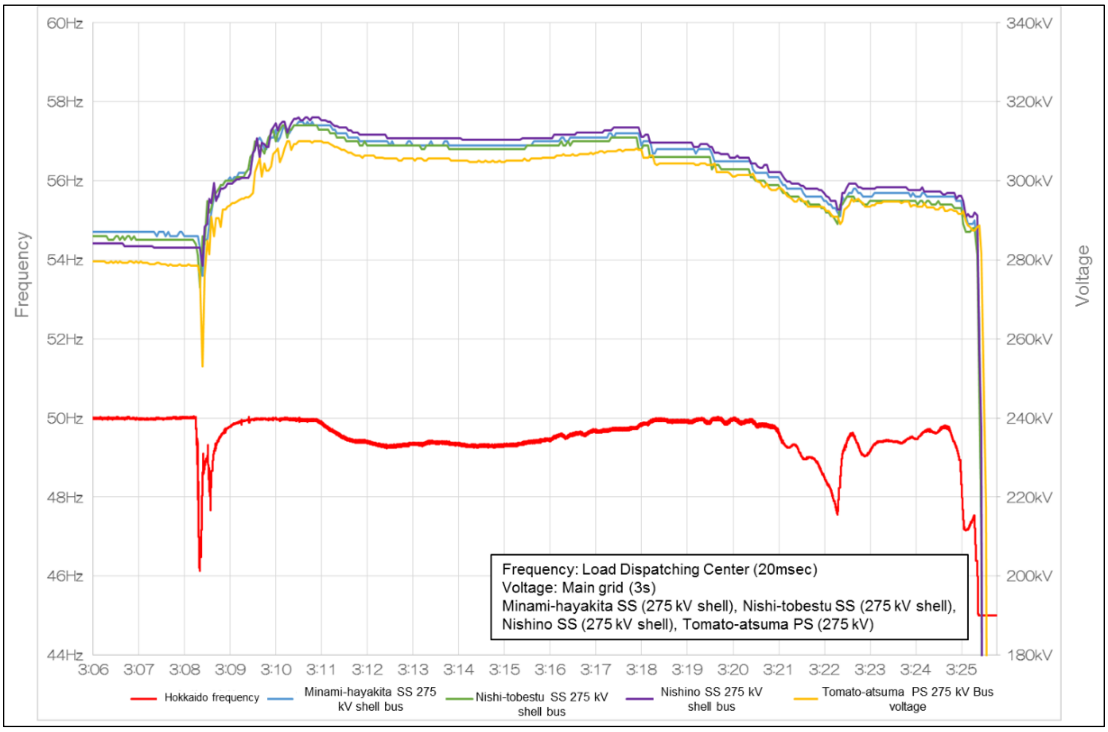


Fig. 2-29 Status of 275kV bus voltage



8. Summary

As far as the sequence of events from the occurrence of the earthquake to the blackout is concerned, we have investigated the details, the factual correlations, and causes in this section, but more specifically, the events were as follows.

The demand immediately before the occurrence of the earthquake was 3,090 MW (at the generating end) and as regards the Unit Commitment planning, the 3 thermal power plants were under planned outage for routine inspection, 2 thermal power plants, excluding Tomato-atsuma plants which was economical from the point of view of fuel charges, were under balance stop in order to maintain the supply-demand balance during the late night demand, and 3 thermal power plants were in a state of readiness for parallel in from 5:30 onwards.

The earthquake occurred at 3:07, following which Tomato-atsuma Unit 2/ 4 immediately shut down due to detection of turbine vibrations while Unit 1 did not shut down as it is not equipped with the automatic shutdown function (it was shut down subsequently at 3:25). Due to this, the supply capacity decreased significantly and the frequency rapidly dropped. Due to this frequency drop, the Hokkaido-Honshu HVDC Link started the emergency power transfer at 49.62Hz and load shedding of 1,300 MW was activated by the emergency load shedding system (UFR) under 48.5Hz. Almost at the same time as this, the wind power plants of 170 MW in total shut down due to the impact of frequency drop.

Moreover, immediately after the occurrence of the earthquake, the ground fault accidents occurred on the Karikachi trunk line and 2 other lines due to the tremors of the earthquake, and the eastern Hokkaido area temporarily became an isolated grid (there was recovery from the accidents approximately about a minute later and the isolated grid was connected again). In this isolated grid, generation outputs exceeded the demand in the eastern Hokkaido area leading to the frequency rise and thereby, 370 MW in total of hydro power plants were shut down (430 MW of hydro power plants were shut down on throughout Hokkaido due to the impact of the earthquake) and the eastern Hokkaido area was temporarily shut down entirely.

As a result of the occurrence of these events, the frequency stopped dropping at 46.13Hz and rapidly recovered, following which the Hokkaido-Honshu HVDC Link automatically adjusted the power flow capacity required to maintain a reasonable frequency and the frequency recovered up to almost 50Hz about a minute after it had started to drop.

The frequency which recovered once up to 50Hz began dropping due to a demand increase from 3:11. To handle this, the outputs of the thermal power plants in parallel were increased, but it could not maintain the stability of the frequency.

Due to this, immediately after the occurrence of the earthquake, hence in spite of having activated the entire remaining UFR load shedding which was not activated because the duration time of the frequency drop was shorter than the relay setting limit, it was not possible to prevent the subsequent frequency decrease caused by the output decrease and shut down of Tomato-atsuma Unit 1. The thermal power plants, hydro power plants, and the Hokkaido-Honshu HVDC Link shut down one after the other, finally leading to the blackout.

Based on the above, it is believed that the blackout took place because in addition to the shutdown of Tomato-atsuma Units 1, 2, and 4 (N-3), there was loss of the frequency control functions (mainly AFC) due to the shutdown of hydro power plants following the transmission line accidents on the Karikachi trunk line and 2 other lines (N-4) which became the compounding factor.

Note that based on the results of verification by simulation, it is believed that under the supply-demand balance status similar to the balance at the time of the actual earthquake, the blackout would not have occurred if had two large-scale pumped-storage hydro power plants (Kyogoku Units 1/ 2) been in operable state, even though events similar to the actual events that followed after the occurrence of the earthquake had taken place (tripping of the Tomato-atsuma Power Plants at the entire one site and the transmission line accidents on the Karikachi trunk line and 2 other lines (N-4) leading to the shutdown of hydro power plants). Moreover, it is believed that even though the two large-scale pumped-storage hydro power plants (Kyogoku Units 1/ 2) had been not in operable state, if had the hydro power plant not shut down due to the transmission line accidents on the Karikachi trunk line and 2 other lines (N-4), it would not have resulted in a blackout. (Explained in detail in Section 4.2. (2).)

Besides we already had said that we were almost able to explain the main events at the stage of the Interim Report, at present, we can say with authority that we can explain the main events as a result of verification through simulations.

Section 3 Details of sequence of events from the blackout to ensuring a certain supply capacity (Approx. 3,000 MW) (September 6 and 7)

1. Method of event clarification

The status of restoration from blackout to transmission to customer load (equivalent to ensuring a certain supply capacity (approx. 3,000 MW)) was investigated from the viewpoint of "early resolution of blackout".

Specifically, the "status of restoration from blackout to transmission to customer load" and "development of a restoration policy in preparation for a blackout and the status of drill", was comprehensively evaluated by organizing the events chronologically based on the recording data, such as status change log, and evaluating them objectively in addition to the interviews with Hokkaido Electric Power Company.

2. Details of the sequence of events from blackout to ensuring a certain supply capacity (Approx. 3,000 MW)

(1) Details regarding various stages leading up to restoration

(a) From blackout to first black start (From 3:25 to 3:57 on September 6)

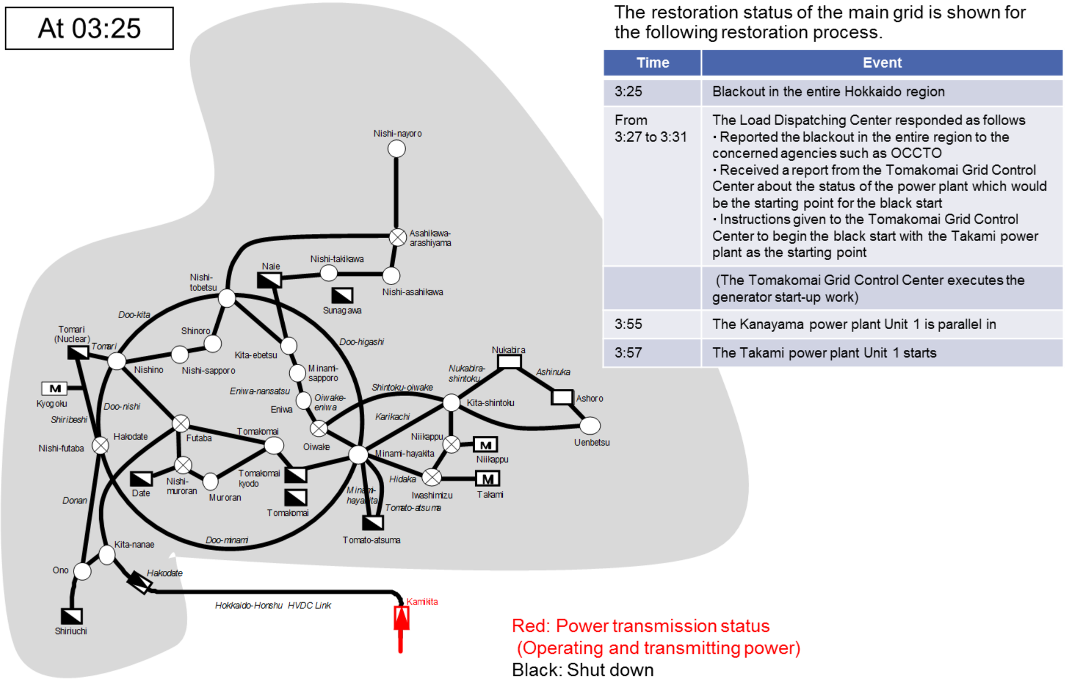
The Investigation Committee verified the facts about the status of restoration from blackout to the first black start (from 3:25 to 3:57 on September 6) and the start of the local grid black start in Figures 3-1 and 3-2.

Fig. 3-1 Events for which fact finding was carried out by the Investigation Committee [5]

Individual events
1. From total grid blackout to the first black start **Beginning of local grid black start** **<Fact finding>** **・ 3:27 to 31 Load Dispatching Center reported the blackout to the concerned agencies and received report status from the Grid Control Centers** *** As the starting point, the Takami power plant responded to the black start instructions.** *** Since the Niikappu power plant is also assumed to be the main starting point of black start in the "Restoration policy and explanation for total grid blackout", it includes the failure detection report for emergency generators with a view to start the generators at the aforesaid power plant. (The emergency gas turbine generators at the Takami power plant and the Niikappu power plant were set to start automatically during total grid blackout.)** **・ The grid restoration operation began from a black start at Takami power plant Unit 1 which was ready for start-up although fundamentally, according to the procedure manual, the restoration is to be carried out with 2 generators at a pumped-storage hydro power plant.** **・ A local grid black start (the first location amongst the 5 locations) was initiated in order to transmit the auxiliary power of the substations until the main grid was restored.** **・ 3:55 The Kanayama power plant Unit 1 was paralleled in (isolated Sapporo grid (Sorachi river system power supply)).** **(A local isolated grid has been clearly described in the procedure manual for the purpose of securing the auxiliary power supply of the power plants/substations or for the neighborhood load transmission, and it was mainly executed by an independent operation of the grid control center.)**

_ is the status concerning the local isolated grid

Fig. 3-2 Status of restoration from blackout to the first black start
(From 3:25 to 3:57 on September 6)



Time	Event
3:25	Blackout in the entire Hokkaido region
From 3:27 to 3:31	The Load Dispatching Center responded as follows ・Reported the blackout in the entire region to the concerned agencies such as OCCTO ・Received a report from the Tomakomai Grid Control Center about the status of the power plant which would be the starting point for the black start ・Instructions given to the Tomakomai Grid Control Center to begin the black start with the Takami power plant as the starting point
	(The Tomakomai Grid Control Center executes the generator start-up work)
3:55	The Kanayama power plant Unit 1 is parallel in
3:57	The Takami power plant Unit 1 starts

(b) All processes from the first black start to the 275kV central Hokkaido loop restoration (From 4:00 to 5:31 on September 6)

The Investigation Committee verified the facts about individual events of restoration status from the first black start to the 275kV central Hokkaido loop restoration (From 4:00 to 5:31 on September 6) in Figures 3-3 and 3-4.

Fig. 3-3 Events for which fact finding was carried out by the Investigation Committee [6]

Individual events
2. From total grid blackout to the commercial the restoration operation (Beginning of black start from the Takami power plant) **Beginning of local grid black start** **<Fact finding>** **・ 4:00 Takami power plant Unit 1 was paralleled in.** **・ 4:12 Shunbetsu power plant Unit 1 was paralleled in.** **・ 4:21 Higashinosawa power plant Unit 1 was paralleled in.** **・ 4:33 Shimoniikappu power plant Unit 1 was paralleled in.** **・The power transmission route was extended by using the power transmission lines from the Takami power plant sequentially to the Iwashimizu switching station and the Minamihayakita substation.** **・ Abnormalities were confirmed in the generators at the Niikappu power plant during the emergency start-up prior to the black start, and as there were various defective indications, the operators determined the generators to be unsuitable for additional operations and hence**

1 generator each from the Shunbetsu power plant, the Higashinosawa power plant and the Shimoniikappu power plant were operated additionally.

- **A local grid black start (from the second location to the fourth location amongst the 5 locations) was initiated in order to transmit the auxiliary power of the substations until the main grid was restored.**
- **4:01 The Taisetsu power plant Unit 1 was paralleled in (Asahikawa grid (Ishikari river system power supply)).**
- **4:39 Uryu power plant Unit 1 was paralleled in (Nishi Nayoro grid (Uryu power supply))**
- **4:47 Sunagawa power plant received power from the local isolated grid (Sorachi river system power supply).**
- **5:30 Shiniwamatsu power plant Unit 1 was paralleled in (Kushiro grid (Tokachi river system power supply)).**

3. Power was transmitted on priority to the thermal power plant by means of reverse power transmission (187kV→275kV) from the Hidaka trunk line and the Minamihayakita substation

<Fact finding>

- **4:49 Tomato-atsuma Power Plant received power.**
- **4:56 Tomakomai-kyodo thermal power plant received power.**
- **One shunt reactor of the Minamihayakita substation was used for voltage control.**

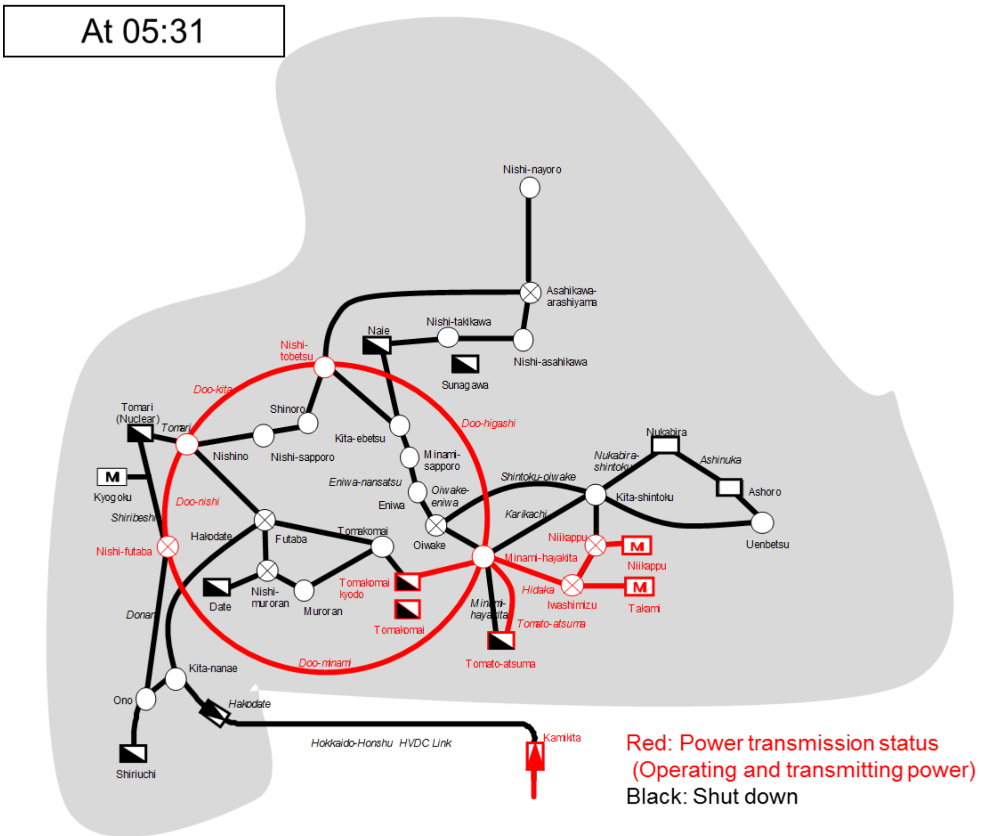
4. The central Hokkaido loop grid was configured by transmitting via the 275kV transmission line while making the voltage control for ensuring an auxiliary power of thermal power plant and nuclear power plant or for ensuring the power supply for starting generators

<Fact finding>

- **5:01 to 5:31 The 275kV central Hokkaido loop was configured by the transmission of power from the Minamihayakita substation as the starting point followed sequentially by the Nishi-tobestu substation, Nishi-futaba switching station and the Nishino substation.**
- **In order to adjust the voltage, 2 shunt reactors of the Minami-hayakita substation, 1 shunt reactor of the Nishi-tobestu substation and 2 shunt reactors of the Kita-shintoku substation for 6 shunt reactors in total were added, and used.**

_ is the status concerning the local isolated grid

Fig. 3-4 Status of restoration from first black start to the restoration of the 275kV central Hokkaido loop (From 4:00 to 5:31 on September 6)



Time	Event
At 4:00	Takami power plant Unit 1 parallel in
At 4:01	Taisetsu power plant Unit 1 parallel in
From 4:01 to 4:03	Power transmission to the Takami lines 1, 2 L
At 4:04	Power reception at the Iwashimizu switching station
At 4:12	Shunbetsu power plant Unit 1 parallel in
At 4:21	Higashinosawa power plant Unit 1 parallel in
At 4:22	Power transmission to the Oku-niikappu line
At 4:33	Shimo-niikappu power plant Unit 1 parallel in
At 4:35	Power reception at the Niikappu switching station
At 4:39	Power transmission to the Hidaka trunk line
At 4:39	Uryu power plant Unit 1 parallel in
At 4:40	Power reception at the Minami-hayakita substation
From 4:41 to 4:46	Reverse power transmission by transformer for connection with the Minami-hayakita substation
At 4:47	Power reception at the Sunagawa power plant [Local isolated grid (Sorachi river water system power supply)]
At 4:48	Power transmission to the Tomato-atsuma line 1L
At 4:49	Power reception at the Tomato-atsuma power plant
At 4:55	Power transmission to the Yufutsu line 1L
At 4:56	Power reception at the Kyodo thermal power plant

Time	Event
At 5:01	Power transmission to the Doo-higashi trunk line 1L
At 5:02	Power transmission to the Doo-minami trunk line 1L
At 5:07	Power reception at the Nishi-tobestu substation
At 5:16	Power reception at the Nishi-futaba substation
At 5:18	Power transmission to the Doo-nishi trunk line 1L
At 5:18	Power reception at the Nishino substation
At 5:26	Power transmission to the Doo-kita trunk line 1L
At 5:30	Shiniwamatsu power plant Unit 1 parallel in
At 5:31	275 kV Doo loop restoration

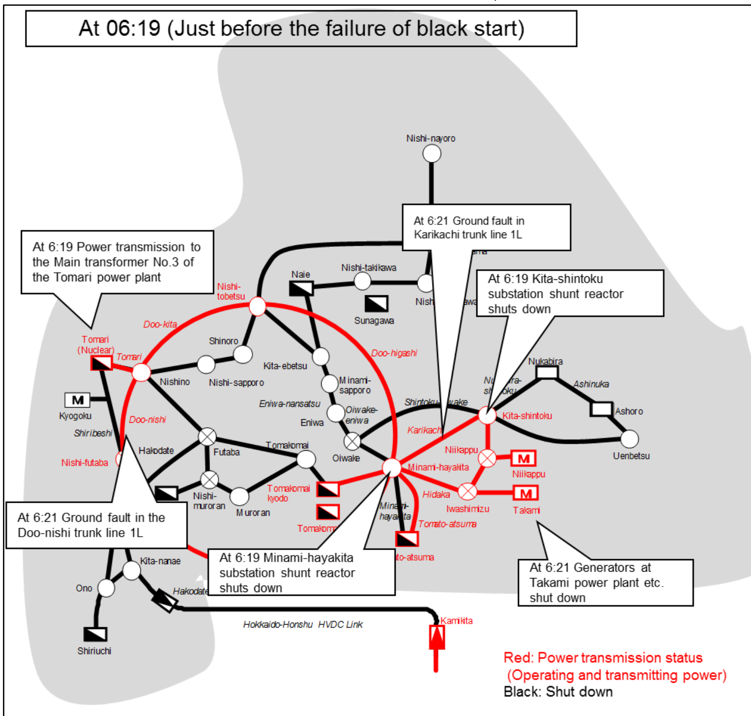
(c) From the restoration of the 275kV central Hokkaido loop to the failure of the first black start (From 5:36 to 6:21 on September 6)

The Investigation Committee verified the facts about individual events of restoration status of the 275kV central Hokkaido loop restoration to the failure of the first black start (from 5:36 to 6:21 on September 6) in the Figures 3-5 and 3-6.

Fig. 3-5 Events for which fact finding was carried out by the Investigation Committee [7]

Individual events
5. Black start failed during the operation of switching the auxiliary power of the Tomari power plant from emergency power supply to external power supply **<Fact finding>** **・Grid restoration status** **5:42 Power was transmitted to the Tomari trunk line 1L from the Nishino substation.** **6:07 The Tomari power plant received power from the Tomari trunk line 1L.** **6:09 Power was transmitted to the No.1 start-up transformer of the Tomari power plant.** **6:10 Power was transmitted to the No.2 start-up transformer of the Tomari power plant.** **6:19 Power was transmitted to the No.3 main transformer of the Tomari power plant.** **6:19 The shunt reactors of the Minamihayakita substation and the Kitashintoku substation shut down. It was followed by a rise in the voltage.** **6:21 Ground faults occurred in the Doo-nishi trunk line 1L and the Karikachi trunk line 1L.** **6:21 Takami power plant and other generators shutdown.** **・For supply capacity** **5:52 Site verification confirmed that Tomato-atsuma Power Plant Units 1/ 2 could not be started.** **Although an attempt was made to start Unit 4 on priority, there was sparking in the vicinity of the turbine axis, so the restoration of Unit 4 was suspended.**

Fig. 3-6 Status of restoration from the restoration of the 275kV central Hokkaido loop to the failure of the first black start (From 5:36 to 6:21 on September 6)



Time	Event
At 5:36	Power transmission to the Karikachi trunk line 1L
At 5:42	Power transmission to the Tomari trunk line 1L
At 5:45	Power reception at the Kitashintoku substation
At 5:59	Power transmission to the Nisshou trunk line 1L
At 5:59	Restoration of the Nisshou trunk line-Hidaka trunk line loop (creation of 2 loops of BS power supply)
At 6:05	Manual shutdown of the Shimo-niikappu power plant Unit 1 (In order to control the rise in water level of the pond (Iwashimizu))
At 6:07	Power reception at the Tomari power plant
At 6:09	Power transmission to the No.1 startup transformer of the Tomari power plant
At 6:10	Power transmission to the No.2 startup transformer of the Tomari power plant
At 6:19	Power transmission to the No.3 main transformer of the Tomari power plant
At 6:19	Minami-hayakita substation shunt reactor shuts down (Electric current imbalance Ry)
At 6:19	Kita-shintoku substation shunt reactor shuts down (Electric current imbalance Ry)
	(Voltage rises following the shut down of the shunt reactors)
At 6:21	Karikachi trunk line 1L shuts down due to ground fault
At 6:21	Doo-nishi trunk line 1L shuts down due to ground fault
At 6:21	Higashinosawa power plant Unit 1 shut down (86-2)
At 6:21	Takami power plant Unit 1 shut down (Transformer overcurrent Ry)
At 6:21	Shunbetsu power plant Unit 1 shut down (Generator bus overcurrent Ry)

(D) From the second black start to the reception of auxiliary power at the Tomari power plant (From 6:25 to 9:25 on September 6)

The Investigation Committee verified the facts about individual events of restoration from the second black start to the reception of auxiliary power at the Tomari power plant (From 6:25 to 9:25 on September 6) in the figures 3-7 and 3-8.

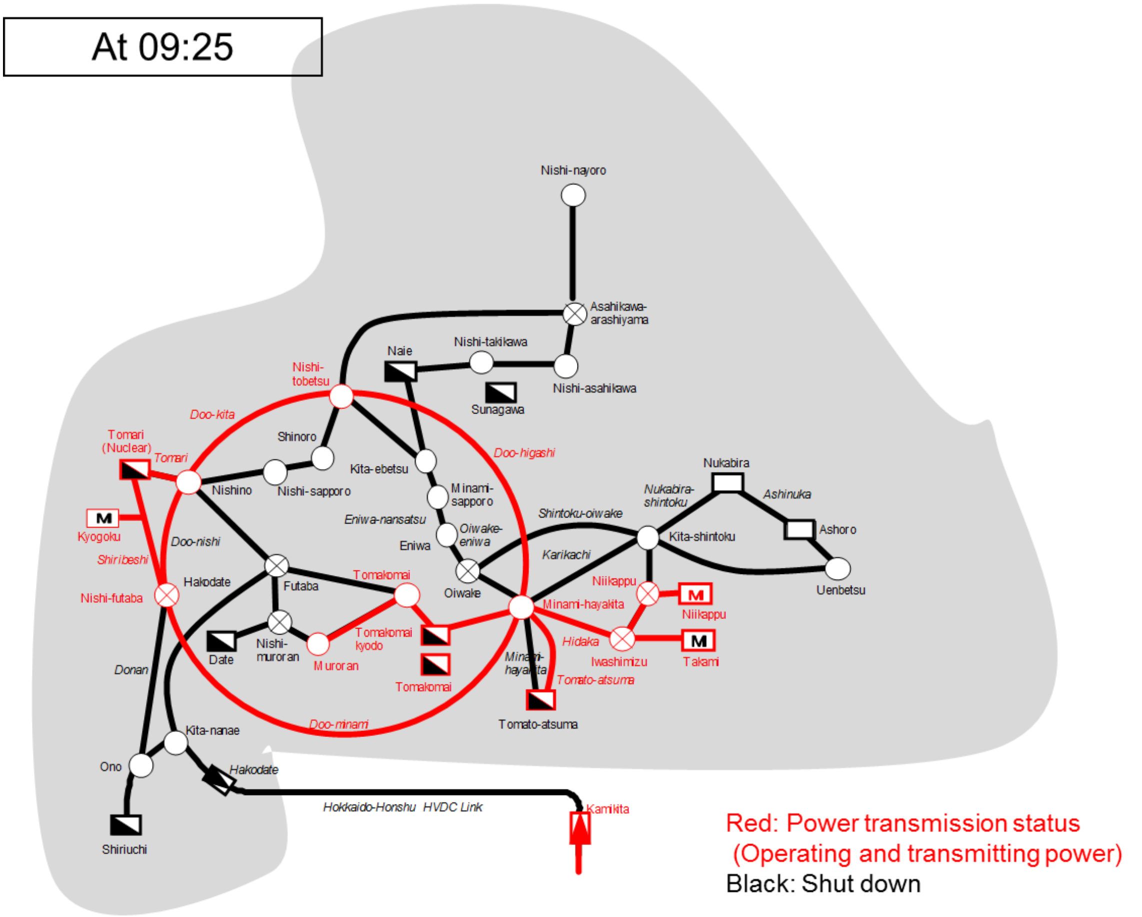
Fig. 3-7 Events for which fact finding was carried out by the Investigation Committee [8]

Individual events
1. Until the second black start **<Fact finding>** **・ From 6:25 to 6:31 Opening operations were executed for all the shut down isolated locations.** **・Status of all the blackout grids was verified (there were isolated grids among the local grids).** **・Establishment of the Restoration policy→Begin black start by using Niikappu Units 1/ 2.(Case 1)** **(Grounds for Judgment)** **・ Site verification of Niikappu power plant Units 1/ 2 determined that the Units were available. In order to carry out site verifications at the Niikappu power plant, the employees were independently forwarded the site at 3:50 and after arrival at the site (5:10), verified the status. After verifying the damage details, the employees checked the emergency generators and the availability of generators (at 5:13).** **・ Instructions were given to parallel in the generators (Unit 1 at 6:27 , Unit 2 at 6:34) after deciding the restoration policy according to the procedure manual.**
2. The restoration operation was initiated with black start **Black start began from the Niikappu power plant** **Power was transmitted on priority to the thermal power plants by means of reverse power transmission (187kV→275kV) from the Hidaka trunk line and the Minamihayakita substation** **Power was transmitted to the Tomakomai thermal power line and the Muroran-higashi trunk line** **<Fact finding>** **・ 6:30 Niikappu power plant Unit 1 was paralleled in.** **・ 6:37 Niikappu power plant Unit 2 was paralleled in.** **・ The power transmission route was extended by using the power transmission line from the Niikappu power plant sequentially to the Niikappu switching station, the Iwashimizu switching station and the Minamihayakita substation.** **・ Only one tie transformer in the Minamihayakita substation was used for connection.** **・ 7:00 The Tomakomai-kyodo thermal power plant received power.** **・ From 7:02 to 7:06 Muroran substation received power from the power transmission via the Tomakomai thermal power line and the Muroran-higashi trunk line. (In order to use the shunt reactor of the Muroran substation due to the change in situation owing to the breakdown of the single tie transformer used in the Minamihayakita substation connection (2 shunt reactors not available).)** **・ 7:13 Tomato-atsuma Power Plant received power.** **・ After voltage adjustments, 1 shunt reactor in the Minamihayakita substation was used.** **・ Due to the change in situation owing to the breakdown of the single transformer used for the Minamihayakita substation connection (2 shunt reactors not available), the operators judged that the use of shunt reactor of the Muroran substation was necessary and gave priority to the restoration of the 187kV grid.**

3. Power was transmitted to the Doo-higashi and the Doo-minami trunk lines (Using the Muroran shunt reactor) **The central Hokkaido grid loop was configured by power transmission through the 2 transmission lines namely, the Doo-kita and the Doo-nishi (Using the respective shunt reactors)** **Local grid black start was initiated** **<Fact finding>** **・ From 7:20 to 7:53 The 275kV central Hokkaido loop was configured by the transmission of power from the Minamihayakita substation as the starting point, and followed sequentially by the Nishi-tobestu substation, the Nishi Futaba switching station and the Nishino substation.** **・The Line No.1 of the Doo-nishi trunk line was the one which had suffered an accident, so instead of using it, Line No.2 was used.** **・Two shunt reactors of the Muroran substation and one shunt reactor of the Nishi-tobestu substation were used additionally (total 4) for the purpose of voltage adjustments.** **・ 7:49 Shizunai power plant Unit 2 was paralleled in.** **・A local grid black start (at the fifth location out of the 5 locations) was initiated in order to transmit the auxiliary power of the substations until the main grid was restored.** **・ 7:41 Hoheikyo power plant Unit 1 was paralleled in (isolated Sapporo grid (Toyohira river system power supply))**
4. Power transmission to the Tomari trunk line, Tomari power plant auxiliary power reception switchover, Kyogoku power plant auxiliary power supply **<Fact finding>** **・ 8:37 Power was transmitted to the Tomari trunk line 1L by the Nishino substation.** **・ 8:52 The Tomari power plant received power through the Tomari trunk line 1L.** **・ 8:58 Power was transmitted to the No.1 start-up transformer at the Tomari power plant. (From 9:57 to 12:51 Unit 1 emergency power load switched to the external power source)** **・ 9:01 Power was transmitted to the No.2 start-up transformer at the Tomari power plant. (From 10:01 to 13:00 Unit 2 emergency power load switched to the external power source)** **・ 9:05 Power was transmitted to the No.3 emergency transformer at the Tomari power plant. (From 10:06 to 12:13 Unit 3 emergency power load switched to the external power source)** **(・ 13:00 Switching of the auxiliary power of the Tomari power plant from the emergency power source to the external power source was completed. (The start-up transformer and the emergency transformer were used without using the No.3 main transformer))** **・ From 9:20~:25 Power was transmitted to the Shiribeshi trunk line, the Tomari power plant loop was operated and the Kyogoku power plant received power.** **・ One shunt reactor of the Nishi-tobestu substation and one shunt reactor of the Nishino substation were used additionally (6 in total) for the purpose of voltage adjustments.**

_ is the status concerning the local isolated grid

Fig. 3-8 Status of restoration from the second black start to the reception of auxiliary power at the Tomari power plant (From 6:25 to 9:25 on September 6)



Time	Event
At 6:30	Niikappu power plant Unit 1 parallel in
At 6:32	Power reception at the Niikappu switching station through Nisshou trunk line 1L
At 6:33	Power transmission to the Nisshou trunk line 2L
At 6:37	Niikappu power plant Unit 2 parallel in
At 6:38	Power transmission to the Oku-niikappu line, Power reception at the Iwashimizu switching station
At 6:40	Power transmission to Takami 2L
At 6:46	Power transmission to the Hidaka trunk line, Power reception at the Minami-hayakita substation
From 6:51 to 6:55	Reverse power transmission by transformer for connection with the Minami-hayakita substation
From 6:59 to 7:00	Power transmission to the Yufutsu line 1L, Power reception at the Kyodo thermal power plant
From 7:02 to 7:04	Power transmission to the Tomakomai-karyoku line 1L, Power reception at the Tomakomai substation
From 7:05 to 7:06	Power transmission to the Muroran-higashi trunk line 1L, Power reception at the Muroran substation
From 7:12 to 7:13	Power transmission to the Tomato-atsuma line 1L, Power reception at the Tomato-atsuma power plant
At 7:20	Power transmission to the Doo-higashi trunk line 1L
At 7:22	Power transmission to Takami 1L

Time	Event
From 7:23 to 7:25	Power reception at the Shunbetsu power plant, Power transmission to the Shizunai line, Power reception at the Shizunai power plant
At 7:22	Power transmission to the Doo-minami trunk line 1L
At 7:34	Power reception at the Nishi-tobestu substation
At 7:40	Power reception at the Nishi-futaba substation
At 7:41	Hoheikyo power plant Unit 1 parallel in
At 7:43	Power transmission to the Doo-nishi trunk line 2L
At 7:44	Power reception at the Nishino substation
At 7:49	Shizunai power plant Unit 2 parallel in
At 7:52	Power transmission to the Doo-kita trunk line 1L
At 7:53	275 kV Doo loop restoration
At 8:37	Power transmission to the Tomari trunk line 1L
At 8:52	Power reception at the Tomari power plant
At 8:58	Power transmission to the No.1 startup transformer of the Tomari power plant
At 9:01	Power transmission to the no.2 startup transformer of the Tomari power plant
At 9:05	Power transmission to the No.3 emergency transformer of the Tomari power plant
From 9:20 to 9:25	Power transmission to the Shiribeshi trunk line 1L, loop restoration, Power reception at the Kyogoku power plant

(E) From the reception of auxiliary power at the Tomari power plant to securing the auxiliary power supply at the thermal power plants and integration of the isolated grids (From 10:20 to 13:35 on September 6)

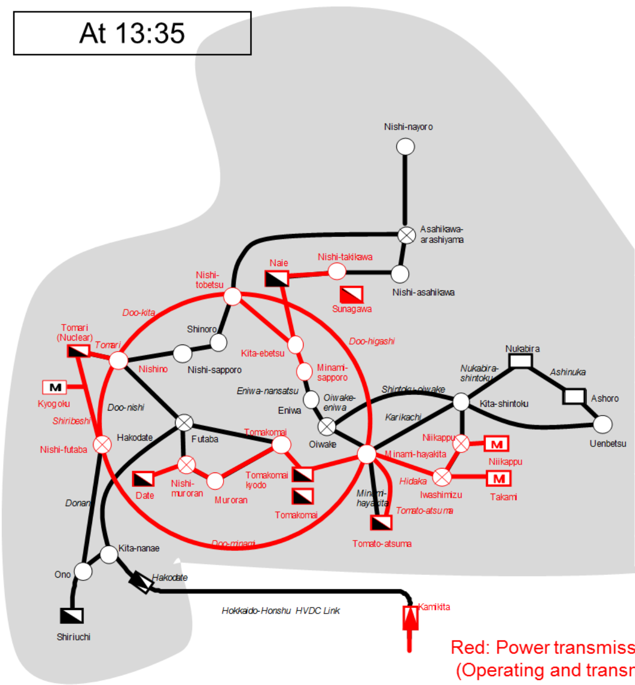
The Investigation Committee verified the facts about individual events of restoration status from the reception of auxiliary power at the Tomari power plant to securing the auxiliary power supply at the thermal power plants and integration of the isolated grids (from 10:20 to 13:35 on September 6) in the Figures 3-9 and 3-10.

Fig. 3-9 Events for which fact finding was carried out by the Investigation Committee [9]

Individual events
5. Black start restoration operation (restoration of main grid, integration of isolated grids, auxiliary power supply at the thermal power plants, load transmission) [1] **<Fact finding>** **・By using the shunt reactor whenever it was necessary, power was transmitted to the main power lines one line at a time while paying attention to the voltage rise.** **・After confirming that there was no abnormality in the power lines, grid restoration operation was carried out during the step when substations received power one by one.** **・For the local isolated grid, grid integration (from the first location to the second location amongst the 5 locations) were carried out sequentially.** **・12:02 Integration with the isolated Sapporo grid (Sorachi river water system power supply) at the Nishi-takikawa substation.** **・13:01 Integration with the isolated Sapporo grid (Toyohira river water system power supply) at the Minami-sapporo substation.** **・ Thermal power grid transmission** **10:37 Naie power plant received power.** **10:54 Nishi-takikawa substation (Sunagawa power plant higher voltage grid) received power. (Sunagawa power plant switched from power reception at local isolated grid (Sorachi river water system power supply) at 4:47 to power reception at Nishi-takikawa substation at 12:02)** **11:26 Date power plant received power.** **13:35 Sunagawa power plant Unit 3 was paralleled in and ensured the supply capacity.** **・ Customer load transmission** **Supply capacity was calculated from the paralleled in arrangement of isolated grids or the parallel in reporting of generators, and customer load transmission was instructed from 11:43 as appropriate.** **Together with securing (increasing) the supply capacity, customer load transmission was performed sequentially.**

_ is the status concerning the local isolated grid

Fig. 3-10 From the reception of auxiliary power at the Tomari power plant to securing the auxiliary power supply at the thermal power plants and integration of the isolated grids (From 10:20 to 13:35 on September 6)



Red: Power transmission status
(Operating and transmitting power)
Black: Shut down

Time	Event
From 10:20 to 10:21	Power transmission to the Kita-ebetsu line 1L, Power reception at the Kita-ebetsu substation
From 10:29 to 10:37	Power transmission to the Naie trunk line 1L, Power reception at the Naie power plant
From 10:49 to 10:54	Power transmission to the Takikawa trunk line 1L, Power reception at the Nishi-takikawa substation
From 11:16 to 11:17	Power transmission to the Muroran-nishi trunk line 1L, Power reception at the Muroran-nishi switching station
From 11:20 to 11:26	Power transmission to the Iburi trunk line 1L, Power reception at the Date power plant
At 12:02	Grid parallel in at the Nishi-takikawa substation Interconnected to the isolated Sapporo grid (Sorachi river water system power supply)
At 12:42	Power transmission to the Minami-sapporo trunk line 1L, Power reception at the Minami-sapporo substation
At 12:52	Takami power plant Unit 1 parallel in
At 13:01	Grid parallel in at the Minami-sapporo substation Interconnected to the isolated Sapporo grid (Toyohira river water system power supply)
From 13:10 to 13:16	Power transmission to the Naebo-kita line 1L of the Nishi-tobestu substation, Power reception at the Naebo substation
At 13:35	Sunagawa power plant Unit 3 parallel in

(F) Until integration of the remaining isolated grids (From 14:15 to 23:48 on September 6)

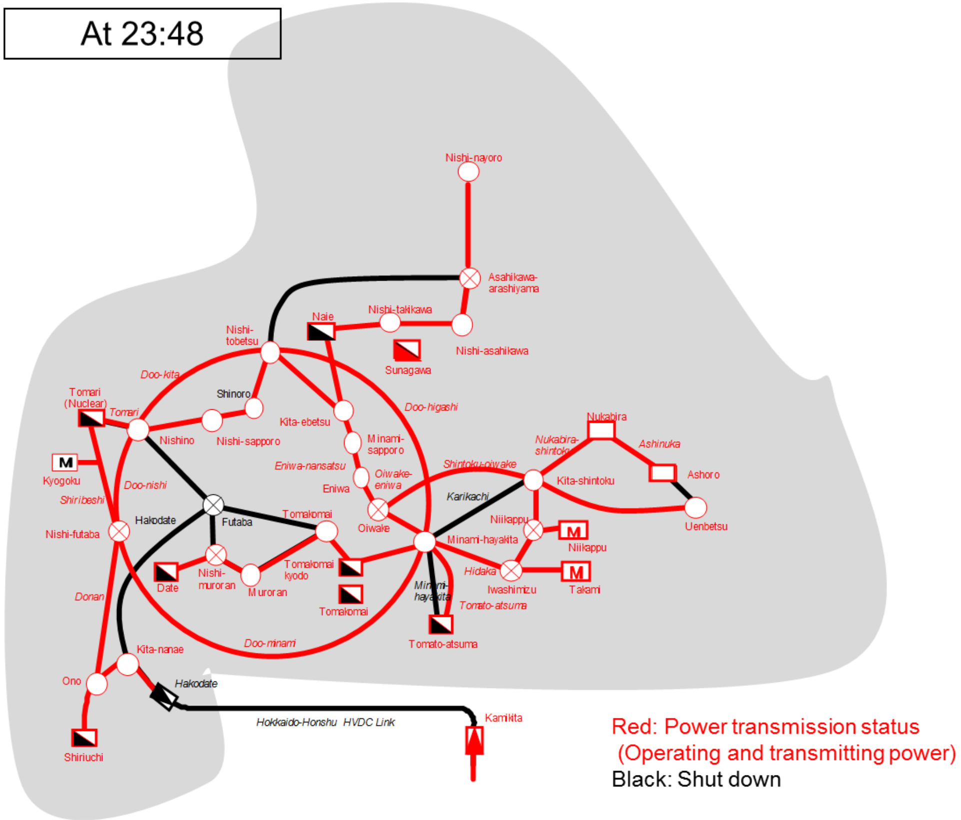
The Investigation Committee verified the facts about individual events of the restoration status until integration of the remaining isolated grids (from 14:15 to 23:48 on September 6) in the Figures 3-11 and 3-12.

Fig. 3-11 Events for which fact finding was carried out by the Investigation Committee [10]

Individual events
5. Black start restoration operation (restoration of main grid, interconnection with isolated grids, auxiliary power supply at the thermal power plants, customer load transmission) [2] **<Fact finding>** **・ While paying attention to the voltage rise, power was transmitted to the main power lines one line at a time and after confirming that there were no abnormalities, power was transmitted to the substations sequentially and the grid restoration operation was executed.** **・ From 14:15 to 16:01, power transmission route was extended to the Donan trunk line, the Hokuto trunk line, the Kitahonnanae line and thereby, power was transmitted to the Hakodate converter station.** **・ For the local isolated grid, grid integration (from the third location to the fifth location amongst the 5 locations) were carried out sequentially and the grid isolation was resolved.** **・15:37 Integration of the Nishi-nayoro grid (Uryu power supply) at the Nishi-asahikawa substation** **・16:11 Integration of the Asahikawa grid (Ishikari river system power supply) at the Asahikawa substation** **・17:32 Integration of the Kushiro grid (Tokachi river water system power supply) at the Kitamemuro substation (Resolution of grid isolation)** **・Power transmission to the thermal power plants** **15:17 Shiriuchi power plant received power.** **・Thermal power plants at parallel in** **20:10 Onbetsu power plant Unit 1 was paralleled in.**

_ is the status concerning the local isolated grid

Fig.3-12 Status of restoration until integration of the remaining isolated grids
(From 14:15 to 23:48 on September 6)



Time	Event
From 14:15 to 14:51	Power transmission to the Donan trunk line 2L, Power reception at the Hokuto convertor station, Power reception at the Ono substation
From 14:27 to 14:43	Power transmission to the Minami-kujo line 1L of the Nishino substation, Power reception at the Minami-kujo substation
From 14:47 to 14:48	Power transmission to the Eniwa-nansatsu line, Power reception at the Eniwa substation
At 14:53	Shimo-niikappu power plant Unit 1 parallel in
At 14:56	Power transmission to the Oiwake-eniwa line 1L
At 15:04	Power transmission to the Nishiotaru line 2L of the Nishino substation, Power reception at the Nishiotaru substation
From 15:07 to 15:16	Power transmission to the Oiwake line 1L, Power reception at the Oiwake switching station
From 15:10 to 15:31	Power transmission to the Muroran-nishi trunk line 1L of the Nishino substation, Power reception at the Nishi-sapporo substation
From 15:16 to 15:17	Power transmission to the Shiriuchi line 1L, Power reception at the Shiriuchi power plant
At 15:18	Minami-sapporo-oiwake loop restoration
At 15:28	Power transmission to the Asahikawa trunk line 1L
At 15:37	Grid parallel in at Nishi-asahikawa substation Interconnection with Nishi-nayoro grid (Uryu power supply)
From 15:57 to 15:58	Power transmission to the Ono line 1L, Power reception at the Kita-nanae substation
From 15:58 to 15:59	Power transmission to the Shinoro line 1L, Power reception at the Shinoro substation
From 16:00 to 16:01	Power transmission to the Asahikawa-minami line 1L of the Asahikawa-arashiyama converter station, Power reception at the Asahikawa substation

Time	Event
At 16:01	Power transmission to the Kitahon-nanae line 1L
At 16:11	Grid parallel in at the Asahikawa substation Interconnection with Asahikawa grid (Ishikari river water system power supply)
From 16:15 to 16:16	Shinoro-Nishi-sapporo loop restoration
From 16:28 to 16:29	Power transmission to the Shintoku-oiwake line 2L, Power reception at the Kitashintoku substation
From 17:20 to 17:22	Power transmission to the Iwamastu-nishi line 1L of the Kitashintoku substation, Power reception at the Kitamemuro substation
At 17:31	Power transmission to the Nisshou trunk line 1L, Niikappu switching station loop restoration
At 17:32	Grid parallel in at the Kitamemuro substation Interconnection with Kushiro grid (Tokachi river water system power supply)
At 17:40	Power transmission to the Tomura line of the Kitashintoku substation, Power reception at the Tokachi power plant
From 17:45 to 17:46	Power transmission to the Doto trunk line 1L, Power reception at the Yubetsu substation
From 19:06 to 19:15	Power transmission to the Nukabira-shintoku line 1L, Power reception at the Nukabira power plant
From 19:23 to 19:29	Power transmission to the Ashinuka line 2L Power reception at the Ashoro power plant
At 20:10	Onbestu power plant Unit 1 parallel in
From 23:47 to 23:48	Power transmission to the shin-nittetsu line of the Nishi-muroran switching station

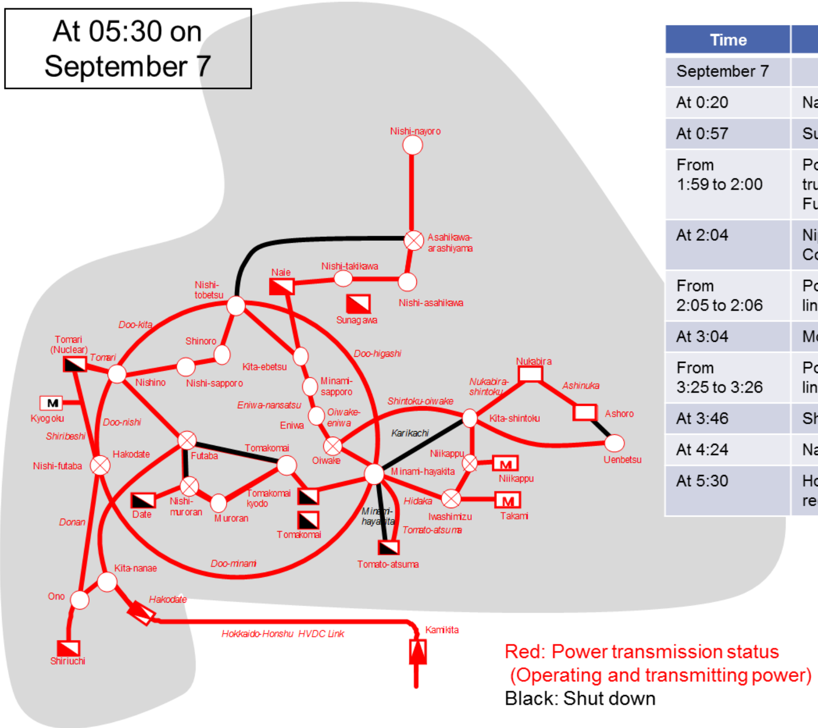
(G) From the integration of isolated grids to the start of receiving power from the Hokkaido-Honshu HVDC Link (From 00:20 to 5:30 on September 7)

The Investigation Committee verified the facts about individual events of the restoration status from the integration of the isolated grids until the start of receiving power from the Hokkaido-Honshu HVDC Link (from 00:20 to 5:30 on September 7) in the Figures 3-13 and 3-14.

Fig. 3-13 Events for which fact finding was carried out by the Investigation Committee [11]

Individual events
6. Black start restoration operation (Securing the supply capacity, Restarting the Hokkaido-Honshu HVDC Link) **<Fact finding>** **・Thermal power plants were sequentially paralleled in and thereby, the supply capacity was secured.** **0:20 Naie power plant Unit 2** **0:57 Sunagawa power plant Unit 4** **2:04 Generators of Nippon Steel and Sumitomo Metal Corporation** **3:04 Mori power plant Unit 1** **3:46 Shiriuchi power plant Unit 1** **4:24 Naie power plant Unit 1** **・ From 1:59 to 3:26, power transmission route was extended to the Muroran-nishi trunk line and the Hakodate trunk line thereby creating the Hokkaido-Honshu loop grid.** **・ In the procedure manual, the criterion for restarting power reception for Hokkaido-Honshu HVDC Link was developed under the condition of combining the operations of 0 to 2 generators of the Shiriuchi power plant, Tomato-atsuma Unit 1, Date Unit 2 and Tomakomai-kyodo Thermal power Unit 3, but Tomato-atsuma Unit 1 could not be paralleled in and hence could not be used, therefore, short-circuit capacity was calculated individually.** **・The grid when power was received at the Hokkaido-Honshu HVDC Link was through 1 line of the Donan trunk line, 2 lines of the Hakodate trunk line, and 1 generator of the Shiriuchi power plant, and it began to receive the transferred power from 5:30 on September 7. The capacity of power received was increased sequentially and 300 MW was received from 7:30 onwards, which contributed in securing the supply capacity within Hokkaido.**

Fig. 3-14 Status of restoration from integration of isolated grids until the start of customer load transmission (From 00:20 to 5:30 on September 7)



Time	Event
September 7	
At 0:20	Naie power plant Unit 2 parallel in
At 0:57	Sunagawa power plant Unit 4 parallel in
From 1:59 to 2:00	Power transmission to the Muroran-nishi trunk line 1L, Power reception at the Futaba switching station
At 2:04	Nippon Steel & Sumitomo Metal Corporation generator parallel in
From 2:05 to 2:06	Power transmission to the Hakodate trunk line 2L, loop restoration
At 3:04	Mori power plant Unit 1 parallel in
From 3:25 to 3:26	Power transmission to the Hakodate trunk line 1L, Joint use of 2 lines
At 3:46	Shiriuchi power plant Unit 1 parallel in
At 4:24	Naie power plant Unit 1 parallel in
At 5:30	Hokkaido-Honshu HVDC link starts receiving the transferred power

(H) Until the completion of transmission of customer load (From 6:20 on September 7 to 00:13 on September 8)

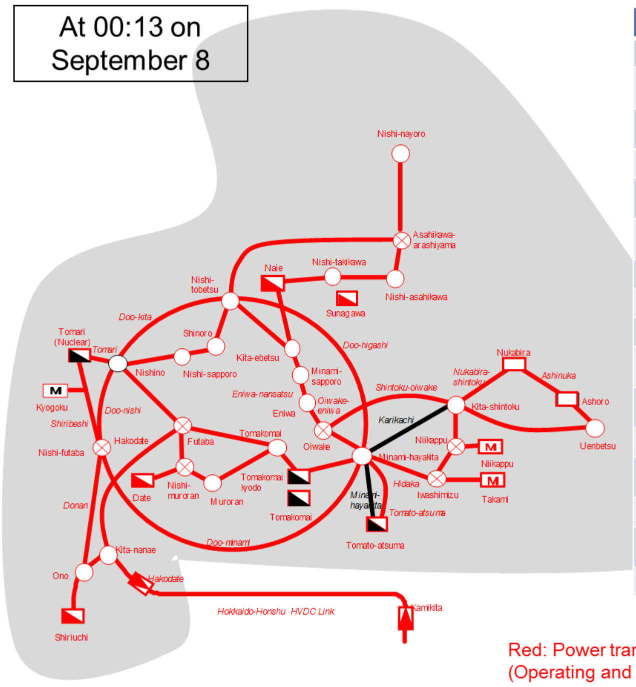
The Investigation Committee verified the facts about individual events of the restoration status until the completion of transmission of customer load (from 6:20 on September 7 to 00:13 on September 8) in Fig. 3-15.

Fig. 3-15 Events for which fact finding was carried out by the Investigation Committee [12]

Individual events
7. Black start restoration operation (Increase in the Hokkaido-Honshu power transfer, completion of customer load transmission) **<Fact finding>** **・The Onbetsu power plant failed at 6:36, so Unit 1 was paralleled off.** **・Thermal power plants were sequentially paralleled in and thereby, supply capacity was secured.** **9:08 Onbestu power plant Unit 2** **11:17 Date power plant Unit 1** **19:18 Date power plant Unit 2** **・Short-circuit capacity was calculated individually, and it was judged that it was possible to receive 600 MW full power transfer at Hokkaido-Honshu HVDC Link by parallel in of 1 generator at Shiriuchi and Date Units 1/ 2.** **・The capacity of power received by the Hokkaido-Honshu HVDC Link was increased sequentially from 21:00 on September 7, and it started to receive the 600 MW full power from 24:00 and in this way, it contributed to securing the supply capacity within Hokkaido.**

・Regarding the transmission to customer load, supply capacity in Hokkaido was secured by starting the thermal power and hydro power and by increasing the Hokkaido-Honshu power transfer, and the restoration of entire customer load was completed at 00:13 on September 8 by transmitting the customer load in the Kushiro region.

Fig.3-16 Status of restoration until the completion of transmission to customer load (From 6:20 on September 7 to 00:13 on September 8)



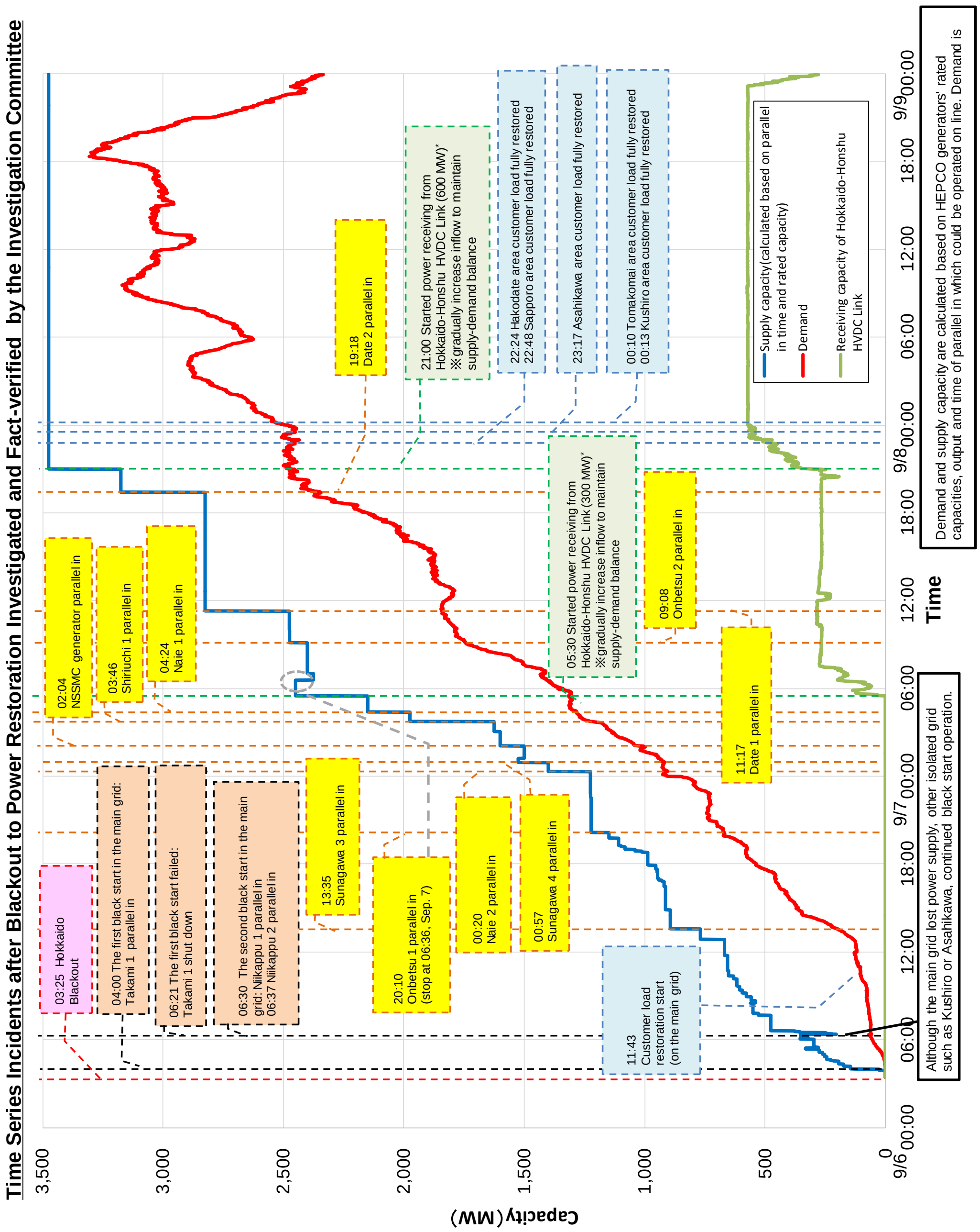
Time	Event
September 7	
At 6:20	Power transmission to the Muroran-nishi trunk line 1L, Loop at the Nishi-muroran switching station
At 6:30	Power transmission to the Futaba trunk line 2L, Loop at the Futaba switching station
At 6:36	Onbestu power plant Unit 1 parallel off
From 6:45 to 6:46	Power transmission to the Dohoku trunk line 1L, Loop at the Asahikawa-arashiyama switching station
From 6:45 to 6:46	Power transmission to the Kushiro trunk line 1L, Loop at the Ashoro power plant
At 9:08	Onbestu power plant Unit 2 parallel in
At 11:17	Date power plant Unit 1 parallel in
At 19:18	Date power plant Unit 2 parallel in
At 21:00	Hokkaido-Honshu HVDC link - Start of increase in the reception of transferred power
At 22:24	Hakodate region - Full transmission of general load supply
At 22:48	Sapporo region - Full transmission of general load supply
At 23:17	Asahikawa region - Full transmission of general load supply
September 8	
At 0:10	Tomakomai region - Full transmission of general load supply
At 0:13	Kushiro region - Full transmission of general load supply

Red: Power transmission status
(Operating and transmitting power)
Black: Shut down

(2) Time series from blackout to the completion of transmission to customer load (From 3:25 on September 6 to 00:13 on September 8)

As described in Section 3.2.(1), the organization of the time series related to restoration from blackout to ensuring a certain supply capacity for which fact finding was done by the Investigation Committee, is as shown in Fig. 3-17.

Fig. 3-17 Organization of the time series related to restoration from blackout to ensuring a certain supply capacity (Restoration status of grid from 3:25 on September 6 to 00:13 on September 8)



3. Points of verification regarding the restoration status from blackout to the completion of transmission to customer load (From 3:25 on September 6 to 00:13 on September 8)

Points of verification concerning the restoration status from blackout to the completion of transmission to customer load (from 3:25 on September 6 to 00:13 on September 8) are as follows:

- Did restoration proceed according to the procedure manual?
  ⇒If the restoration procedure differed from that in the manual, what was the reason for it? And was it valid?
  — *Verification point [1]*
- Did restoration take too much time?
  ⇒ Why did the first black start fail?
  If there was no failure, would the restoration be faster?
  — *Verification point [2]*
  ⇒Why was it not possible to receive power from the Hokkaido-Honshu HVDC Link more quickly?
  — *Verification point [3]*

(1) Did restoration proceed according to the procedure manual? (Verification point [1])

The Investigation Committee confirmed whether the restoration proceeded as described in the procedure manual (refer to Fig. 3-1) and also verified the reason if the restoration was carried out using a procedure different from the procedure manual (refer to Fig. 3-19).

Fig.3-18 Hokkaido Electric Power Company's Procedure Manual for Blackout Restoration ("Restoration Policy and Explanation for Total Grid Blackout")

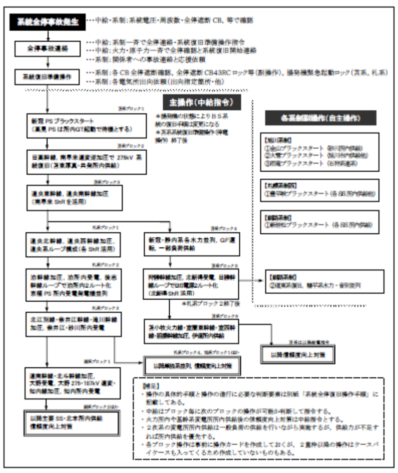
Procedure summary **・Based on the state of generators subject to black start, develop a pattern for the order of activating the generators (Prepare a total of 7 patterns)** **In order to stabilize the grid, restoration using two pumped-storage hydro power plants is the norm.** **・Clarification of grid restoration priorities after black start** **To be implemented from the 275 kV grid which has few operational steps in order to secure the auxiliary power supply for the security of the thermal and nuclear power plants and to re-parallel in the grids at an early stage** **Load supply** **・The Load Dispatching Center shall calculate the supply capacity from the generator parallel in status and instruct the Grid Control Center to resolve the supply disturbance** **・Considering the frequency and voltage fluctuations due to the load supply of the black start grid, the Grid Control Center will transmit power of about 3 MW units**	 **Excerpt from the "Restoration Policy and Explanation for Total Grid Blackout" (Hokkaido Electric Power Company)**

Fig. 3-19 Items for which operations differed during the first and second black start and differences with the procedure manual

	First	Second	Reason
Generators subject to black start	Takami Unit 1 (According to the procedure manual Low priority)	Niikappu Unit1 Niikappu Unit 2 (According to the procedure manual Procedures different from the first black start)	Although the Niikappu power plant was the main starting point of the black start, due to the failure of the auxiliary power supply at the Niikappu power plant, the first black start was started from the Takami power plant.
(Additional generators)	Shunbetsu Unit 1 Higashinosawa Unit 1 Shimoniikappu Unit 1	Shizunai Unit 2	For the second black start, the failure at the Niikappu power plant was reserved and it became ready for operation and therefore, black start was carried out from the Niikappu power plant as the starting point.
Central Hokkaido grid loop configuration		Power transmission to the Muroran substation through the Tomakomai thermal power line and the Muroran-higashi trunk line	Since the use of equipment and transmission lines where failure has occurred may cause accident again, other equipment and adjacent lines were used. Since voltage reduction equipment of the Minamihayakita substation became unavailable, and since equipment of the Muroran substation had to be used as a substitute, power transmission was additionally executed from the Muroran substation.
	Doo-higashi trunk line No.1 Doo-minami trunk line No.1 Doo-nishi trunk line No.1 Doo-kita trunk line No.1 (As per the procedure manual)	Doo-higashi trunk line No.1 Doo-minami trunk line No.1 Doo-nishi trunk line No.2 Doo-kita trunk line No.1 (As per the procedure manual)	
Reception of auxiliary power supply at Tomari power plant	Startup transformer No.1 Startup transformer No. 2 Main transformer No.3 Emergency transformer No.3 (As per the procedure manual)	Startup transformer No.1 Startup transformer No.2 Emergency transformer No. 3	Although the auxiliary power of Unit 3 is supposed to receive power from the main transformer No.3 and the emergency transformer No.3, due to the failure of the first black start, the auxiliary power supply during the second black start was only from the emergency transformer No.3. During the first black start, the Takami power plant shut down before the power transmission to the emergency transformer No.3.

Matters confirmed on the basis of Fig. 3-18 and Fig. 3-19 are as follows:

- The restoration procedure was carried out more or less according to the procedure manual.
- The Niikappu power plant which was the starting point of the black start could not be immediately operated due to the failure of the auxiliary power supply during blackout, hence a black start was executed according to the procedure manual from the Takami power plant where the start was feasible.
- During the second black start, restoration started from the Niikappu power plant which was considered feasible based on site verification and the grid restoration was carried out more or lower as described in the procedure manual, making the failure of the first black start as lessons learned.
- In the early stages of restoration during both the first and second black start, power was supplied to the Tomari power plant as described in the procedure manual.
- During the restoration of the Tomato-atsuma Power Plant, an attempt was made to start Unit 4 which had an undamaged boiler, but since there was sparking near the turbine axis, restoration of Unit 4 had to be suspended. Note that for the Sunagawa power plant, restoration was carried out in parallel corresponding to Tomato-atsuma Unit 4.

Moreover, the evaluation results for validation of the verified matters are as follows:

- After blackout at 3:25, from 3:27 to 3:31, the Load Dispatching Center ordered the Tomakomai grid control center to execute a black start from the Takami power plant as the starting point, and the unavailability of the Niikappu power plant for the first black start did not serve as a delay in the restoration time.
- Further, restoration of the Sunagawa power plant was carried out in parallel with the Tomato-atsuma Power Plant Unit 4 and the attempt to start Tomato-atsuma Power Plant Unit 4 did not serve as a delay in the restoration time.
- There are some procedures that are different from the procedure manual because during the second black start, restoration procedures, such as avoiding the equipment that were damaged at the time of the first black start, are appropriate.
- Like the Tomari power plant, power is supplied to other thermal power plants as soon as possible as it is generally reasonable to supply power at an early stage in order to ensure auxiliary power supply for security purposes.

(2) Did restoration take too much time? (Verification points [2] **and** [3]**)**

The Investigation Committee carried out verification from the viewpoint of "Did restoration take too much time?" and investigated the following two events for which the Committee believed that the take time.

(a) Failure of the first black start

Verification point [2] *Events during the first black start*

(b) Delay in the capacity increase of power received (+300 MW) from the Hokkaido-Honshu HVDC Link

Verification point [3] Timing of power reception from the Hokkaido-Honshu HVDC Link

(a) *Verification point [2]* Events during first black start

The Investigation Committee investigated the reason for the failure of first restoration, and also if there had been no failures, would the restoration be faster.

During the first black start, following the commercial the generator operations (at 4:00) at the Takami power plant, according to the procedure manual, restoration was carried out aiming to secure auxiliary power supply for the safety of the thermal and nuclear power plants or for the auxiliary equipment to be used for starting the generators, but after the transmission of power to the main transformer No.3 (at 6:19) at the Tomari power plant, the black start generator shut down in just 2 minutes (at 6:21). In those 2 minutes following events occurred and the black start generator shut down:

At 6:19, when power was transmitted to the main transformer No.3 at the Tomari power plant, a large capacity of current (excitation inrush current) flowed in.

At 6:19, shunt reactors of the Minamihayakita substation and the Kitashintoku substation stopped due to the effect of large capacity of current from the Tomari power plant.

At 6:21, due to the voltage rise after the shutdown of the shunt reactors at both substations, ground fault occurred on the Doo-nishi trunk line and the Karikachi trunk line.

At 6:21, due to the impact of the ground fault accident, the Takami power plant and other power plants detected an abnormal current and the generators shut down.

* For details, simulation etc.is necessary.

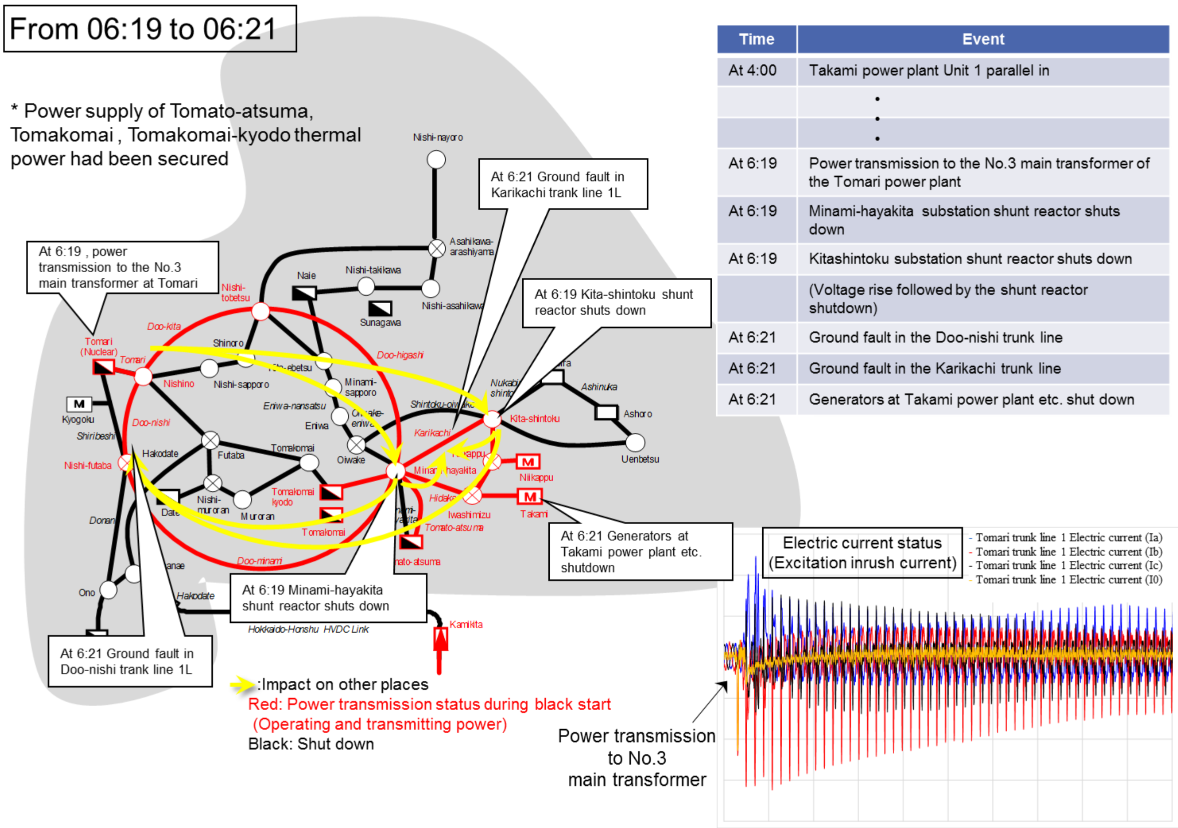
The evaluation results of the verified matters are as follows:

- After the blackout, procedures were executed for 35 minutes until the commercial power generation at Takami power plant and thereafter also, the procedures for securing the auxiliary power supply for the safety of the power plant or the power supply for the auxiliary equipment in order to start the generators were carried out quickly and appropriately.
- At the time of power transmission to the main transformer No.3 of the Tomari power plant, a large capacity of current was generated. This phenomenon of flow of a large capacity of current during power transmission to a transformer is not

limited to black start and can usually happen in case of any transformer. This time, the grid at the initial stage of black start was small and although it was assumed that this large current flow would have various effects on the power grid, it is a complicated phenomenon and difficult to predict.

- Therefore, as a whole, we could evaluate that the restoration work had been appropriately carried out based on the given procedures. On the other hand, it is desirable to improve the restoration procedure considering the abnormal events when power is transmitted in the no-load state.

Fig. 3-20 Events related to the first black start



(b) Timing of power received from the Hokkaido-Honshu HVDC Link (*__Verification point [3]__*)

The Investigation Committee verified why power from the Hokkaido-Honshu HVDC Link could not be received more quickly.

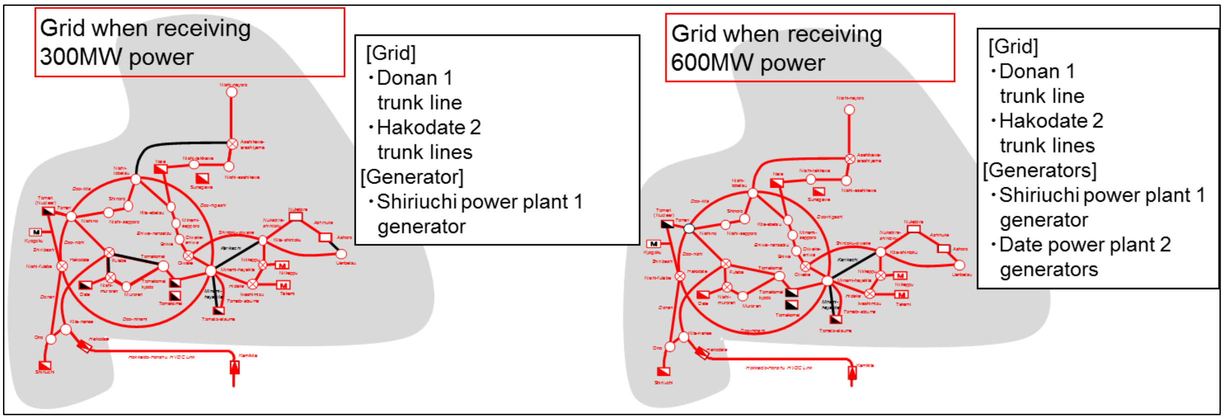
If the voltage of the power grid is unstable, the Hokkaido-Honshu HVDC Link may shutdown and therefore, it is necessary to increase the size of certain grids. The necessary grid size for stable power reception was calculated and after confirming that the conditions were satisfied, power reception was started between the Hokkaido-Honshu.

This time, with the restoration of the power lines (Hakodate trunk line, Donan trunk line) around Hokkaido-Honshu HVDC Link, it was calculated that 300 MW could be received from the Hokkaido-Honshu HVDC Link by restoring one generator at the Shiriuchi power plant and 600 MW (+300 MW) could be received by restoring two generators at the Date power plant (Refer to Fig. 3-21).

The delay in the restoration of the Date power plant, compared to other power plants, due to the failure of the auxiliary power supply is presumed to be the cause of the delay in receiving +300 MW power from the Hokkaido-Honshu HVDC Link.

Note that the new Hokkaido-Honshu HVDC Link is of the "self commutation type" and does not require the Hokkaido grid voltage, therefore this problem will not arise.

Fig. 3-21 Grid status when power was received from the Hokkaido-Honshu HVDC Link



Note that the verifications carried out regarding the Hokkaido-Honshu HVDC Link and the reception of the transferred power are as shown below:

- Since the reception of transferred power from the Hokkaido-Honshu HVDC Link is decided on the basis of the short circuit capacity ratio (3 times more than the power transfer capacity) which is in turn determined by the parallel in generators or the number of interconnection lines of the Hokkaido side grid, the transferred power is received while securing the required number of interconnection lines (Refer to the criteria described in the procedure manual of Fig. 3-22).

  However, since the limiter of the Hokkaido-Honshu HVDC Link is automatically set by Shiriuchi's generator under the parallel in condition or the line conditions etc., the appropriate limiter value is set corresponding to the receivable power capacity manually (requested to the Electric Power Development Co., Ltd.).

- In this case, since the generators shown in Fig. 3-22 could not be paralleled in, the short circuit capacity is calculated individually and the short circuit capacity of the Hakodate converter station site is confirmed.

Fig. 3-22 Criteria for receiving power from Hokkaido-Honshu HVDC Link after thermal power parallel in (Source: “Restoration policy and explanation for total grid blackout”)

Conditions		Grid: One line of each 275kV/ 187kV central Hokkaido loop grid, configuration of two lines of each thermal power line, Ohno SVC operation (66kV grid loop), Generator: Shows possible capacity of power transfer line after parallel in with 0 generators of nuclear power, Tomato-atsuma Unit 1/ Kyodo Unit 3/ Date Unit 2. () shows the case when Date is not paralleled in. Kyodo Unit 3/ Date Unit2 are for standby and reserve generator operations (Response to tripping of largest generator and parallel in of Sunagawa/ Naie are not considered since it will not significantly affect the short circuit capacity.)					
	Shiriuchi Conditions	4 Lines	3 Lines	2 Lines			1 Lines
		D2 + H2	D2 + H2	D2	D1 + H1	H2	D1 or H1
Short circuit capacity(MW)	1	1853(1616)	1744	1602	1620(1472)	1413	1204
	0	1091(835)	960	844	839(631)	581	369
Upper stage: Limiter value (MW) Lower stage: Possible capacity of power received (MW)	2	600	450	550	250	0	0
	1	600 600(500)	600 550	600 500	300	300	150
	0	600 350(250)	600 300	500(300*1) 250	300 250(200)	300 150	150 100

D: Donan trunk line, H: Hakodate trunk line, *1: Limiter value at the time of SVC shutdown, [grey box]: Limiter value for which manual setting is necessary

The evaluation results of the verified matters are as follows:

- If the generators at the Date power plant could be paralleled in at an early stage, the +300 MW power from the Hokkaido-Honshu HVDC Link could also have been received at an early stage. As a result, blackout could also have been restored earlier. In addition to the delay in parallel in at the Date power plant due to the equipment failure, if speed constraints of the power supply (about 3MW for every few minutes) on the load upon the black start grid is considered, a significant shortening of the restoration time cannot be expected with the continuation of tremors.
- Even without receiving +300 MW from Hokkaido-Honshu HVDC Link, it is believed that the supply capacity at this point (on September 8 at 0:13) had almost been covered by the time Date Unit 1 was paralleled in.

4. Points of verification regarding the development of restoration policy and the status of drills in preparation for blackouts

The points of verification regarding the development of restoration policy and the status of drills in preparation for blackouts are as given below:

What is the status of preparation of the procedure manual and the actual condition of training?

(1) Development of restoration procedures ･･･Verification point [4]-1

(2) Implementation Status of Drills ･･･Verification point [4]-2

(3) Restoration System (Securing Personnel) ･･･Verification point [4]-3

(1) Development of restoration procedures *(Verification point [4]-1)*

The matters confirmed about the Hokkaido Electric Power Company's blackout restoration procedures are as given below (Refer to Fig. 3-23):

- It is confirmed that "Restoration policy and explanation for total grid blackout" is developed as a policy to restore a grid during blackout.

The evaluation results of the verified matters are as follows:

- In the procedure manual, the roles and procedure details are clearly notified to the relevant parties. Since the restoration procedures have been developed in such a way that restoration is carried out efficiently, the Investigation Committee recognizes that the preparations for restoration in the event of total grid blackout are done.
- Although the procedure manual assumes a small damage to the main grid distribution equipment, it is preferable to lay down a policy for handling cases where some equipment in the main grid is damaged.
-

Fig. 3-23 Hokkaido Electric Power Company's Procedure Manual for Blackout Restoration

("Restoration policy and explanation for total grid blackout")

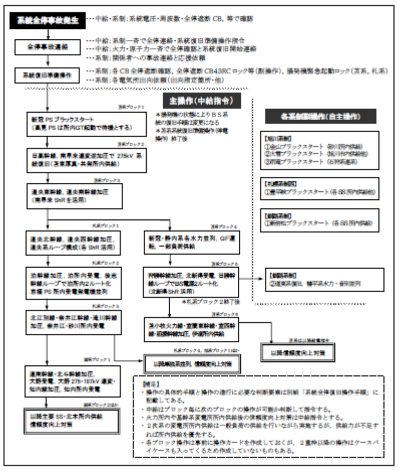
■ **Development of restoration procedures**

- **"Restoration policy and explanation for total grid blackout" has been developed as a policy to restore a grid in the event of a blackout.**

(Example of the described contents)

➢ **Basic policy for restoration operations**

- **Based on the state of generators subject to black start, develop a pattern for the order of activating the generators (Prepare a total of 7 patterns)**
  In order to stabilize the grid, restoration using two pumped-storage type generators is the norm
- **Clarification of grid restoration priorities after black start**
  To be implemented from the 275 kV grid which has few operational steps in order to secure the auxiliary power supply for the security of the thermal and nuclear power plants and to re-parallel in the grids at an early stage



Excerpt from the "Restoration Policy and Explanation for Total Grid Blackout" (Hokkaido Electric Power Company)

(2) Implementation Status of Drills *(Verification point [4]-2)*

The matters verified regarding the implementation status of restoration drills are as given below (refer to Fig. 3-24):

- The Investigation Committee confirmed that the drill is conducted regularly.

The evaluation results of the verified matters are as follows:

- The drill is conducted on the basis of the procedure manual, and the Investigation Committee recognizes that the preparations for restoration in the event of total grid blackout are done.
- Since drill is being conducted through simulated work, it is desirable to incorporate the experience obtained through actual work into drills.

Fig. 3-24 Implementation status of restoration drills in preparation for blackout

■ **Implementation status of training (Interviews with Hokkaido Electric Power Company)**

- **Frequency: Once a year × 5 shifts**
- **Target workers: Shift workers of both the Load Dispatching Center and the Grid Control Centers related to Load Dispatching Center**
- **Details: Simulation and actual work is carried out for the specified restoration procedures**
  During the inspection of the generators subject to black start, make sure that the generators, which are in a blackout state, have started
- **Other: Conducted in February 2018 in the recent times**
  The training scale differs according to the year. In the recent years, the training scale for February 2017 was large

(3) Restoration System (Securing Personnel) *(Verification point [4]-3)*

The matters verified regarding the restoration system (securing personnel) are as given below (Refer to Fig. 3-25):

- The Investigation Committee confirmed that the notification and liaison system and standards for emergency attendance to office are prepared:

The evaluation results of the verified matters are as follows:

- Restoring operation can be executed promptly by the shift workers of the Load Dispatching Center and Grid Control Centers.

Furthermore, it is recognized that the preparations concerning restoration, such as emergency gathering of personnel for restoration support in the event of a total grid blackout, is complete.

Fig. 3-25 Status of development of restoration system in preparation for a blackout

■ **Restoration system (securing personnel)**

Make the following preparations to establish a system to be used in the event of a major disaster:

- **Establish an emergency sequential reporting system as a notification and liaison system within the Head Office in case of an accident or a natural disaster**
- **Develop the standards for emergency attendance to work in case of a major earthquake**

5. Appendix

Regarding the blackout restoration period, when other major blackouts that occurred in foreign countries are compared with this blackout (refer to Fig. 3-26), it is necessary to bear in mind that a simple comparison and verification does not work because the restoration speed differs in accordance with the difference in grid size. It is also necessary to investigate whether the situation is such that power can be received from the adjacent synchronous AC grid area quickly.

For example, a major blackout that occurred in South Australia in September 2016 was restored in about 26 hours based on receiving power from the adjacent area, but it took 3 and a half hours for the initial power start-up from blackout. On the other hand, examples of blackouts in isolated grids include the blackouts in Hawaii in the USA (Oahu Island) and in Jamaica, but the grid size is different, so as a reference, if the restoration time per 1,000 MW blackout is compared, the case in Hokkaido (about 15 hours) will be positioned between that of Hawaii (over 16 hours) and of Jamaica (about 11 hours).

Fig. 3-26 Restoration in case of major blackouts in foreign countries

	Blackout scale (Maximum demand in 2017)	Duration (Per 1,000 MW)	Remarks
South Australia (Tornado: September 2016)	About 1,900 MW (All Australian grids are unknown)	About 26 hours (About 13 hours)	Restoration by receiving power from adjacent areas (About 3 and a half hours until the initial power start-up) Maximum demand of South Australia: About 3,100 MW
Hawaii (Oahu Island) (Earthquake: October 2006)	Unknown (About 1,200 MW)	About 19 hours (Over 16 hours)	Restored by black start
Jamaica (Operational error: August 2016)	About 500 MW (About 700 MW)	About 5 hours30 minutes (About 11 hours)	Restored by black start
Hokkaido (Earthquake: September 2018)	About 3,090 MW (About 5,300 MW)	About 45 hours (About 15 hours)	Restored by black start (Power received from Hokkaido-Honshu HVDC Link during restoration)

*Excluding damage caused by earthquake on distribution lines

6. Brief Summary

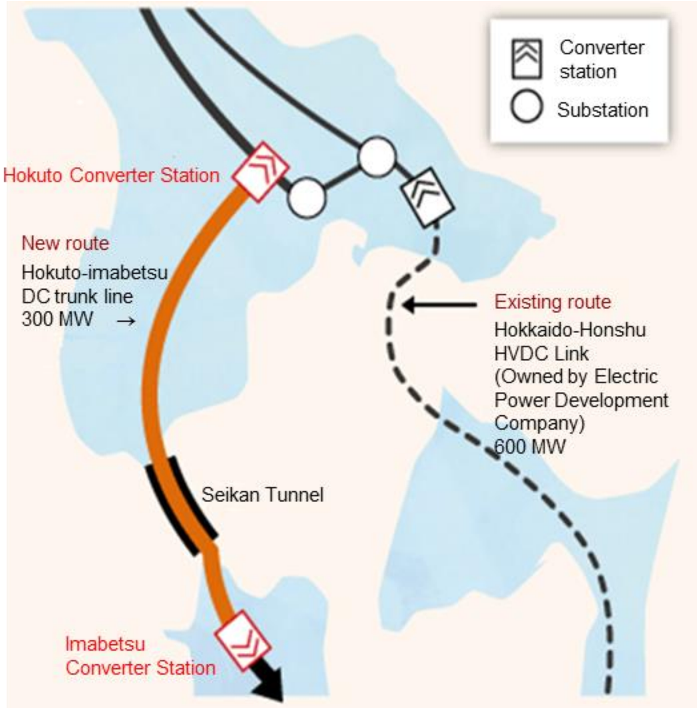
This chapter confirms that the preparation of the procedure manual assuming a blackout and training for the same has been surely carried out more reliably than in the past. For the restoration from this accident was confirmed to be more or less in accordance with the procedures. Though there were a few points where the restoration was performed using a procedure different from that in the procedure manual, the procedures can be said to be generally appropriate taking into account the condition of the equipment used for restoration and the fact that the procedures were overlooked to avoid the accident equipment that had been used for the first black start attempt.

If the first black start had not failed, the blackout might have been restored a couple of hours earlier. Moreover, if the Date power plant could be paralleled in early, +300 MW from Hokkaido-Honshu HVDC Link would have been received early and would have helped to restore blackout even earlier. However, when power is supplied to the customer load in the black start grid, it must be carried out in phases while monitoring the voltage and frequency and carefully ensuring a balance with the generator output. Moreover, the first event caused by the shutdown of shunt reactors at Minami-hayakita and Kitashintoku substations is technically complicated and it is extremely difficult to predict the shutdown under the situation at the time. Therefore, even if the first black start event had happened ideally without a failure, only a few hours could have been shortened at the maximum considering the grid size of the Hokkaido Electric Power Company.

From the above, it is believed that the period required for restoration from blackout in a real grid, which has never been experienced so far, was reasonable. However, improvements in the procedure manual and training based on this event is desirable in order to shorten the restoration period.

Note that the restoration procedure will be reviewed with the start of operations of the new Hokkaido-Honshu HVDC Link (operations to start in March 2019, refer to Fig. 3-27), and we hope it will contribute to shortening the restoration period.

Fig. 3-27 Construction Route of new Hokkaido-Honshu HVDC Link



Section 4 Recurrence Prevention Measures
1. Overview

About the measures based on the causes of the events mentioned in Chapter 2 "Details of Sequence of Events from the Occurrence of the Earthquake to the Blackout" and Chapter 3 "Details of sequence of events from the blackout to ensuring a certain supply capacity (Approx. 3,000 MW)", as a general theory, in addition to the fact that there are items that require considerable time and some others that do not require time to investigate and implement measures (including their feasibility), the effect of the crunch in power supply and demand during intense cold on the life and safety of the people is enormous in the Hokkaido area, therefore, we believe that it is necessary to take short-term measures for the time being (winter), and to take medium-to-long-term measures thereafter.

Since the Investigation Committee is mainly engaged in technical investigation, we believe that investigation and verification from a comprehensive perspective, including that of economic efficiency, must be separately conducted by the Government and OCCTO on the basis of the investigation by the Investigation Committee through the interim report and final report.

Investigation and verification from this perspective shall be performed on the basis of the interim report at the cabinet meeting on emergency inspection of critical infrastructure and Working Group on Electricity Resilience. The Interim Summary of the Working Group on Electricity Resilience has requested to ensure thorough operations based on the interim report of the Investigation Committee for the time being (winter 2018/19).In addition, (or) In conjunction with this decision, the Interim Summary has also consolidated the “medium-term measures” to prevent blackouts to the maximum possible extent as well as to minimize the damages or risks in the event of a blackout, which should be started investigation instantly after the Interim Summary of Working Group on Electricity Resilience. At present, with reference to the "medium-term measures", the government and OCCTO are moving to a stage where investigations will be carried out to obtain certain conclusions by next spring.

Moreover, through the verification by the Investigation Committee, the issues that became evident and lessons learned from blackout and black start, which occurred in Japan for the first time, are extremely valuable from the perspective of improving the blackout recurrence prevention measures and black start response measures not only in the Hokkaido area, but also in areas other than Hokkaido in the future. Therefore, we think that it is necessary to share the experiences, the knowledge obtained, and measures across the nation, to investigate the feasibility of reviewing the existing blackout recurrence prevention measures and black start response measures and to develop training programs to enhance the effectiveness of these response measures in each area and wider areas.

In addition, it might not be possible to use the measures obtained as a result of the investigation by the Investigation Committee as they are because there is a difference in the characteristics of each area. However, based on the main purport of the considerations and recommendations in the interim report and the final report, we believe it is necessary to expand the measures to areas other than the Hokkaido area or across the country.

2. Measures based on the causes of events from the occurrence of the earthquake to blackout (Blackout recurrence prevention measures)

(1) Basic approach

As stated in Section 2.8, in terms of the events from earthquake occurrence to the blackout, the blackout mainly occurred due to the multiple factors including the shutdown of Units 1, 2, and 4 of the Tomato-atsuma Power Plant (N-3) and loss of the automatic frequency control function (mainly, AFC) due to the shutdown of hydro power plants caused by the transmission line accident on the Karikachi trunk line and two other lines (N-4).[6]

Note that based on the results of verification by simulation, it is believed that under the supply-demand balance status similar to the time of actual earthquake, the event of blackout would not have taken place even if events similar to the events that followed after the occurrence of the earthquake had taken place (tripping of 1 site at the Tomato-atsuma Power Plant and the transmission accident on the Karikachi trunk line and 2 other lines (N-4) leading to the shutdown of hydro power) had there been 2 large-scale pumped-storage generators (Kyogoku power plant Units 1/ 2) available. Moreover, it is believed that even if the 2 large-scale pumped-storage generators (Kyogoku power plant Units 1/ 2) had shut down, but had the hydro power not shut down due to the transmission accident on the Karikachi trunk line and 2 other lines (N-4), it would not have resulted in a blackout.

Although we had said that we were almost able to explain the main events at the stage of the Interim Report, as a result of verification through simulations, at present, we can say with authority that we can explain the main events.

Therefore, the basic approach to measures based on the causes of events from the occurrence of the earthquake to blackout is as follows:

- The current rules on facility formation allow a fixed power outage against the risks with rare occurrence over N-2 failure (two generators, simultaneous failure of two transmission lines)[7]. According to the international standards, though there are some differences in the approach to N-1 (single failure of power equipment), as for the N-2 or higher events, it is a general rule to prevent cascading outage in operations (In

[6] The method of expressing the number of occurrences of failure locations such as power generation equipment and transmission lines, such as N-1, N-2, N-3, N-4, … N-X is originally used for facility formation. The Investigation Committee has conveniently used this for operations, as a method of expressing the number of occurrences of failure locations in the shutdown of the Tomato-atsuma Power Plant Units 1, 2, 4, and accident on the Karikachi trunk line and two other lines.

[7] Even in the event of simultaneous loss of one generator and one transmission line, the failure is considered as N-2 failure. The same shall apply hereinafter.

other words, although power outages are acceptable, blackout must be avoided to the extent possible through operations).

- Regarding the facility formation of Hokkaido Electric Power Company, no inappropriate points have been found with respect to current rules on facility formation, and upon verification of the operations of Hokkaido Electric Power Company, including the operational measures assumed beforehand, we cannot necessarily say that the measures were inappropriate.
- However, based on the events this time, we believe that it is necessary to investigate and implement operational measures to reduce the risk or occurrence time of power outages so that blackouts can be avoided to the extent possible in the future.
- As the operational measures, we believe that it is necessary to take short-term measures for the time being (winter 2018/19) and to take medium-to-long term measures after that.
- Moreover, in the operational measures, there can be times when it is difficult to avoid blackouts. Therefore, equipment measures must be examined in parallel with the operational measures. We believe that the measures must be implemented if necessary after ascertaining the investigation results of the operational measures.
- Note that, in particular, we believe it is desirable to technically implement the medium-to-long term measures for operations and facility formation necessary to avoid blackouts to the extent possible, assuming response measures against risk of rare occurrence such as simultaneous tripping of all generators of the largest power plant in the Hokkaido area, but we also believe that the Government must carry out investigations and verification from a comprehensive perspective, including from the economic viewpoint.[8]

[8] Investigation and verification from this perspective shall be performed by the Government specifically on the basis of the interim report at the cabinet meeting on emergency inspection of critical infrastructure and Working Group on Electricity Resilience. The Interim Summary of the Working Group on Electricity Resilience has requested to ensure thorough operations based on the interim report of the Investigation Committee for the time being (winter 2018/19), In addition, (or) In conjunction with this decision, the Interim Summary has also consolidated the “medium-term measures”to prevent blackouts to the maximum possible extent as well as to minimize the damages or risks in the event of a blackout, which should be started investigation instantly after the Interim Summary of Working Group on Electricity Resilience. At present, with reference to the "medium-term measures", the government and OCCTO are moving to a stage where investigations will be carried out to obtain certain conclusions by next spring.

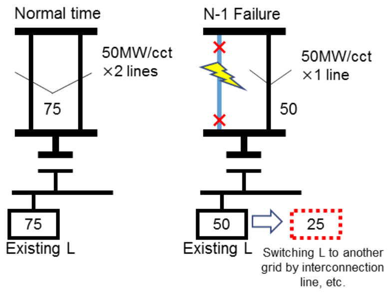
<Appendix 1: N-1Standards>

Fig. 4-1 N-1 Standards

[Summary]

Even if N-1 failure occurs, facility formation must be such that short-term thermal capacity does not exceed and power outage does not occur. However, if the social impact of obstructed supply is limited even when power outage occurs, the relevant performance shall be considered satisfactory.

[Image]



Network Codes of the Organization
(Requirements for outage of single electric facility)
Article 64
1. Upon outage of one transmission or distribution circuit line, one transformer, one generating facility or other single electric facility (hereinafter "N-1 outage"), requirements which the electric network must satisfy with shall be as follows.
i. Thermal capacity: Power flow in each transmission and distribution facility after the part where the N-1 outage occurred is isolated from the electric network shall not surpass the short-term thermal capacity (which means a value of power flow under which the temperature of the facility at the time when the current flows into the facility becomes the upper limit of the temperature under which such facility can be used for only short period of time, hereinafter, the same shall apply).
ii. Voltage stability: Stability of voltage shall be maintained even after the part where the N-1 outage occurred is isolated from the electric network
iii. Synchronized stability: Synchronized stability of generation facilities shall be maintained even after the part where the N-1 outage occurred is isolated from the electric network.
2. Even when the performances specified in Paragraph 1 are not sufficient, in a case where all the requirement in each following item are satisfied, performance specified in Paragraph 1 above shall be treated as sufficient.
i. In a case where the interruption of supply does not occur, or social influence from the interruption of supply is limited even when the interruption occurs (including a case where the interruption of supply occurs due to N-1 outage of single-circuit distribution line at the place of demand where the electricity is received from such distribution line)
ii. In a case where the interruption of power generation does not occur, or when the following requirements are satisfied when the disturbance occurs
a. Influence of interruption of power generation on voltage stability of electric network, synchronized stability and frequency is limited
b. Electric power suppliers who maintain and operate the generation facilities subject to the power generation shedding (suppression of output from generation facilities or electrical separation from electric network of the facilities in accordance with load-dispatch instruction (specified in Article 189, hereinafter, the same shall apply) hereinafter, the same shall apply) agree on the shedding upon N-1 outage and such companies have a system and ability to shed power generation (including a case where the companies can shed power generation certainly by protection relays) according to the load-dispatching instruction based on such an agreement
c. Other cases where risks on electricity supply and public safety from allowing the power generation shedding are not big

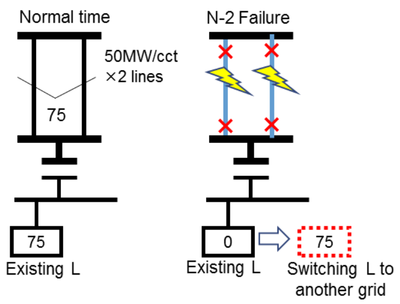
<Appendix 2: N-2 standards>

Fig. 4-2: N-2 Standards

[Summary]

Even if N-2 failure occurs, if a significant social impact is a concern, study the measures to decrease this impact. Moreover, regarding the accidents beyond this level, limited power outage is permissible as far as possible. However, make sure that the impact of the failure does not spread to other grids.

[Image]



Network Codes of the Organization
(Measures against outage accompanied by simultaneous loss of two parts of electric facilities)
Article 66
When the outage accompanied by simultaneous loss of two parts of transmission and distribution lines, transformers, power generators or other electric facilities occurs, the Organization or the general transmission and distribution companies shall consider the scale of the interruption of supply or power generation and the influence on stability of electric networks accompanying with such outage and shall discuss about the measures to mitigate social influence, if they concern that such influence might become critical.

<Appendix 3: Concept of overseas N-1 standards>

Fig. 4-3: Concept of overseas N-1 standards

ENTSO-E, Operating Handbook P3-Policy: Operational Security

A1-D2.1. Normal type of contingency. The normal type of contingency is defined as the loss of a single element. Single elements are as follows:
A1-D1.1.1. a single line,
A1-D1.1.2. a single generating unit,
A1-D1.1.3. a single transformer or two transformers connected to the same bay respectively, a Phase Shifter Transformer,
A1-D1.1.4. a large voltage compensation installation,
A1-D1.1.5. a DC link considered as a generating unit or a large consumer.

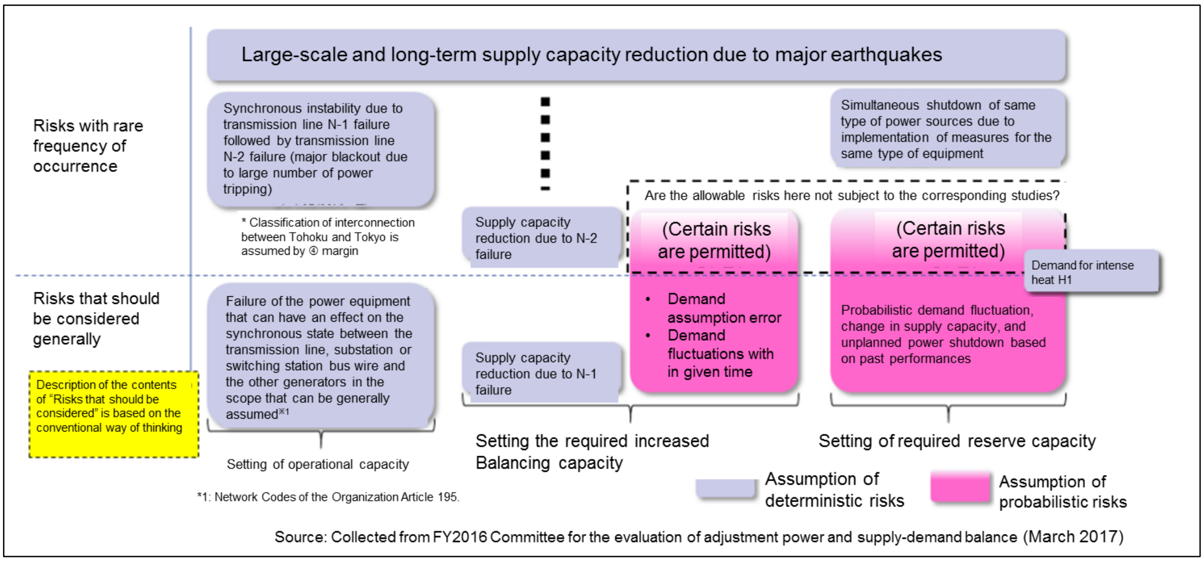
<Appendix 4: Risks with rare frequency of occurrence>

N-1 indicates risks that must be taken into account usually and the facility formation is such that there are no supply obstacles due to these risks.

N-2 indicates risks with rare frequency of occurrence and require measures to be taken to reduce the social impact of the accident.

For events above the N-2 level, measures are taken through operations and not through facility formation so that cascading accidents are not caused.

Fig. 4-4: Concept of risks with rare occurrence



(2) Short-term measures on operation in the Hokkaido area (winter 2018/19)

The investigation of black start confirmed that about 45 hours were required from blackout until power could be supplied to roughly the entire area.

Generally, blackout restoration by black start greatly affects the life and economic activities of the general citizens.

Therefore, first of all, it is necessary to take short-term operational measures to avoid the blackout to the extent possible. To be more precise, regarding the concept of load shedding and operations of Tomato-atsuma Power Plant Units 1/ 2, and 4, the following measures (a) to (c) are presented as the necessary measures for winter 2018/19.

(a) The under frequency relay (UFR) settings at the Hokkaido Electric Power Company

Regarding UFR load shedding capacity, one route was used for power transmission from Tomari Power plant until 2007. Therefore, the Investigation Committee confirmed that a decreased supply capacity (maximum: ▲1,160 MW) was assumed due to route disconnection from Tomari power plant Units 1/ 2, which had started operating at the time, and the load shedding capacity was calculated.

On the other hand, in 2007, power supply from the Tomari power plant was changed to a 2-route supply, however, no review was carried out thereafter. Since Tomato-atsuma Power plant already had 2 routes, it was not considered for calculation. If review was carried out based on creation of 2 routes, maximum single Units (Tomari power plant Unit 3, 910 MW, operations started in 2009) were assumed and the review led to a reduction in the load shedding capacity.

Originally, it was assumed that appropriate review should be carried out assuming various simulations, however, consequently it can be said that the setting for the load shedding capacity prevented blackout even more.

The Investigation Committee examined the additional load shedding based on the event this time.

In that case, the present Hokkaido-Honshu HVDC Link is of line commutation type. Therefore, the investigation was also carried out keeping in mind that for stable use, the short-circuit capacity inside Hokkaido Electric Power Company must be ensured 3 times that of the power received.

Moreover, as described above, setting unlimited load shedding not only unstablizes the entire grid, but it might also delay the black start. Originally it was necessary to set the load shedding capacity after carrying out appropriate simulations and evaluating stabilization measures. However, we believe that tripping at least at 1 place (3 Units) in the Tomato-atsuma Power Plant should be assumed to reduce the possibility of early blackout and measures should be taken at an early stage by adding the necessary load shedding capacity.

Assuming that the Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link will start operating until March 2019, it is necessary to carry out simulations and review the UFR settings hereafter. The Investigation Committee investigated the load shedding capacity required to control the frequency as a measure to avoid blackout by setting more strict conditions than the present events wherein one location at Tomato-atsuma Power Plant (3 Units), wind power, and hydro power trip at the same time, along with simultaneous tripping of power sources[9] of approximately 230 MW, for which cause or time of tripping cannot be confirmed at the present time.

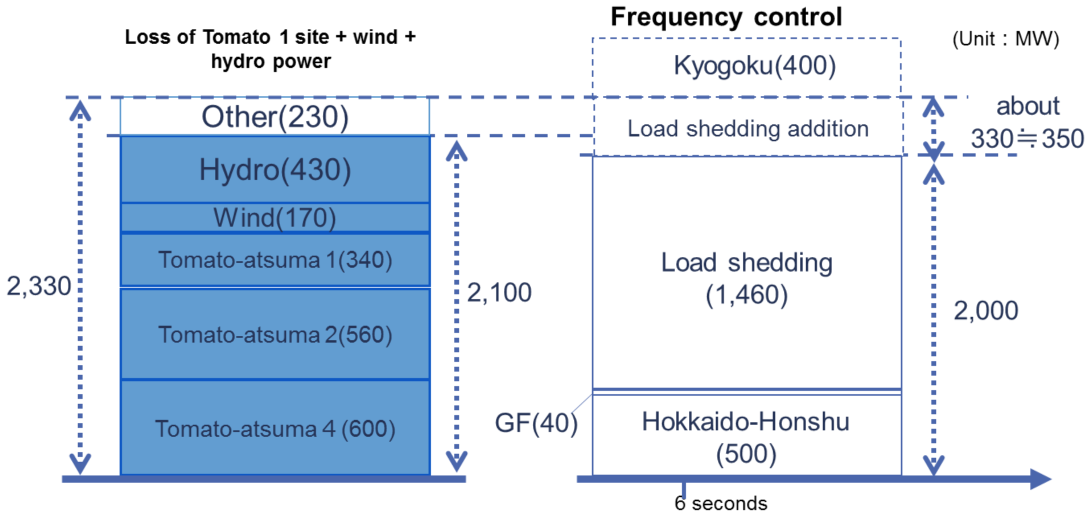
In this case, the power received from the Hokkaido-Honshu HVDC Link and load shedding becomes 2,000 MW against the simultaneous tripping of 2,330 MW, causing a deficit of 350 MW (Refer to Fig. 4-5).

It is operationally difficult to secure 350 MW required for normal times only through Kyogoku Units 1/ 2 which are pumped-storage hydro power plants, therefore, the additional capacity must be secured by UFR. Also, the additional UFR capacity must be set at a level at which the Hokkaido-Honshu HVDC Link can be used in a stable manner.

When all the various factors are considered together, it is believed to be appropriate to add 350 MW UFR (350 MW when the demand is 3,090 MW. Additional capacity is equivalent to approximately 11% of the demand ratio. The same shall apply hereinafter) as an early measure for winter 2018/19.

[9] The power sources worth 110 MW, which did not trip until the end, subtracted from 340 MW organized as “Other (the off grid power obtained by subtracting the sum of the thermal/hydro/major wind/ Hokkaido-Honshu HVDC Link from the demand)” in Fig. 2-4 Grid status immediately before the earthquake (Operational status of generators).

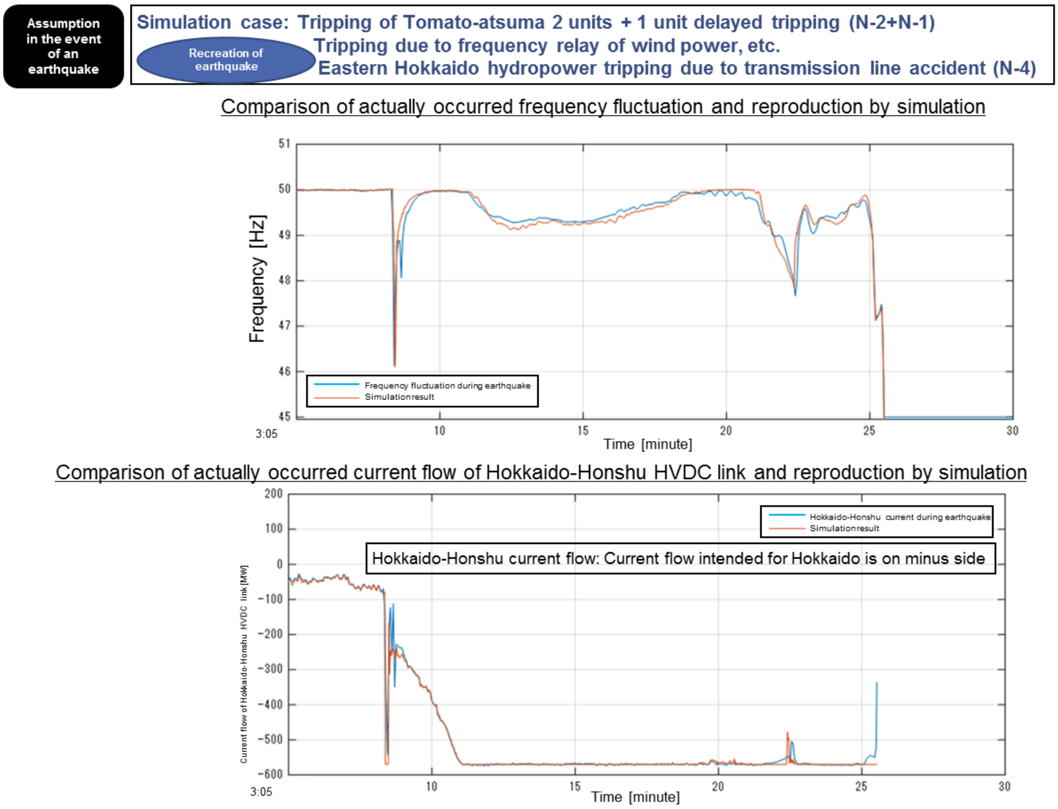
Fig. 4-5 Capacity of load shedding required to control the frequency when one location at Tomato-atsuma Power Plant (3 Units), wind power, and hydro power trip at the same time, along with simultaneous tripping of power sources of approximately 230 MW, for which cause or time of tripping cannot be confirmed at the present time



(b) Short-term operational measures during winter 2018/19

On estimating the total demand from the actual value, and carrying out a simulation by arranging all the events from the occurrence of the earthquake to blackout in a chronological order, the Investigation Committee confirmed that the sequence of events from the occurrence of the earthquake to blackout could be reproduced (Refer to Fig. 4-6).

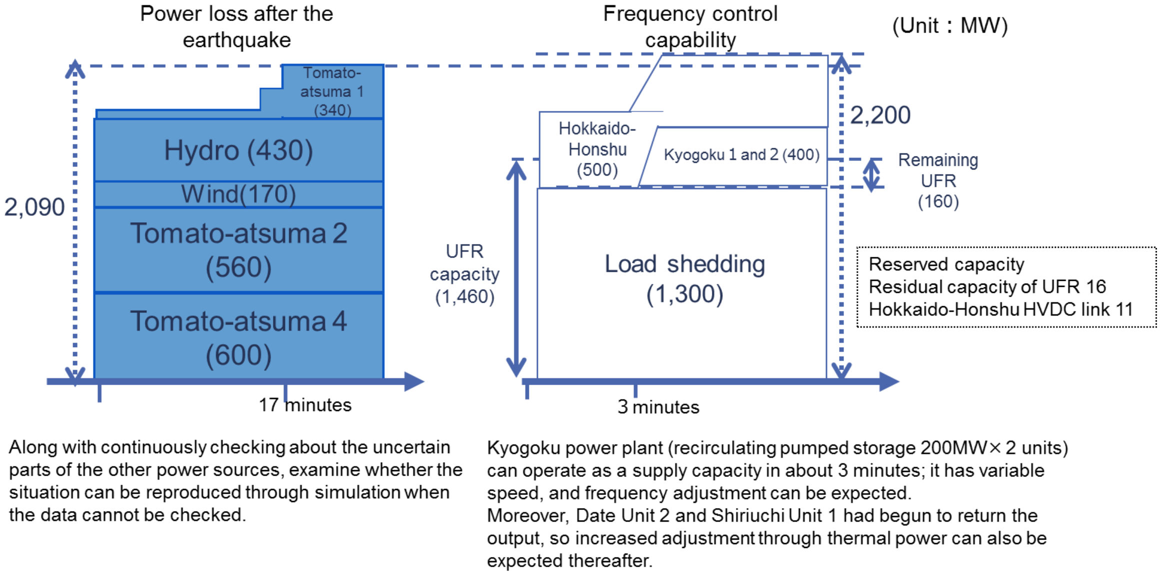
Fig. 4-6 Comparison of the results related to the sequence of events from the occurrence of the earthquake to blackout and the results of simulated reproduction of events



One of the point in question is that when the large-scale pumped-storage generators (Kyogoku power plant Units 1/ 2 (200 MW x 2)) were shut down in the Hokkaido area during the earthquake, the supply capacity was concentrated at one location at the Tomato-atsuma Power Plant (3 Units).

Even if one location at Tomato-atsuma Power Plant (3 Units) had tripped in the supply-demand balance situation during the earthquake, if operations of Kyogoku power plant Units 1/ 2 (200 MW x 2) had been available, we believe that there was a high possibility that the situation would not have led to a blackout (Refer to Fig. 4-7).

Fig. 4-7 Comparison between situations of loss of power and control frequency control during the earthquake

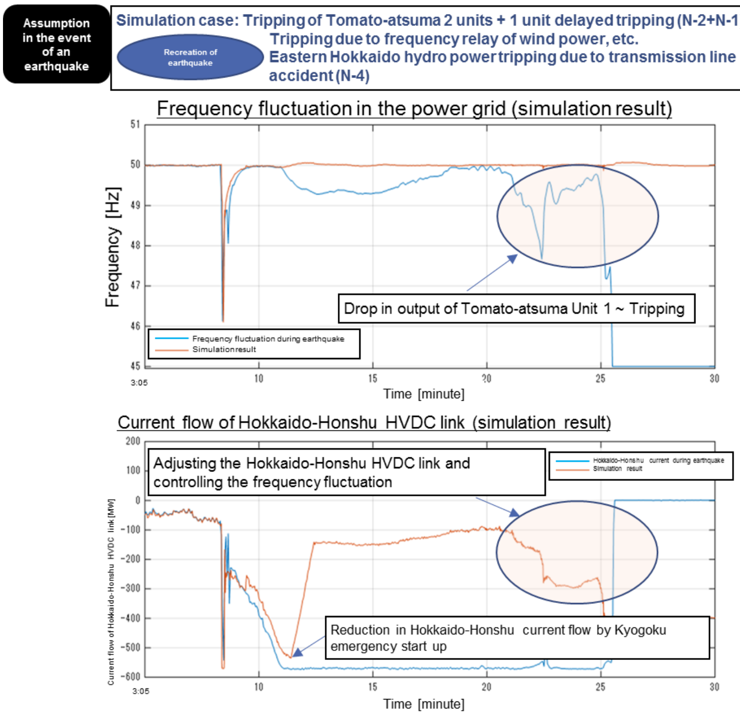


All the assumptions in Fig. 4-7 estimate an equivalent reserved capacity, so even though the initial frequency drop immediately after the earthquake stood at 46.13Hz or higher, we didn’t consider this as a problem at first, but we confirmed it through a detailed simulation.

On conducting a simulation, the AFC reserved capacity of the Hokkaido-Honshu HVDC Link was restored by starting up the Kyogoku power plant Units 1/ 2 as soon as the frequency dropped, and even for the frequency drop during the output decrease and tripping of the Tomato-atsuma Power Plant Unit 1, the frequency could be stabilized without load shedding by UFR as assumed in the above description (Refer to Fig. 4-8).

As a result, even during a recent event similar to the earthquake (Tomato-atsuma Power Plant 1 site and hydro power), we confirmed that had the operation of Kyogoku Units 1/ 2 (200 MW x 2) been available, blackout would not have occurred.

Fig. 4-8 Simulation results assuming operation of two generators at Kyogoku power plant



Emergency start of Kyogoku 2 units

Tripped Capacity (MW)		
Tomato-atsuma	1G	338
	2G	556
	4G	598
	Total	1492
Hydro power		430
Wind power		166
PV		0
Other		234.5
	Total	2322.5

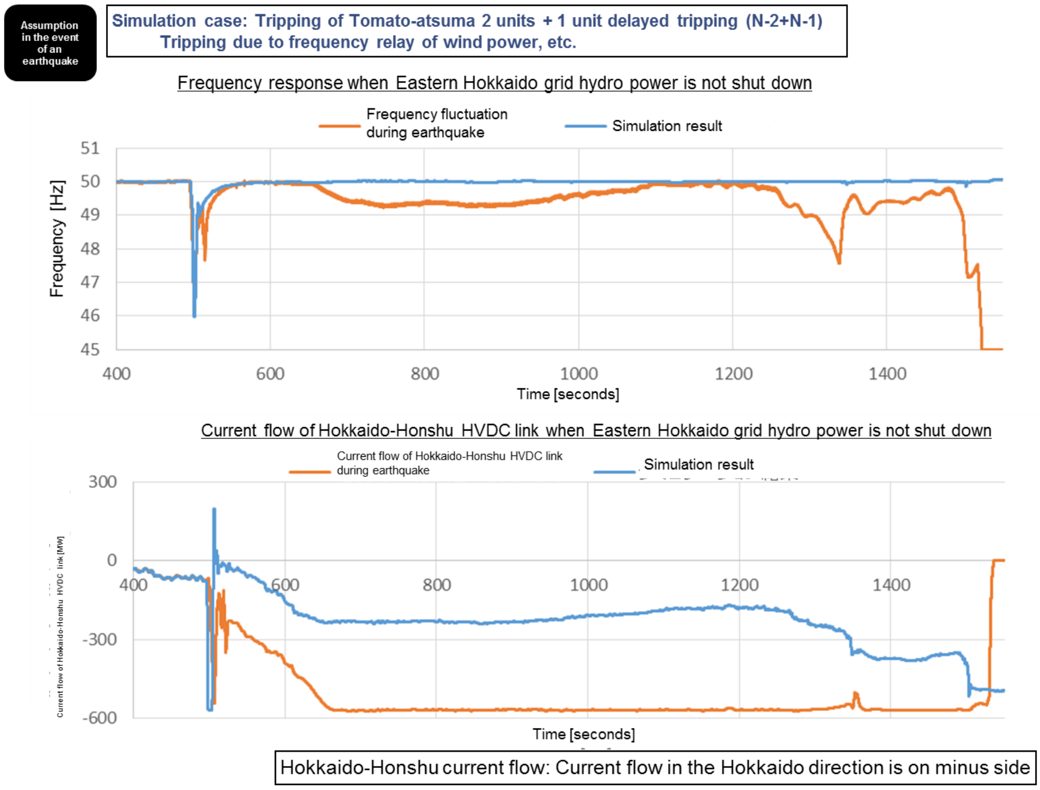
Simulation Result	
Blackout avoidance possibility	○
Lowest frequency point immediately after the earthquake (Hz)	46.10
UFR operation (MW)	1288.0
Remaining UFR (MW)	158.3
Hokkaido-Honshu current final value (MW)	-398.1
Period remaining at 49Hz or less (s)	8.3

Demand ratio 42%

Moreover, even if the 2 large-scale pumped-storage generators (Kyogoku Units 1/ 2) had shut down, but had the hydro power not shut down due to the transmission accident on the Karikachi trunk line and 2 other lines (N-4), we believe that there was a high possibility that the situation would not have led to a blackout.

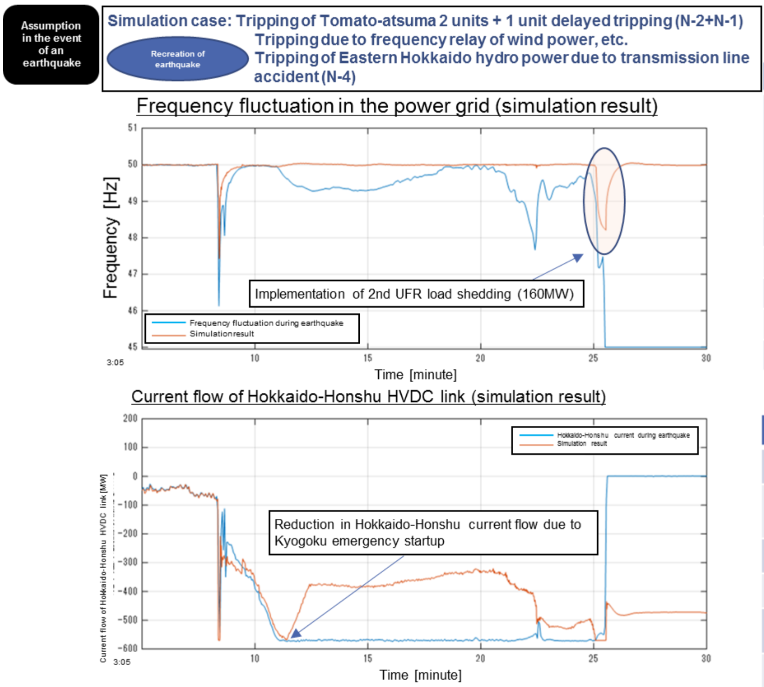
Therefore, a simulation was performed and based on the results, we believe that it would not have resulted in a blackout (Refer to Fig. 4-9).

Fig. 4-9 Simulation results of a situation where there was no accident on the four transmission lines (N-4 accident) (and shut down of hydro power associated with it)



Even for the case when one generator of Kyogoku power plant could not be operated due to problems, a simulation was carried out by adding UFR 350 MW. The results showed that the current flow of the Hokkaido-Honshu HVDC Link decreased due to the emergency start and the AFC reserved capacity increase, so the second load shedding was activated when the Tomato-atsuma Power Plant Unit 1 tripped and blackout could be avoided (Refer to Fig. 4-10).

Fig. 4-10 Simulation results assuming operation of only one generator at Kyogoku power plant



UFR Expansion

Emergency start of Kyogoku unit 1

Tripped Capacity (MW)		
Tomato-atsuma	1G	338
	2G	556
	4G	598
	Total	1492
Hydro power		430
Wind power		166
PV		0
Other		234.5
	Total	2322.5

Simulation Result	
Blackout avoidance possibility	○
Lowest frequency point immediately after the earthquake (Hz)	47.43
UFR operation (MW)	1413.0
Remaining UFR (MW)	397.0
Hokkaido-Honshu current final value (MW)	-473.9
Period remaining at 49Hz or less (s)	3.4

Demand ratio 46%

However, we believe that certain measures must be taken since load shedding is activated twice due to UFR, the final value of Hokkaido-Honshu current flow (received power) is 470 MW, which is near the upper limit, and AFC reserve capacity is less. Therefore, it is necessary to take measures such as limiting the output of Tomato-atsuma Power Plant Unit 1 by 200 MW (equivalent of one Kyogoku Power Plant generator capacity) in case one of the Kyogoku power plant Units shuts down. However, during a high-demand period, instead of curtailing the output, thermal power plants could be operated to increase the 200 MW of output within a 10-minute timeframe from the viewpoint of stable supply.

As a severe condition, simulation was also conducted for the case wherein entire Tomato-atsuma Power Plant, wind power, and hydro power trip at the same time, along with simultaneous tripping of power sources of approximately 230 MW, for which cause or time of tripping cannot be confirmed at the present time. From the simulation results, UFR was performed twice, but the additional capacity was also operated and blackout was avoided, therefore, we could confirm that it was appropriate to increase the load shedding by UFR to 350 MW (Refer to Fig. 4-11).

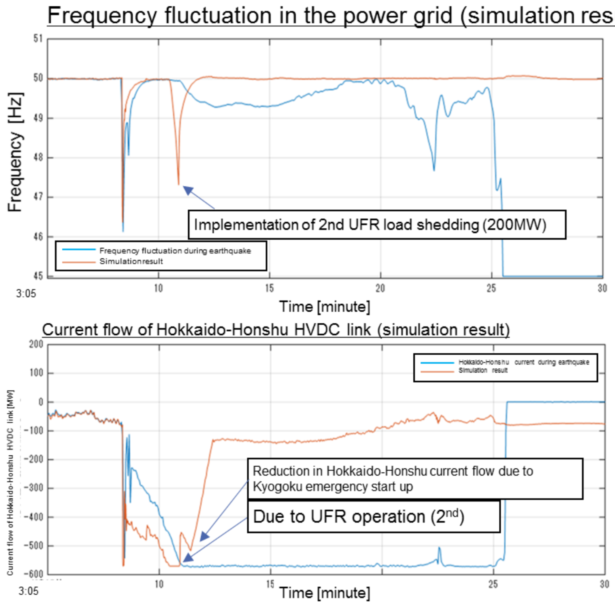
Therefore, we believe that at the present point it is not necessary to request further addition of UFR since the load shedding capacity by UFR is sufficient. However, Hokkaido Electric Power Company must continuously investigate the UFR period and review, or if necessary, revise the period.

Fig. 4-11 Simulation result assuming simultaneous tripping of entire Tomato-atsuma Power Plant, wind power, hydro power + power sources of approximately 230 MW

Assumption in the event of an earthquake

Simulation case: Tomato-atsuma 3 units simultaneous tripping (N-3)

more severe case: **Tripping due to frequency relay of wind power, etc.**
Tripping of Eastern Hokkaido hydro power due to transmission line accident (N-4)



UFR Expansion

Emergency start of Kyogoku 2 units

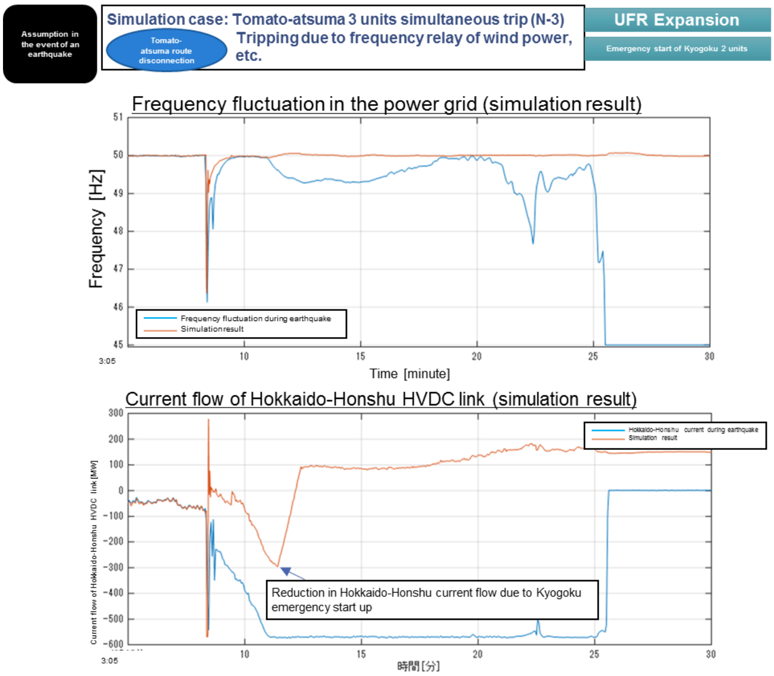
Tripped capacity (MW)		
Tomato-atsuma	1G	338
	2G	556
	4G	598
	Total	1492
Hydro power		430
Wind power		166
PV		0
Other		234.5
	Total	2322.5

Simulation Result	
Blackout avoidance possibility	○
Lowest frequency point immediately after the earthquake (Hz)	46.37
UFR operation (MW)	1611
Remaining UFR (MW)	199
Hokkaido-Honshu current final value (MW)	-75.6
Period remaining at 49Hz or less (s)*1	6.7

Demand ratio 52% (UFR operation and remaining UFR)

In addition, we conducted a simulation and confirmed that blackout can be avoided even in the case of simultaneous tripping (N-3) of entire Tomato-atsuma Power Plant that is probably to occur (Refer to Fig. 4-12).

Fig. 4-12 Simulation result assuming simultaneous tripping (N-3) of entire Tomato-atsuma Power Plant



Tripped capacity (MW)		
Tomato-atsuma	1G	338
	2G	556
	4G	598
	Total	1492
Hydro power		0
Wind power		166
PV		0
Other		234.5
	Total	1892.5

Simulation Result		
Blackout avoidance possibility	○	
Lowest frequency point immediately after the earthquake (Hz)	46.37	
UFR operation (MW)	1413.0	Demand ratio 46%
Remaining UFR (MW)	397.0	
Hokkaido-Honshu current final value (MW)	148.9	
Period remaining at 49Hz or less (s)*1	4.2	

Based on the above simulation results, we focused only on the supply-demand balance by setting UFR due to frequency control by UFR settings, and tried taking into account the capacity of power supply that must be allowed for operations in proportion to the measures that can be taken immediately, such as the margin of Hokkaido-Honshu HVDC Link or load shedding according to the demand.

In other words, the basic principle for the specified UFR capacity (after adding 350 MW) is that it is approximately 58% of the demand. Against a demand of 2,800 MW to 4,000 MW on the three generators of the Tomato-atsuma Power Plant with a high ratio, if the Hokkaido-Honshu margin of about 500 MW is about 13~18% of the demand, in this light, the measures by which frequency can be instantaneously controlled will become 71~76% of the demand (winter 2018/19).

Therefore, at least 24~29% of the actual demand must be supplied from operating power sources that can continue operation (hereinafter referred to as 'continuous operating power') even when the frequency drops to about 46~47 Hz, such as thermal power plants other than the Tomato-atsuma Power Plant (Refer to Fig. 4-13).

With respect to the above idea, we confirmed that the supply- demand balance during the period until winter 2018/19 is 33% (24~ 29% or more) even assuming a scenario of full output at entire Tomato-atsuma Power Plant and a high power tripping ratio (demand 3,750 MW) which is a high-output renewable energy (Refer to Fig. 4-14).

Fig. 4-13 Percentage of 'continuous operating power' that must be secured for the demand

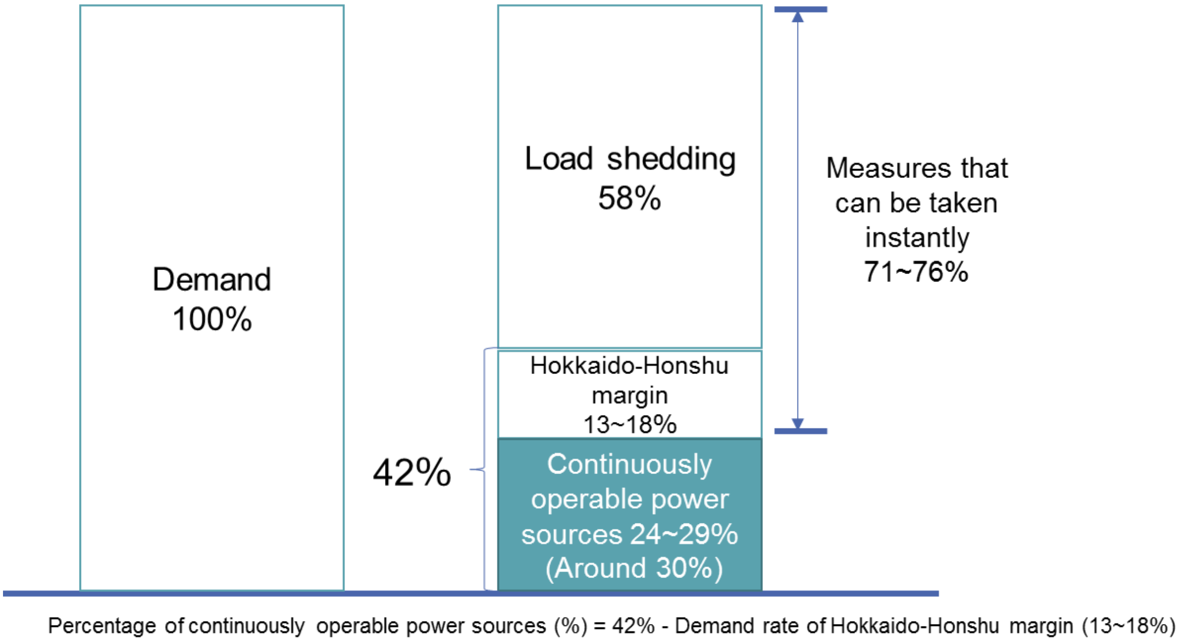
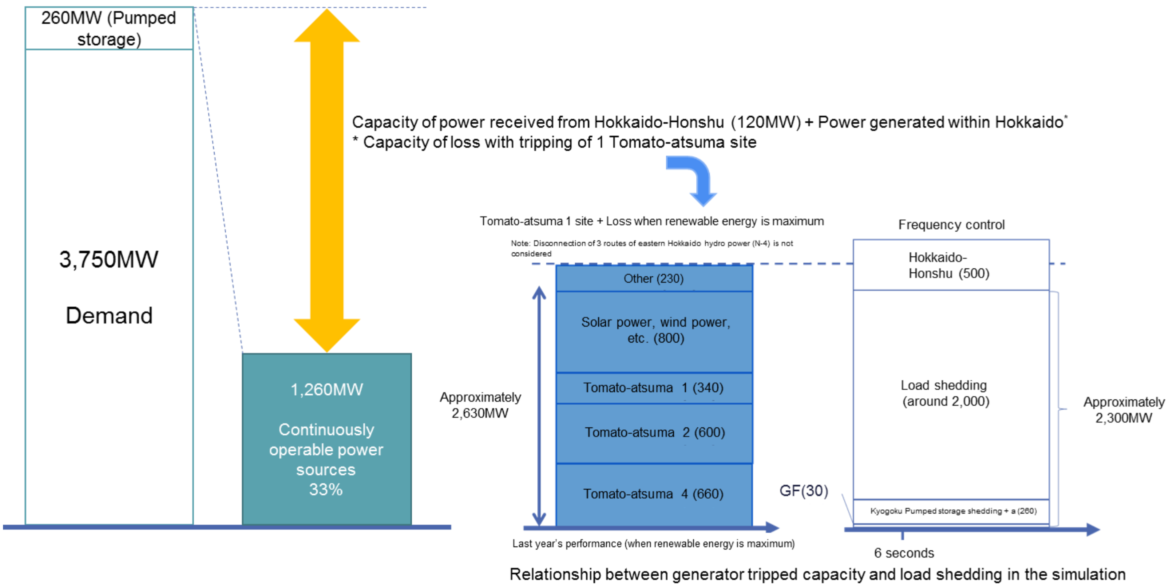


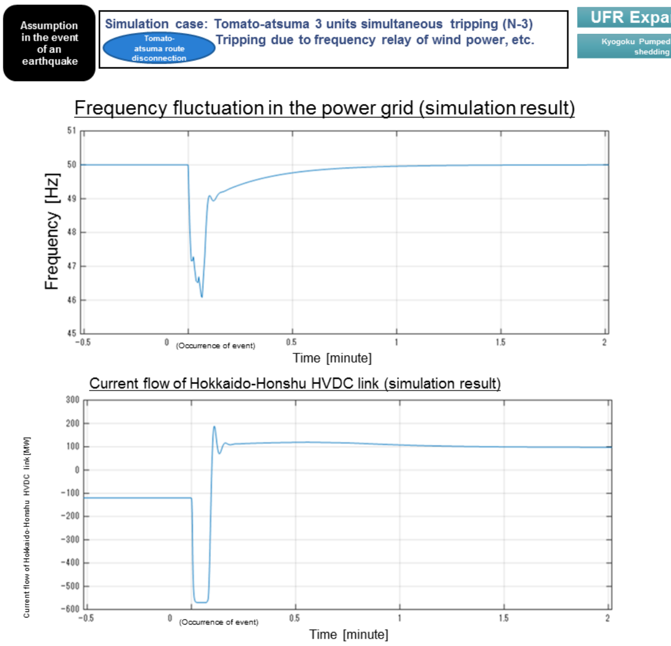
Fig. 4-14 Percentage of 'continuous operating power' that must be secured for the high-output renewable energy



As a result of this simulation, we confirmed that blackout can be avoided because not only is load shedding activated by UFR, but the pumped-storage plants for handling high-output renewable energy are also automatically tripped, even if wind and solar power trip due to frequency drop (Refer to Fig. 4-15).

However, regardless of the fact that UFR is activated only up to 52% of the demand size ratio, the lowest point of the frequency was 46.08 Hz, therefore, it was believed that UFR with a long load-shedding response time, could not be used. With reference to this point, if the Hokkaido Electric Power Company does not review the duration of UFR 48.0 Hz that was not activated this time (6%), we believe that the ratio of continuously operable power source 24~29% must be increased to 30~35% (+6%).

Fig. 4-15 Simulation result assuming high-output renewable energy



Tripped capacity (MW)		
Tomato-atsuma	1G	340
	2G	600
	4G	660
	Total	1600

Simulation Result	
Blackout avoidance possibility	○
Lowest frequency point immediately after the earthquake (Hz)	46.08
UFR operation (MW)	1957.0 (Demand ratio 52%)
Remaining UFR (MW)	241.7
Hokkaido-Honshu current final value (MW)	97.8
Period remaining at 49Hz or less (s)	7.6
Hydro power tripped capacity (MW)	0
Wind power/ PV tripped capacity (MW)	802
Other tripped capacity (MW)	226

Based on the above facts, the following measures must be taken in Hokkaido for winter 2018/19 to reliably ensure that blackout is avoided. Note that the implementation status of the measures for winter 2018/19 shall be continuously verified by OCCTO.

1. As an early measure, add 350 MW (at the demand of 3,090 MW) to the UFR load-shedding for emergency.
2. On condition that Kyogoku power plant Units 1 and 2 are operational, the three Units of the Tomato-atsuma Power Plant.
3. However, in order to secure some margin in case one of the Kyogoku Power Plant Units shuts down, limit the output of Tomato-atsuma Power Plant Unit 1 by approximately 200 MW (equivalent of one unit of Kyogoku Power Plant).In case of a high-demand period, instead of that curtailment, thermal power plants could be operated to increase the 200 MW of output within a 10-minute timeframe as an

additional measure.

4. Approximately 30~35% of the total demand shall be supplied from continuously operable power sources when frequency is dropped, such as thermal power plants.
5. Do not take power generation capacity of Tomato-atsuma Power Plant into account when calculating the short-circuit capacity required to operate the Hokkaido-Honshu HVDC Link.
6. Thoroughly consider the available reserved capacity when generators are stopped in consideration of supply and demand balance. Make sure that thermal power plants secure reserved capacity to supply power within a few minutes to several hours according to the demand fluctuations for the time being.
7. When additional measures are taken in case one of the Kyogoku Power Plant Units shuts down, OCCTO shall monitor the operation to make sure that the measures taken are appropriate.

The Interim Summary of the Working Group on Electricity Resilience stated that the operations for winter 2018/19 (above mentioned measures) shall be implemented thoroughly based on the Interim Report of the Investigation Committee.

(c) Comprehensive inspection of the power generation and transmission equipment in the Hokkaido area

The boiler tube of the Tomato-atsuma Power Plant Unit 1 (rated output 350 MW) was damaged due to the earthquake. The output of the generator started to decrease from 3:20 on September 6 and the generator shut down at 3:25.

At 3:08 on September 6, there was power outage in the eastern Hokkaido area and Kitami area due to transmission line accident (N-4: 3 routes, 4 lines) on the Karikachi trunk line, Shintoku-oiwake line, and Hidaka trunk line, and hydro power generators of 370 MW shut down. The cause for this is believed to be a ground fault due to the contact of jumper wire with the line hardware.

Though the security of equipment such as power generation equipment and transmission equipment was not subject to investigation by the Investigation Committee, it is believed that the blackout took place because in addition to the shutdown of Tomato-atsuma Units 1, 2, and 4 (N-3), there was loss of the frequency control functions (mainly AFC) due to the shutdown of hydro power following the transmission accident on the Karikachi trunk line and 2 other lines (N-4) which became the compounding factor. Therefore, to prevent the recurrence of a blackout, we believe that from the viewpoint of reinforcing network resilience, the Government must carry out comprehensive investigation of conformance to regulations related to the transmission equipment and power generation equipment in the Hokkaido area as short-term measures for winter 2018/19.

In the Interim Summary of the Working Group on Electricity Resilience, investigation was carried out for the ground fault on the 3 route transmission lines in eastern Hokkaido and equipment failure at the Tomato-atsuma Power Plant. For the ground fault in the 3 route transmission lines in eastern Hokkaido, although it is necessary to examine appropriate recurrence prevention measures to prevent blackout in the densely populated zones of the transmission lines in the vicinity of important substations, there are no legal problems since the ground-fault measures for each transmission equipment provided in the Electricity Business Act are appropriately carried out. As far as equipment failure is concerned, we found that there were no inappropriate points as compared to the rules when general seismic motion (seismic intensity 5) is exceeded.

(3) Simulation conducted to examine the medium-to-long term measures for operations and facility formation in Hokkaido area

The interim report recommended "The Under Frequency Relay (UFR) settings in the Hokkaido area", "Operations of the largest capacity power plant generators", "Settings for the generator relay (wind and solar power)", and "Re-evaluation of the frequency control functions, such as governor-free systems, Automatic Frequency Control (AFC) function, and interconnection equipment margin" as the medium-to-long term measures for operation in Hokkaido area.

Among these, for "The Under Frequency Relay (UFR) settings in the Hokkaido area", "Operations of the largest capacity power plant generators", and "Re-evaluation of the frequency control functions, such as governor-free systems, Automatic Frequency Control (AFC) function, and interconnection equipment margin", the Investigation Committee conducted simulations as described above to verify the efficacy of necessary measures for the final report in the light of commercial operations of Ishikariwan-shinko power plant or the new Hokkaido-Honshu HVDC Link by March 2019, and also investigated the necessary measures.

Thereafter, during the comprehensive inspection of electricity resilience by the Government, the blackout risk was investigated based on the events that occurred this time and the interim report. Specifically, as an investigation of the risk of blackout due to tripping of the largest site, an investigation was carried out about whether blackout would occur due to frequency drop as in this recent event or are necessary measures taken, including operations, even in case the largest site trips due to the most severe scenario throughout the year. In addition, among the important transmission lines, investigation was carried out about whether the occurrence of the

N-4 transmission line accident would result in locations at which (functions of large power supply site or important sub-stations shut down and) blackout could occur due to frequency drop as in this recent event.

As a result of investigation of the tripping of the largest site, in the Hokkaido area, the Investigation Committee carried out investigations including the way specific operations must be conducted in winter 2018/19 in preparation for the tripping of Tomato-atsuma Power Plant that is presently the largest operating site. For winter 2018/19 the Investigation Committee has requested that operations be ensured thoroughly based on the interim report of the Investigation Committee.

Moreover, assuming cases wherein the Tomari Power Plant, which is currently under long-term shut down, resumes operations and then trips in addition to the tripping of the Tomato-atsuma Power Plant after commercial operation of the Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link in February to March 2019, the Investigation Committee plans to carry out investigations based on the simulation for the final report, and the Committee has requested that the necessary response measures be taken in light of this investigation result.

As a result of investigation of N-4 transmission line accident, based on the fact that an N-4 fault occurred in a 275kV voltage domain in the Hokkaido area, the Investigation Committee and the Second Working Group on Electricity Resilience assessed in their investigations and discussions that the Hokkaido Electric Power Company must examine proper recurrence prevention measures in the dense zone of transmission lines near important substations and that the situation will "not lead to a blackout" if necessary measures, including measures for the transmission lines adjoining important substations in the area, are taken.

Therefore, simulation was carried out for the case of tripping of the largest power plant (largest site) due to the most severe scenario through the period that can be assumed at present (the Tomari Power Plant, which is currently under long-term shut down, resumes operations (although the time period is undecided as yet) and then trips in addition to the tripping of the Tomato-atsuma Power Plant after commercial operations of the Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link in February to March 2019), and the necessary measures were examined as the medium-to-long term measures for operations in the Hokkaido area.

It should be noted that to maintain the demand-supply balance in the event of tripping of the largest site, not only the capacity of adjustment power, but the operation time (time limit) is also important and sufficient attention must be paid to them at the same.

The lowest point of frequency, Hokkaido-Honshu Emergency AFC control capacity, and UFR load shedding are mutually confirmed using the simulation methods of [1] CRIEPI model (frequency response analysis program created on MATLAB/Simulink in cooperation with the

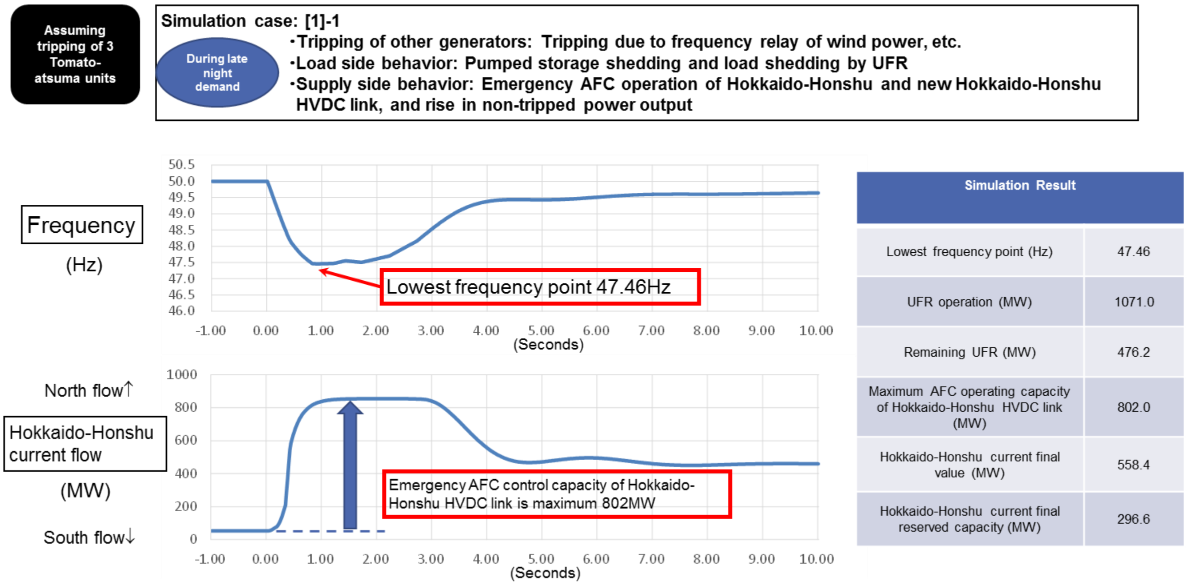
Central Research Institute of Electric Power Industry), [2] TEPCO Power Grid model (frequency response analysis program owned by the TEPCO Power Grid Inc.[10]).

The verification results are shown in Fig. 4-16 and Fig. 4-17. Significant difference was not found and validity of both the models was confirmed (Therefore, the investigation result of this Investigation Committee was evaluated with the results of the CRIEPI model.)

Regarding the review of UFR settings, the suggestions related to the idea of specifying the settings from the TEPCO power grid was incorporated in the measures for effective utilization (Fig. 4-18 and Fig. 4-19) of the frequency fluctuations rate element (df/dt), as one of the methods to speed up the UFR activation.

As the analysis condition for frequency simulation, the simulation period necessary to confirm the recurrence prevention measures was assumed to be 120 seconds (-10 seconds to 110 seconds, power tripping 0 seconds). In terms of program specifications, the analysis step is 20 ms for the CRIEPI model and 100 ms for the TEPCO Power Grid model.

Fig. 4-16 Simulation results using the simulation model of Central Research Institute of Electric Power Industry



Simulation Result	
Lowest frequency point (Hz)	47.46
UFR operation (MW)	1071.0
Remaining UFR (MW)	476.2
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	802.0
Hokkaido-Honshu current final value (MW)	558.4
Hokkaido-Honshu current final reserved capacity (MW)	296.6

[10] This program enables verification of the frequency status from the short period areas (inertia, governor, LFC area) to long period areas (EDC control) by detailed simulation of the control logic of LFC or generators, frequency characteristics of the load, etc.

Fig. 4-17 Simulation result using the simulation model of TEPCO Power Grid Inc.

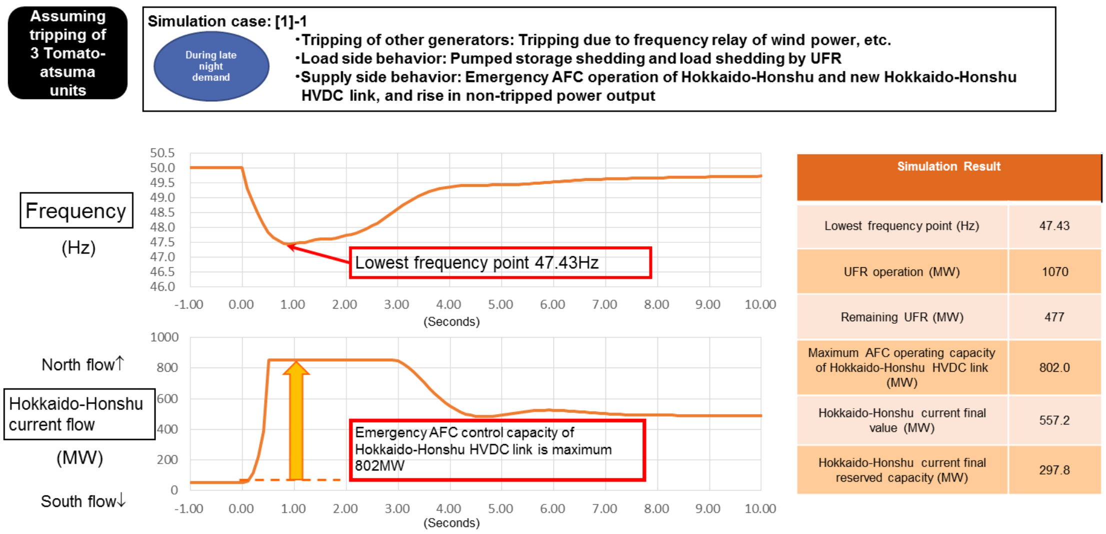


Fig. 4-18 UFR Mechanism

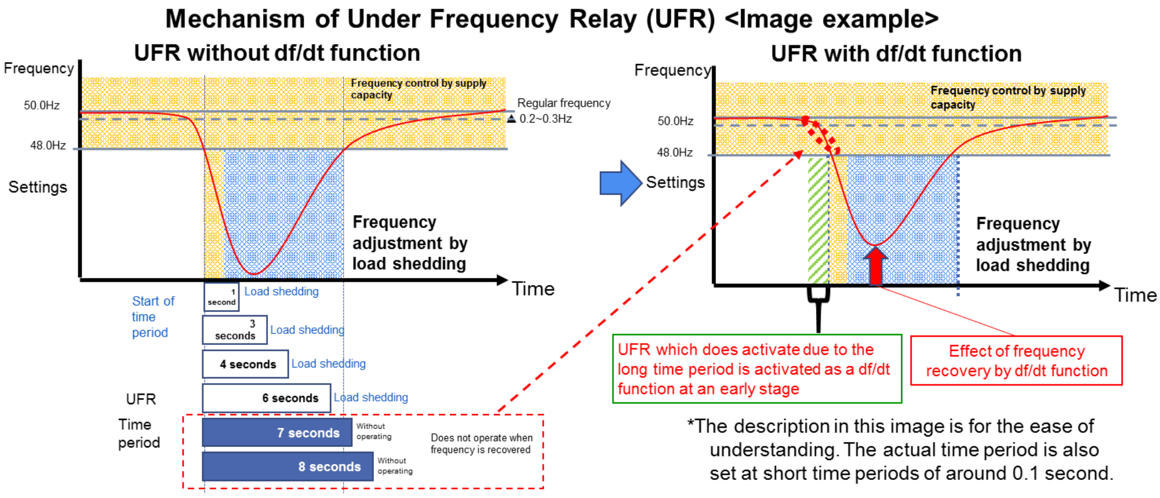
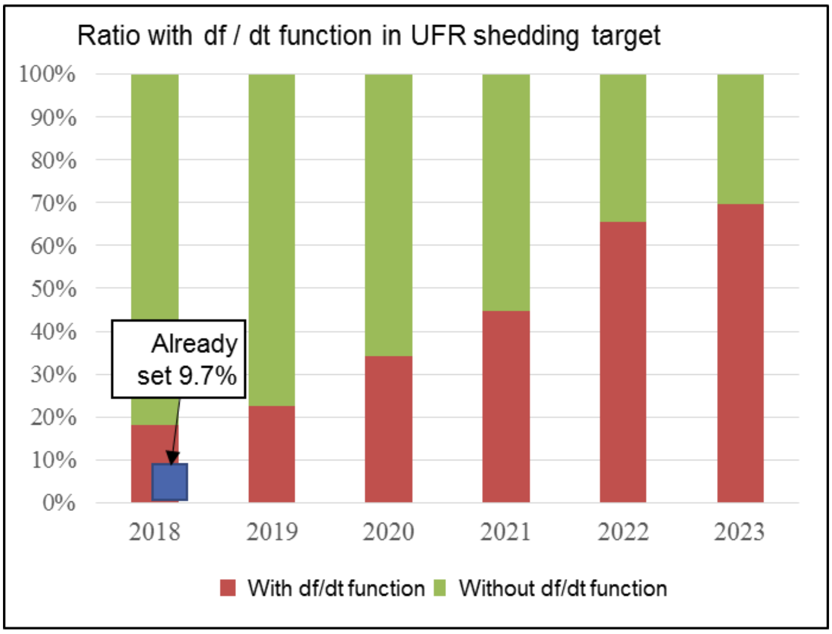


Fig. 4-19 Ratio with df / dt function in UFR shedding target



* Renewal plan is a plan at the current stage and is likely to be reviewed hereafter.

We decided to confirm the following two points regarding the simulation result:

[Lower limit of frequency]

In the final report, as a criterion for confirming whether blackout occurs in the simulation at the time of examining the medium-to-long-term measures, the lower limit of frequency that can be allowed is set to 47.0Hz, which is specified as the lower limit of the operating limit frequency in the existing grid interconnection technology requirement of Hokkaido Electric Power Company, and we checked if the frequency recovers from the lowest point of 47.0 Hz or higher to about 50 Hz (refer to Fig. 4-20).

[AFC reserved capacity and margin of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link]

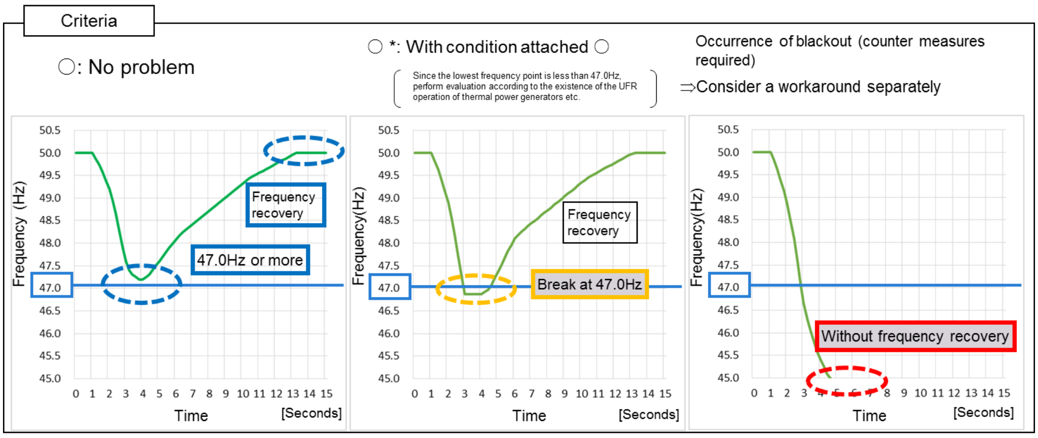
In the simulation at the interim report stage, we had checked whether AFC reserve capacity of Hokkaido-Honshu HVDC Link is left over to a certain extent. However, in the simulation at the time of examining the medium-to-long-term measures recommended in the final report, we confirmed whether the frequency adjusted reserve capacity can be ensured against the demand fluctuation when the final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is a certain degree below the transmission capacity of 855 MW[11] at the end of simulation, for the purpose of confirming

[11]Equipment capacity 855 MW (= 855 MW = 900 MW x (1 - 0.05)) after considering the loss rate of 5% of Hokkaido-Honshu HVDC Link and new Hokkaido-Honshu HVDC Link. The same shall apply hereinafter.

whether AFC reserved capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is left over to a certain extent. As for the transmission margin of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, presently, the current flow in the reverse direction and towards Hokkaido has been calculated by the "Largest power tripping - Grid constant (6%MW/Hz) x Δ1Hz x Demand in Hokkaido area". However, we checked whether Hokkaido-Honshu AFC operation capacity is below the above-mentioned value.

Note that the short-term operational measures for winter 2018/19 proposed in the interim report specified that "Hokkaido Electric Power Company will continue to examine the UFR time period and review it if necessary”. Moreover, the new UFR terminal, which is being updated sequentially (about 20% of the total UFR have been updated as of the end of 2018), provides functions (half of updated UFR terminals as of the end of 2018 (10% of entire UFR) are set to operate as df/dt function) to activate load shedding by detecting (df/dt) frequency fluctuation rate in preparation for rapid frequency drop. Therefore, the relevant functions were incorporated into the simulation.

Fig. 4-20 Criteria for judging probability of blackout



(a) If the Tomato-atsuma Power Plant, which is the largest power plant, were to trip after the commercial operations of Ishikariwan-shinko Power Plant and the new Hokkaido-Honshu HVDC Link in February to March 2019

If Tomato-atsuma Power Plant Unit 1 is assumed to have tripped, at the time of identifying the most severe scenarios in which there is a risk of significant frequency drop, availability of water pumping operation that can be used as a measure against frequency drop, and the prior current flow situation of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link have been considered on the basis of "late night demand when demand is low and frequency drop has a severe impact", "demand for high-output renewable energy for which massive tripping due to frequency drop is a concern". Further, at the time of setting up the most severe scenarios, considering the fact that the introduction of renewable energy has expanded in recent years, we have narrowed down to the following three scenarios (refer to Fig. 4-21 to Fig. 4-23) from the latest actual demand data (from April 1, 2017 to September 30, 2018).

Case [1]-1: A demand scenario where the demand is lowest while Tomato-atsuma Power Plant Units 1, 2, and 4 meet the conditions of full output

Case [1]-2: A demand scenario where renewable energy meets high output conditions when Tomato-atsuma Power Plant Units 1, 2, and 4 are fully operated

Case [1]-3: A demand scenario where Tomato-atsuma Power Plant Units 1, 2, and 4 meet full output without water pumping, on the same day as Case[1]-1.

In Case[1]-1, since water pumping operations were performed at Takami Power Plant and Niikappu Power Plant, the water pumping operations were not performed although the demand increased slightly, and Case [1]-3 was added as a scenario where the water pumping curtailing could not be expected due to UFR. Moreover, must-run power source (short-circuit capacity constraint after Tomato-atsuma Power Plant site shutdown) required for continuous operation of Hokkaido-Honshu HVDC Link was Shiriuchi 1 Unit + Ishikariwan-shinko 1 Unit, and the distribution of the actual supply capacity above the minimum output for which governor-free operation is possible, was changed.

- Case [1]-1: Demand scenario of late-night zone (2,560 MW, result at one o'clock on August 13, 2017 (Sunday))
  - ・Actual supply capacity: Tomato-atsuma (thermal power) 1,600 MW operation, Sunagawa (thermal power)/ Date (thermal power)/ Tomakomai-kyodo (thermal power) about 260 MW, other thermal power about 340 MW, hydro power 350 MW, Niikappu (pumped-storage)/ Takami (pumped-storage) 180 MW, renewable energy 120 MW, Hokkaido-Honshu current flow 50 MW north flow

・Change in supply capacity: Actual value equivalent of Sunagawa (thermal power)/ Date (thermal power)/ Tomakomai-kyodo (thermal power) was distributed to Shiriuchi Unit 2 (thermal power)/ Ishikariwan-shinko Power Plant Unit 1 (thermal power).

- Case [1]-2: Demand scenario during high-output renewable energy (2,810 MW, result at 11 o'clock on October 1, 2017 (Sunday))

  ・Actual supply capacity performance: Tomato-atsuma (thermal power) 1280 MW operation, Naie (thermal power)/ Shiriuchi (thermal power)/ Tomakomai-kyodo (thermal power) about 290 MW, other thermal power about 260 MW, hydro power 340 MW, Kyogoku (pumped-storage) 200 MW, renewable energy 1,100 MW, Hokkaido-Honshu current flow 280MW south flow

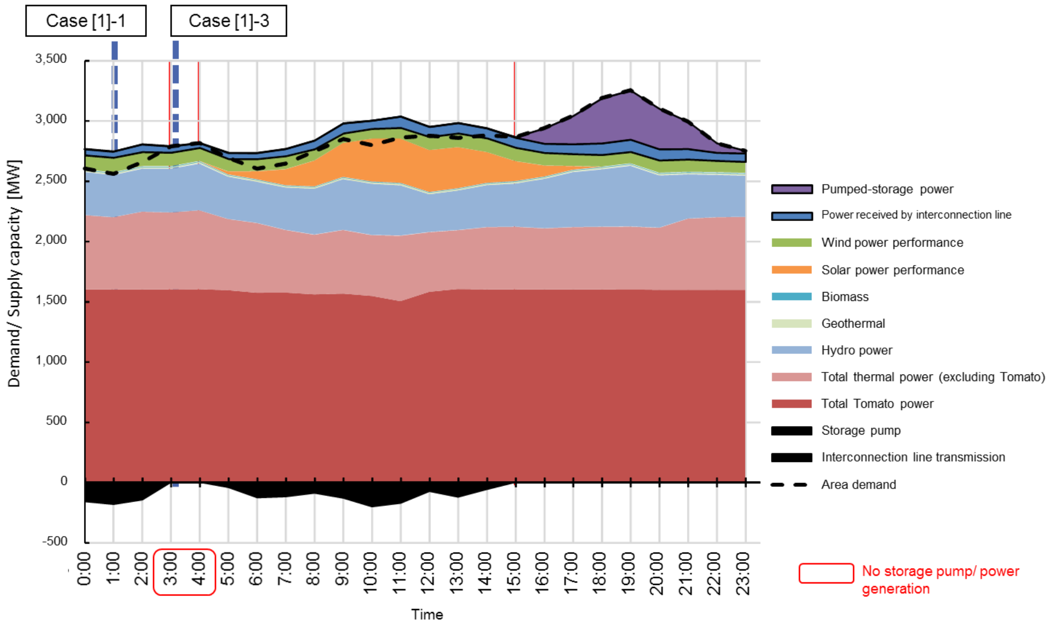
  ・Change in supply capacity: Actual value equivalent of Tomato-atsuma (thermal power) 1,600 MW, Naie (thermal power)/ Shiriuchi (thermal power)/ Tomakomai-kyodo (thermal power) was distributed with minimum output to Shiriuchi Unit 2 (thermal power)/ Ishikariwan-shinko Power Plant Unit 1 (thermal power). Since the supply capacity exceeds the demand by assuming full output of Tomato-atsuma Power Plant, Kyogoku (pumped-storage) was assumed to be 460 MW, and Hokkaido-Honshu current flow was changed to south flow 300 MW.

- Case [1]-3: Demand scenario of late-night zone (2,790 MW, no pumped-storage, result at 3 o'clock on August 13, 2017 (Sunday))

  ・Actual supply capacity performance: Tomato-atsuma (thermal power) 1,600 MW operation, Sunagawa (thermal power)/ Date (thermal power)/ Tomakomai-kyodo (thermal power) about 300 MW, other thermal power about 340 MW, hydro power 370 MW, pumped-storage 0 MW, renewable energy 110 MW, Hokkaido-Honshu current flow 50 MW north flow

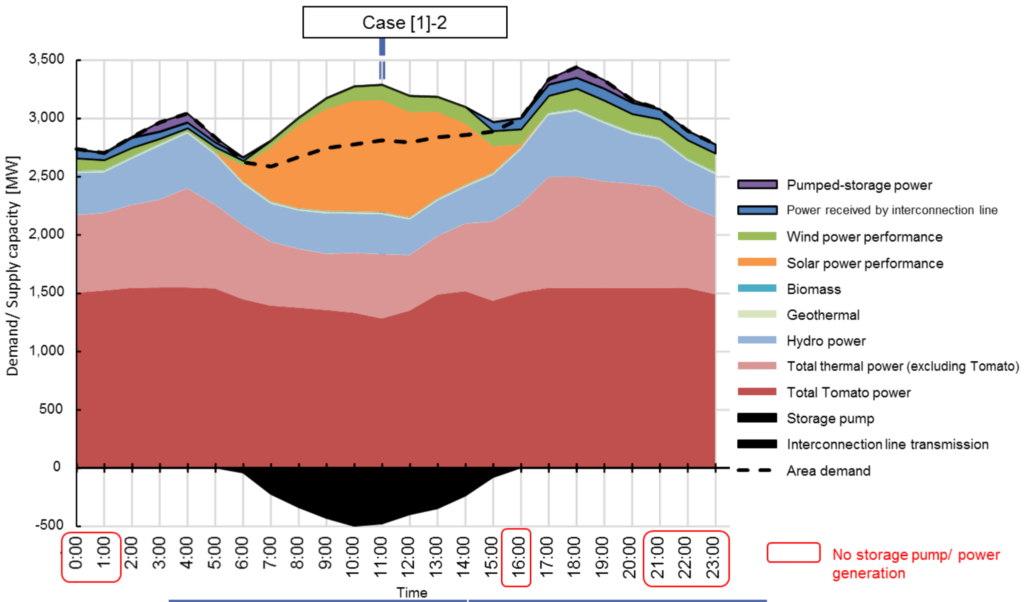
  ・Change in supply capacity: Actual value equivalent of Sunagawa (thermal power)/ Date (thermal power)/ Tomakomai-kyodo (thermal power) was distributed with minimum output to Shiriuchi Unit 2 (thermal power)/ Ishikariwan-shinko Unit 1 (thermal power).

Fig. 4-21 Daily demand-supply balance for demand scenario of late-night zone (August 13, 2017 (Sunday))



Pumped storage capacity [MW /day]	Power generation capacity [MW/day]
1,640	1,820

Fig. 4-22 Daily demand-supply balance for demand scenario during high-output renewable energy (October 1, 2017 (Sunday))



Pumped storage capacity [MW/ day]	Power generation capacity (MW/ day)
1,700	440

Fig. 4-23 Simulation investigation case (If Tomato-atsuma Power Plant, which is the largest power plant, were to trip after the start of commercial operations of Ishikariwan-shinko Power Plant and the new Hokkaido-Honshu HVDC Link in February to March, 2019)

Unit: MW

Case No.			[1]-1	[1]-2	[1]-3
Scenarios			Tomato-atsuma 3 units full output		
			Late-night demand	Light load and high renewable energy output	Late-night demand and no pumped storage
Demand		Demand	2564	2811	2792
		Pumped storage power	183	*1 460	0
		Hokkaido-Honshu (Power transmission to Hokkaido is regular)	53	-301	55
Supply capacity	*3 Generators simulated to be tripped	Tomato-atsuma	1598	1598	1598
		Renewable energy – Solar power	0	960	0
		Renewable energy – Wind power	125	138	115
		Other thermal power	143	70	149
		Subtotal	1866	2766	1862
	*4 Generators simulated not to be tripped	Shiriuchi Unit 2	110	110	110
		Ishikariwan-shinko Unit 1	155	142	189
		Other hydro power	352	340	366
		Geothermal	14	16	13
		Biomass	5	5	5
		Other thermal power	192	193	192
		Subtotal	828	806	875
*2 Governor-free capacity			122 (4.8%)	122 (4.3%)	122 (4.4%)

*1 Kyogoku is full pumped storage
*2 In any scenario, the power from Shiriuchi Unit 2 and Ishikariwan-shinko Unit 1, which are non-tripped power sources, is 77MW, 2% or more is secured.
*3 Power sources assumed to have tripped (Tomato-atsuma if considered this time) + Generator UFR settling time is 47 Hz or more and operation period is about 1 s solar power, wind power, other thermal power
*4 Power sources other than *3

The same shall apply hereinafter

The simulation results if the 3 Units at Tomato-atsuma Power Plant tripped simultaneously in the three most severe scenarios mentioned above are as follows:

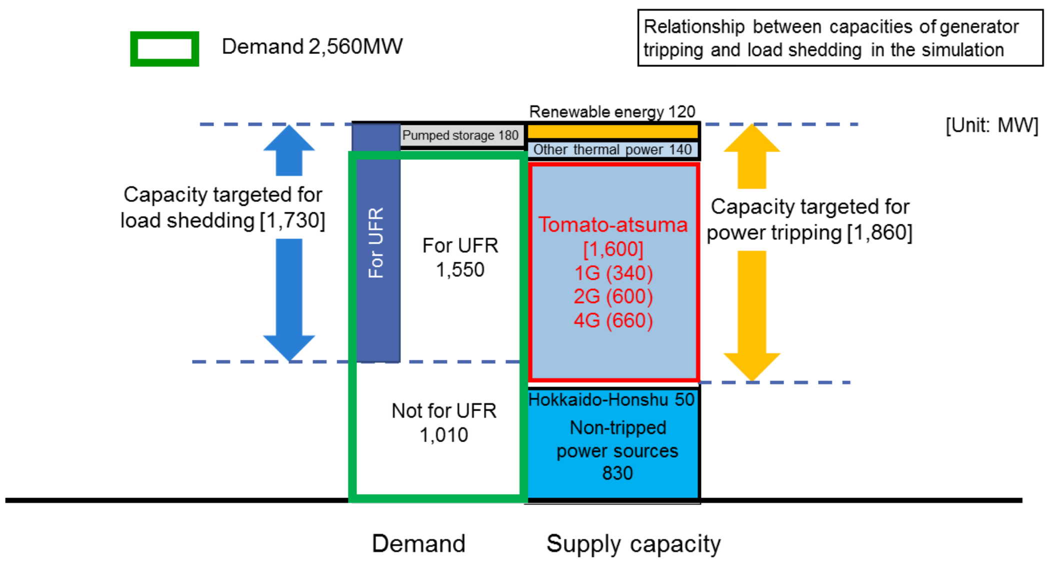
- Case [1]-1: Three Units of Tomato-atsuma Power Plant trip simultaneously (with water pumping operations) in a demand scenario where the demand is lowest while Tomato-atsuma Power Plant Units 1, 2, and 4 meet the conditions of full output (2,560 MW, result at one o'clock on August 13, 2017 (Sunday)) (Refer to Fig. 4-24 and Fig. 4-25)

  After simultaneous tripping of 3 generators at Tomato-atsuma Power Plant, even though wind power tripping occurs due to UFR, the frequency drop is controlled by water pumping curtailment and load shedding through UFR operations, the emergency AFC of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and increase from generator simulated not to trip such as hydro power. The lowest point of the frequency is 47.46 Hz, which is above 47.0 Hz. Moreover, the frequency recovered to about 50 Hz.

The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 558.4 MW and the operating reserved capacity of 296.6 MW is secured against transmission capacity of 855 MW.

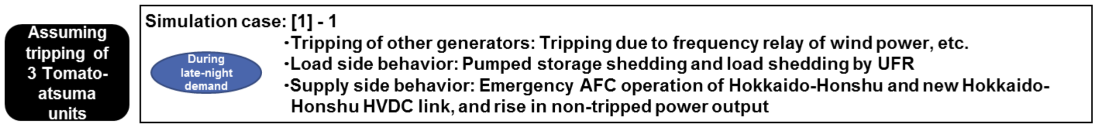
However, emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 802 MW. If the initial current flow is considered to be little less than 50MW in the reverse direction/ Hokkaido direction, it exceeds the maximum margin in 546MW in the reverse direction/ Hokkaido direction.

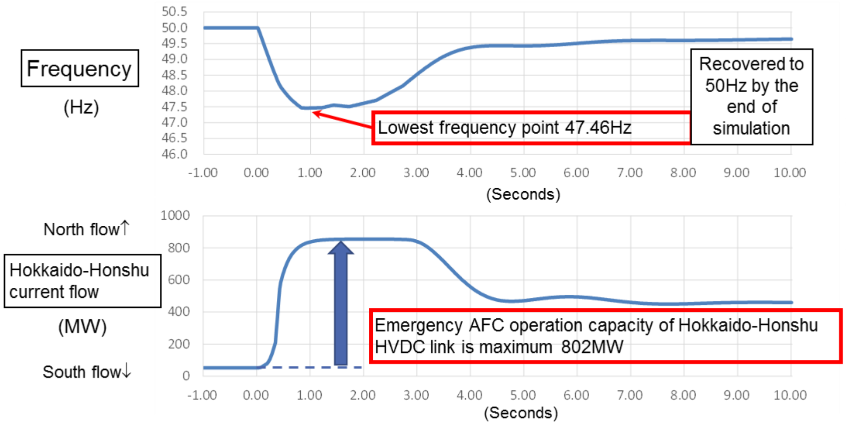
Fig. 4-24 Simulation results [1] of Case [1]-1: Three Units of Tomato-atsuma Power Plant Units 1, 2, and 4 trip simultaneously (with water pumping operations) in a demand scenario where the demand is lowest while Tomato-atsuma Power Plant Units 1, 2, and 4 meet the conditions of full output (2,560 MW, result at one o'clock on August 13, 2017 (Sunday))



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-25 Simulation results [2] of Case [1]-1: Three Units of Tomato-atsuma Power Plant Units 1, 2, and 4 trip simultaneously (with water pumping operations) in a demand scenario where the demand is lowest while Tomato-atsuma Power Plant Units 1, 2, and 4 meet the conditions of full output (2,560 MW, result at one o’clock on August 13, 2017 (Sunday))





Simulation result	
Result	O
Lowest frequency point (Hz)	47.46
UFR operation (MW)	1071.0
Remaining UFR (MW)	476.2
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	802.0
Hokkaido-Honshu current final value (MW)	558.4
Hokkaido-Honshu current final reserved capacity (MW)	296.6

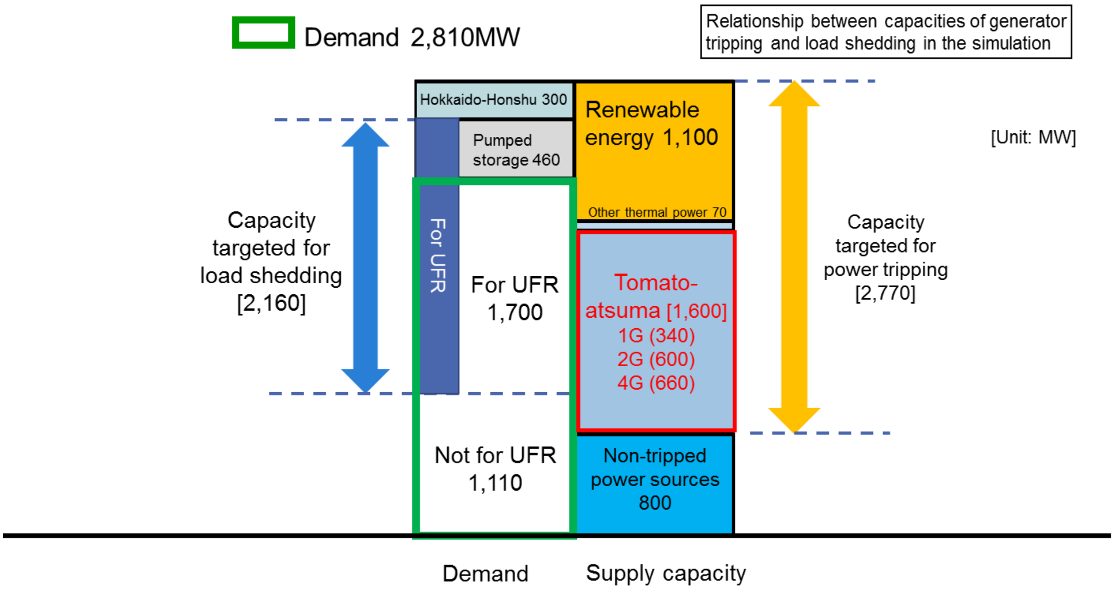
- Case [1]-2: Three Units of Tomato-atsuma Power Plant trip simultaneously (with water pumping operations) in a demand scenario where renewable energy meets high output conditions when Tomato-atsuma Power Plant Units 1, 2, and 4 are fully operational (2,810 MW, result at 11 o'clock on October 1, 2017 (Sunday)). (Refer to Fig. 4-26 and Fig. 4-27)

  After simultaneous tripping of 3 generators at Tomato-atsuma Power Plant, even though solar power and wind power tripping occurs due to UFR, the frequency drop is controlled by water pumping curtailing and load shedding through UFR operations, the emergency AFC of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power. The lowest point of the frequency is 47.87 Hz, which is above 47.0 Hz. Moreover, the frequency recovered to about 50 Hz.

  The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 533.2 MW and the operating reserve capacity of 321.8 MW is secured against transmission capacity of 855 MW.

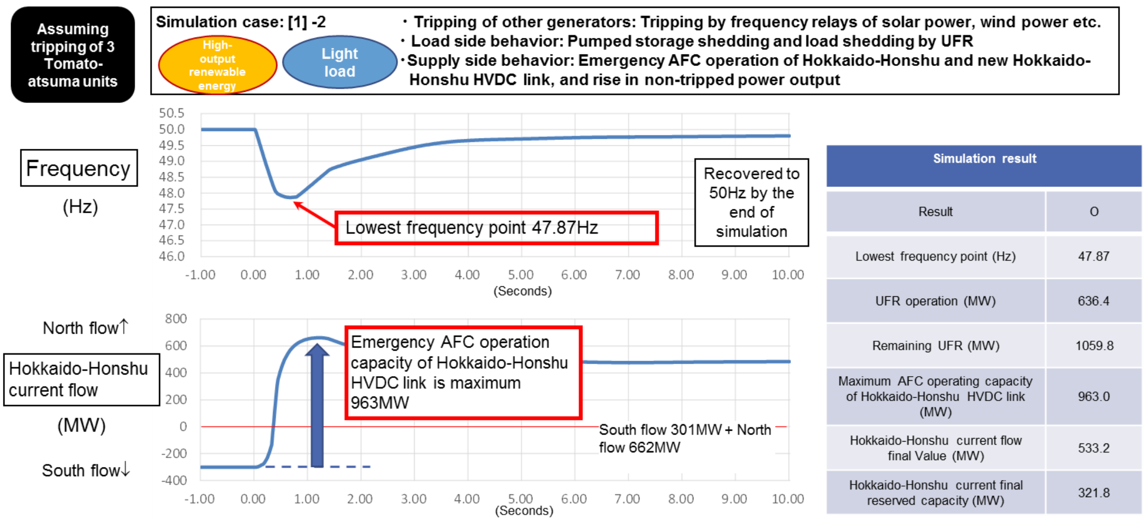
  However, emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 963 MW. If an allowance is made for the fact that the initial current flow is up to 300 MW in the forward direction/ Honshu direction, it exceeds the maximum margin of 531 MW in the reverse direction/ Hokkaido direction.

Fig. 4-26 Simulation results [1] of Case [1]-2: Three Units of Tomato-atsuma Power Plant trip simultaneously (with water pumping operations) in a demand scenario where renewable energy meets high output conditions when Tomato-atsuma Power Plant Units 1, 2, and 4 are fully operational (2,810MW, result at 11 o'clock on October 1, 2017 (Sunday))



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-27 Simulation results [2] of Case [1]-2: Three Units of Tomato-atsuma Power Plant trip simultaneously (with water pumping operations) in a demand scenario where renewable energy meets high output conditions when Tomato-atsuma Power Plant Units 1, 2, and 4 are fully operational (2,810 MW, result at 11 o'clock on October 1, 2017 (Sunday))



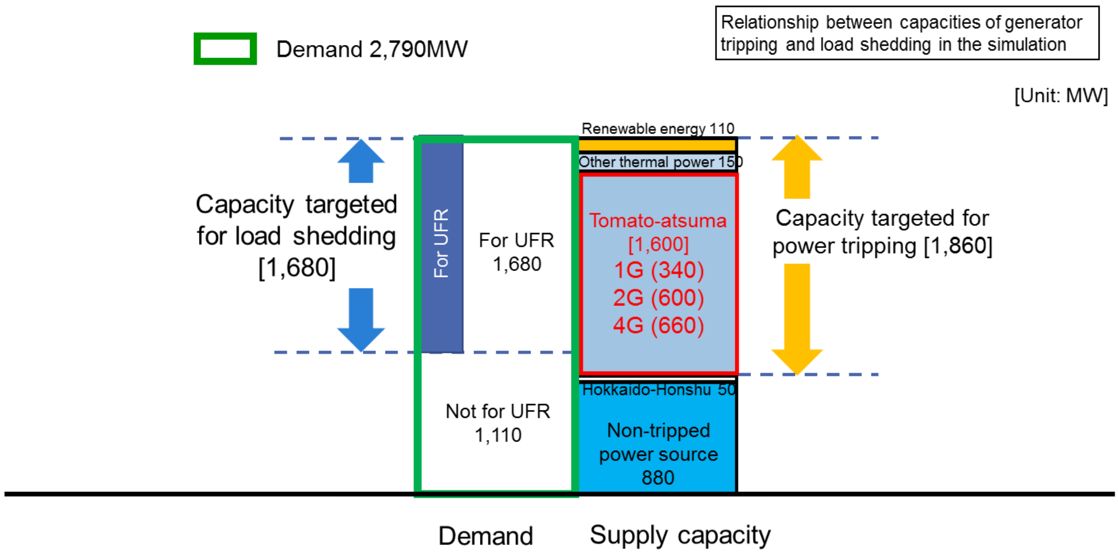
- Case [1]-3: Three Units of Tomato-atsuma Power Plant trip simultaneously (without water pumping operations) in a demand scenario where Tomato-atsuma Power Plant Units 1, 2, and 4 meet full output without water pumping, on the same day as Case[1]-1 (2,790 MW, result at 3 o'clock on August 13, 2017 (Sunday)) (Refer to Fig. 4-28 and Fig. 4-29)

  After simultaneous tripping of 3 generators at Tomato-atsuma Power Plant, on the one hand wind power tripping occurs due to UFR, and although the frequency drop is controlled by load shedding through UFR operations, the emergency AFC of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power, the lowest point of the frequency is 46.95 Hz, which is below 47.0 Hz. Moreover, the frequency recovered to about 50 Hz.

  The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 651.6MW, and the adjusted reserve capacity of 203.4MW is secured against the equipment capacity of 855 MW.

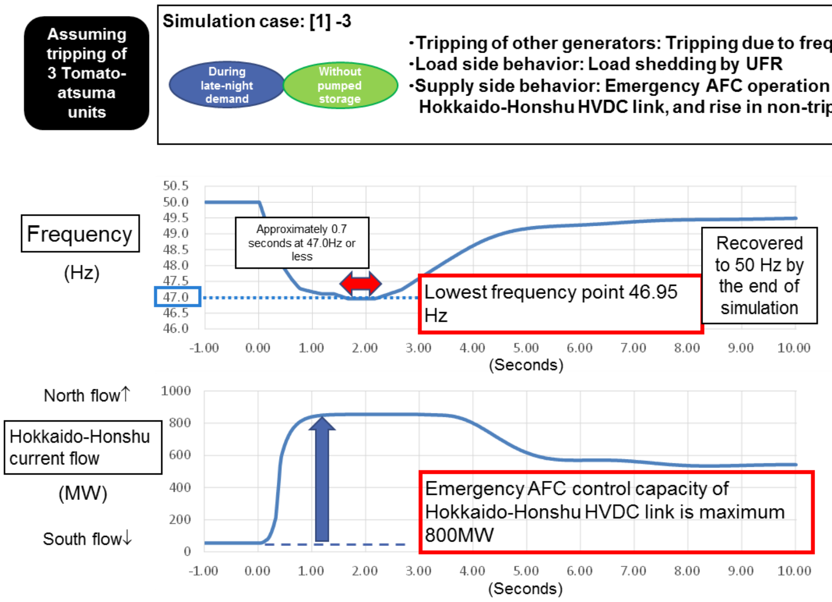
  However, emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 800 MW. If the initial current flow is considered to be little less than 50 MW in the reverse direction/ Hokkaido direction, the maximum margin exceeds 531 MW in the reverse direction/ Hokkaido direction.

Fig. 4-28 Simulation results [1] Case [1]-3: Three Units of Tomato-atsuma Power Plant trip simultaneously (without water pumping operations) in a demand scenario where Tomato-atsuma Power Plant Units 1, 2, and 4 meet full output without water pumping, on the same day as Case [1]-1



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-29 Simulation results [2] Case [1]-3: Three Units of Tomato-atsuma Power Plant trip simultaneously (without water pumping operations) in a demand scenario where Tomato-atsuma Power Plant Units 1, 2, and 4 meet full output without water pumping, on the same day as Case [1]-1



Simulation result	
Result	O*
Lowest frequency point (Hz)	*1 46.95
UFR operation (MW)	1166.2
Remaining UFR (MW)	518.5
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	800.0
Hokkaido-Honshu current final Value (MW)	651.6
Hokkaido-Honshu current final reserved capacity (MW)	203.4

*1 Though it is below 47 Hz, the situation does not lead to a blackout as there was no UFR load shedding at the power plant (47 Hz-10 seconds)

Even if the three Units of Tomato-atsuma Power Plant at full output, trip simultaneously in the three most severe scenarios as mentioned above, blackout can be avoided on the assumption that necessary measures are taken to resolve certain reservations. Moreover, with the exception of Case [1]-3, it was confirmed through simulation that the lowest point of the frequency exceeded 47.0 Hz and the frequency recovered to about 50 Hz.

For Case [1]-3, the lowest point of the frequency is 46.95 Hz, which is below 47.0 Hz. However, the thermal power generator UFR (47.0 Hz, time period 10 seconds) with frequency 47.0 Hz or lower for a duration of about 0.7 seconds does not work, so the situation does not lead to blackout.

Moreover, on the presumption of taking the necessary measures to resolve certain reservations, the final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is below a certain level of the equipment capacity 855 MW. It was confirmed through simulation that the frequency adjusted reserve capacity for demand fluctuation has been secured.

However, in all the cases, the maximum operation capacity of emergency AFC of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link exceeds the maximum margin in the reverse direction/ Hokkaido direction if the initial current flow is considered. (Refer to Fig. 4-30).

Fig. 4-30 Summary table of simulation results for cases if full-output three Units of Tomato-atsuma Power Plant, which is the largest power plant, were to trip simultaneously after the commercial operations of Ishikariwan-shinko Power Plant and the new Hokkaido-Honshu HVDC Link in February to March 2019

Unit: MW

Case No.			[1]-1	[1]-2	[1]-3
Scenario			Tomato-atsuma 3 units full output		
			Late-night demand	Light load and maximum renewable energy	Late-night demand and no pumped storage
Demand		Demand	2564	2811	2792
		Pumped-storage power	183	460	0
		Hokkaido-Honshu (Power transmission to Hokkaido is regular)	53	-301	55
Supply capacity	Generators simulated to be tripped	Tomato-atsuma	1598	1598	1598
		Other renewable energy	268	1168	264
		Subtotal	1866	2766	1862
	Generators simulated not to be tripped	Shiriuchi Unit 2	110	110	110
		Ishikariwan-shinko Unit 1	155	142	189
		Other	563	554	576
		Subtotal	828	806	875
Simulation result		Result	O	O	O*
		Lowest frequency point (Hz)	47.46	47.87	*2 46.95
		UFR operation (MW)	1071	636	1166
		Remaining UFR	476	1060	519
		Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)*1	802 (546)	963 (531)	800 (532)
		Hokkaido-Honshu current final value	558	533	652

* 1 () indicates margin (Tripping of largest single unit)

* 2 Though it is below 47 Hz, the situation does not lead to a blackout as there was no UFR load shedding at the thermal power plant (47 Hz-10 seconds)

Apart from this, there is a possibility that the emergency AFC operation capacity of the Hokkaido-Honshu HVDC link and new Hokkaido-Honshu HVDC link is limited (decreases), Tomato-atsuma is 1500MW or more. Actual scenario which the spot market divides into the Hokkaido-Honshu HVDC link and new Hokkaido-Honshu HVDC link in the north flow is high with the Hokkaido area demand of 4700 ~ 5100MW. It is confirmed that there will be no blackout.

(b) If the Tomari Power Plant, which is currently under long-term shutdown, tripped after resuming of operations

If all the Units at one site of the Tomari Power Plant is assumed to have tripped, at the time of identifying the most severe scenarios in which there is a risk of significant frequency drop, the availability of water pumping operation that can be used as a measure against frequency decrease, and the prior current flow situation of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link have been considered on the basis of "late night demand when demand is low and frequency drop has a severe impact", "demand for high-output renewable energy for which massive tripping due to frequency drop is a concern".

At the time of setting the most severe scenario, since all Units of the Tomari Power Plant are under long-term shutdown and the timing of resuming operation is not yet decided, if a case is specified to carry out simulation after resuming operation at Tomari Power Plant from the actual records of latest demand as in point (1), in terms of demand-supply balance, along with the late-night demand scenario and the high-output renewable energy scenario, full operations with water pumping will be carried out at Kyogoku, and water pumping operation will also be carried out at Takami and Niikappu in the high-output renewable energy scenario. Furthermore, the current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link will increase in the forward direction/ Honshu direction. There is an increase in water pumping curtailment by UFR and increase in the operation capacity of Hokkaido-Honshu emergency AFC. Since we believed that it will not become the most severe scenario in a substantial way, at the latest Government council (Advisory Committee for Natural Resources and Energy, Committee on Energy Efficiency and Renewable Energy, WG on Grids (18^{th})), the operating conditions of the three Units of Tomari Power Plant were determined by referencing the demand-supply balance of light-load period reported by the Hokkaido Electric Power Company, thermal power operations were incorporated for the stable operation of Hokkaido-Honshu HVDC Link, and the scenarios were narrowed down to four scenarios, including late-night demand scenario when demand is the lowest and a high-output renewable energy scenario. Note that after operations resume at Tomari Power Plant, the output of the Tomato-atsuma Power Plant Units will be constricted due to the operation of the Tomari Power Plant generators, and thereafter, the tripping of largest site will indicate the tripping of one Tomari Power Plant site. (Refer to Fig. 4-31 and Fig. 4-32).

Based on the above, we decided that the scenarios used for investigating the medium-to-long-term measures when resuming operations of Tomari power plant, shall be the following scenarios, assumed by accumulating conditions under which the frequency drop is significant:

a. Simultaneous tripping when 3 Units of Tomari Power Plant are operational and when 2 Units are operational were confirmed respectively.

b. Output of must-run thermal power for stable operation of Hokkaido-Honshu HVDC Link was assumed as the minimum output at which GF is operable.

c. Output of thermal power (other thermal power) other than the must-run thermal power for stable operation of Hokkaido-Honshu HVDC Link was assumed as an output presuming that the renewable energy is controlled (consistent with the contents reported by Hokkaido Electric Power Company to Grid-WG (18th)).

d. Demand scenario of late-night zone is assumed to be without water pumping operation, the high-output renewable energy scenario is assumed to be with water pumping operation. (According to the contents reported by Hokkaido Electric Power Company to Grid-WG (18th), 422 MW)

e. In the case of low late-night demand, the current flow of the Hokkaido-Honshu and the new Hokkaido-Honshu HVDC Link was assumed to be in the reverse direction/ Hokkaido direction (Hokkaido flow) after ensuring a margin equivalent to the Hokkaido flow, which has a low effect of emergency AFC operation of the Hokkaido-Honshu and the new Hokkaido-Honshu HVDC Link as a risk. Even though we believe that the current flow is in the forward direction/ Honshu direction from the viewpoint of utilizing the Hokkaido-Honshu and the new Hokkaido-Honshu HVDC Link in the case of high-output renewable energy, the emergency AFC operation capacity of Hokkaido-Honshu and the new Hokkaido-Honshu HVDC Link is increased. Since we believed that this would not serve as the most severe scenario and it was not realistic that the current flow would be in the reverse direction/ Hokkaido direction, the case of 0 MW current flow was also examined as a risk case.

Fig. 4-31 Demand-supply balance in light-load period and hydro power settings (Contents of Hokkaido Electric Power Company report in the Grid-WG (18th))

Demand/Supply balance during light load period

○ The demand/supply balance for the calculation conditions on the minimum demand day (May 21) at 11:00 to 12:00 and 19:00 to 20:00 are as described in the tables below.

[Minimum daytime demand*1 May 21 11:00 to 12:00]

(MW)

Demand (excluding isolated islands)			2,686
Power source I/II (Thermal power)	Coal	Tomato-atsuma Unit 2	200
		Tomato-atsuma Unit 4	128
	Oil	Shiriuchi Unit 2	116
	LNG	Ishikariwan-shinko Unit 1	0
	Total		444
Power source II	Power received from other companies		0
	Other		0
Nuclear power			1,755
Renewable energy	General hydro power		824
	Solar power		912
	Wind power		30
	Geothermal		59
	Biomass		73
	Sub-total		1,898
	Restrained solar power capacity		▲ 379
	Restrained wind power capacity		0
	Total		1,519
Pumped-storage hydro power			▲ 422
Utilization of interconnection lines			▲ 610
Total supply capacity			2,686

[Peak lighting demand May 21 19:00 to 20:00]

(MW)

Demand (excluding isolated islands)			3,224
Power source I/II (Thermal power)	Coal	Tomato-atsuma Unit 2	280
		Tomato-atsuma Unit 4	326
	Oil	Shiriuchi Unit 2	163
	LNG	Ishikariwan-shinko Unit 1	0
	Total		769
Power source II	Power received from other companies		0
	Other		0
Nuclear power			1,755
Renewable energy	General hydro power		967
	Solar power		0
	Wind power		30
	Geothermal		59
	Biomass		73
	Sub-total		1,129
	Restrained solar power capacity		0
	Restrained wind power capacity		0
	Total		1,129
Pumped-storage hydro power			181
Utilization of interconnection lines			▲ 610
Total supply capacity			3,224

*1 In the event of minimum demand at 11:00 to 12:00 on a sunny day in May, excluding Holidays.

Hydro power settings

(Note) Hydro power settings for May are high. The lowest hydro power supply capacity is adopted from that of October, which is similar to May in terms of demand size.

[Lowest month-wise general hydroelectric power supply capacity (excluding isolated islands)]

	April	May	June	July	August	September	October	November	December	January	February	March
Run-of- river powerplant	194	230	207	190	186	166	172	177	164	140	129	130
Regulating reservoir type	155	459	320	243	257	189	187	166	83	71	109	92
Reservoir type	0	0	0	0	0	0	0	0	0	0	0	0
Total	349	689	527	433	443	355	359	343	247	211	238	222

Fig. 4-32 Simulation inspection case (If the Tomari Power Plant, which is currently under long-term shutdown, tripped after resuming operations)

Unit: MW

				[2]-1	[2]-2	[2]-3	[2]-4
Case No.				[2]-1	[2]-2	[2]-3	[2]-4
				Late-night zone scenario		Scenario at the time of high output in renewable energy	
Scenario				Tomari 3 units in operation	Tomari 2 units in operation	Tomari 3 units in operation	
Demand		Demand		3,123	2,507	2,793	3,438
		Pumped storage power		0	0	422	422
		Hokkaido-Honshu (Power transmission to Hokkaido is regular)		175	138	-645	0
Supply capacity	Power targeted for tripping	Tomari		2,070	1491	2,070	2,070
		Renewable energy	Solar power	0	0	912	912
			Wind power	30	30	30	30
		Other thermal power		0	0	0	0
		Subtotal		2,100	1,521	3,012	3,012
	Non-tripped power source	Shiriuchi Unit 2		110	110	110	110
		Ishikariwan-shinko Unit 1		142	142	142	142
		Tomato-atsuma		105	105	105	105
		Other hydro power		359	359	359	359
		Geothermal		59	59	59	59
		Biomass		73	73	73	73
		Other thermal power		0	0	0	0
		Subtotal		848	848	848	848
* Governor free capacity				77 (2.5%)	77 (3.1%)	77 (2.8%)	77 (2.2%)

Content reported by Hokkaido Electric Power Company to Grid WG

Current flow that ensure the Hokkaido-Honshu and the new Hokkaido-Honshu HVDC Link margin towars Tohoku → Hokkaido.
[2]-3 is the south flow (Hokkaido→Tohoku direction).

Content reported by Hokkaido Electric Power Company to Grid WG

Thermal Power which is necessary for stable operation of Hokkaido-Honshu HVDC link

Content reported by Hokkaido Electric Power Company to Grid WG
Used the minimum output value in October only for hydro power

* Note that Tomato-atsuma is set to minimum output as a measure to avoid renewable energy output control

* In any scenario, the power from Shiriuchi Unit 2 and Ishikariwan-shinko Unit 1, which are non-tripped power sources, is 77MW, 2% or more is secured.

Simulation results if full-output 3 Units or 2 Units of Tomari power plant were to trip due to the above-mentioned 4 most severe scenarios, is as shown below:

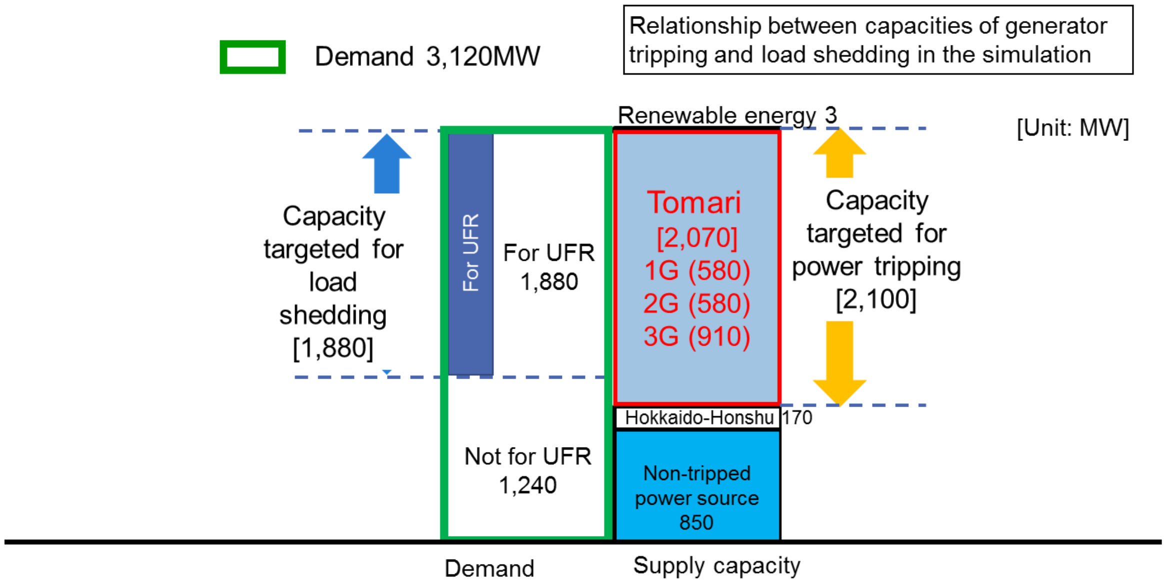
- Case [2]-1: Demand scenario of late night zone (demand size 3,120 MW, without water pumping, full output at 3 Units of Tomari power plant)(Refer to Fig. 4-33 and Fig. 4-34)

  After 3 Units of the Tomari power plant trip simultaneously, on one hand, tripping occurred due to wind power UFR, and the frequency drop was not controlled even by load shedding through the UFR, emergency AFC and operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power. The lowest point of frequency was below 45.0Hz, and in the absence of additional measures, finally there is a high possibility of blackout.

  The final reserved capacity of the current flow of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is lost at the time of blackout.

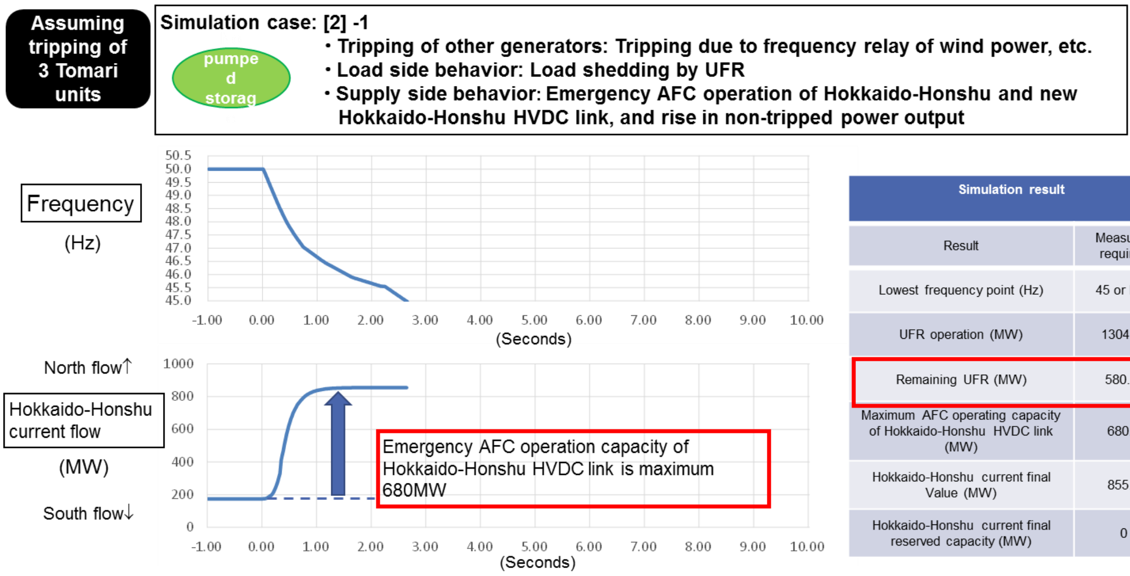
  Note that the emergency AFC operation capacity of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 680 MW.

Fig. 4-33 Simulation results [1] of Case [2]-1: Three full-output Units of Tomari power plant trip simultaneously in the demand scenario of late night zone (3,120 MW, without water pumping, full output at 3 Units of Tomari power plant)



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-34 Simulation results [2] of Case [2]-1: Three full-output Units of Tomari power plant trip simultaneously in the demand scenario of late night zone (3,120 MW, without water pumping, full output at 3 Units of Tomari power plant)



Simulation result	
Result	Measures required
Lowest frequency point (Hz)	45 or less
UFR operation (MW)	1304.5*
Remaining UFR (MW)	580.0*
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	680.0
Hokkaido-Honshu current final Value (MW)	855.0
Hokkaido-Honshu current final reserved capacity (MW)	0

* Value up to 2.5 seconds on simulation

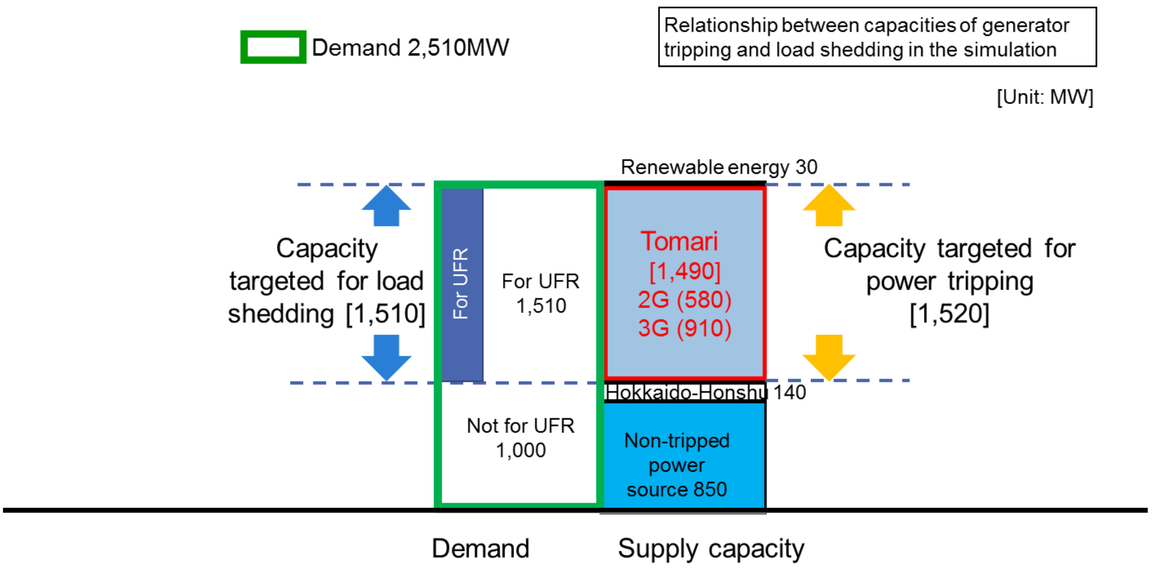
- Case [2]-2: Demand scenario of late night zone (demand size 2,510 MW, without water pumping, full output at 2 Units of Tomari power plant)(Refer to Fig. 4-35 and Fig. 4-36)

  After 2 Units of the Tomari power plant trip simultaneously, on one hand, tripping occurred due to wind power UFR, and the frequency drop was controlled by load shedding through the UFR, emergency AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase generators simulated not to trip such as hydro power. The lowest point of frequency was below 47.41Hz, and it exceeds 47.0Hz. The frequency recovered to about 50Hz.

  The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 547.4MW, and the adjusted reserve capacity of 307.6MW is secured against the transmission capacity 855 MW

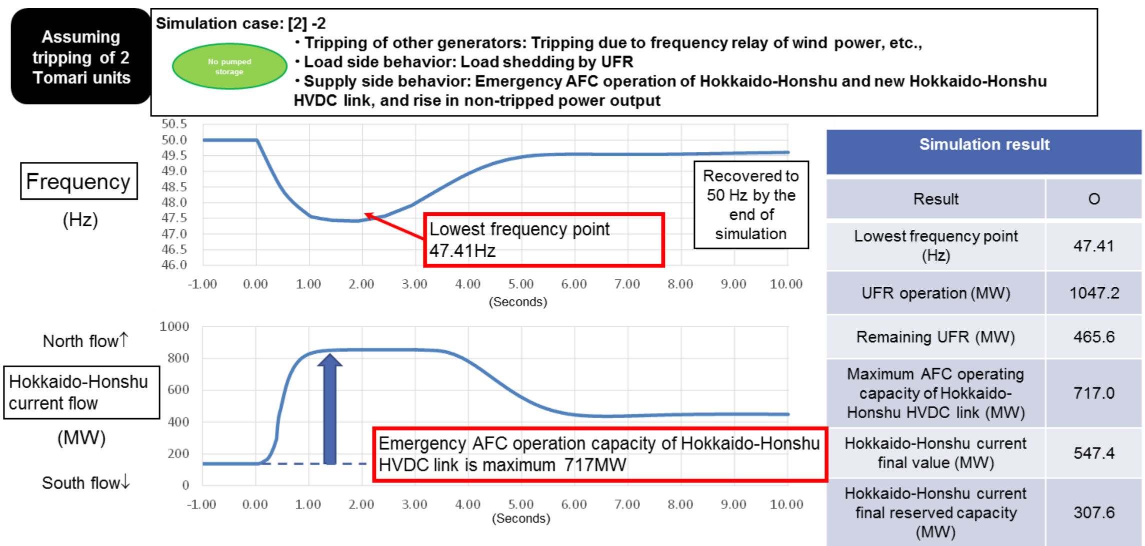
  The emergency AFC operation capacity of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 717 MW. If the initial current flow is considered to be more than 100 MW in the reverse direction/ Hokkaido direction, activated AFC falls below the margin 762 MW in the reverse direction/ Hokkaido direction.

Fig. 4-35 Simulation results [1] of Case [2]-2: Two full-output Units of Tomari power plant trip simultaneously in the demand scenario of late night zone (2,510 MW, without water pumping, full output at 2 Units of Tomari power plant)



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-36 Simulation results [2] of Case [2]-2: Two full-output Units of Tomari power plant trip simultaneously in the demand scenario of late night zone (2,510 MW, without water pumping, full output at 2 Units of Tomari power plant)



- Case [2]-3: Demand scenario in the event of high-output renewable energy (demand size 2,790 MW, with water pumping, full output at 3 Units of Tomari power plant) (Refer to Fig. 4-37 and Fig. 4-38)

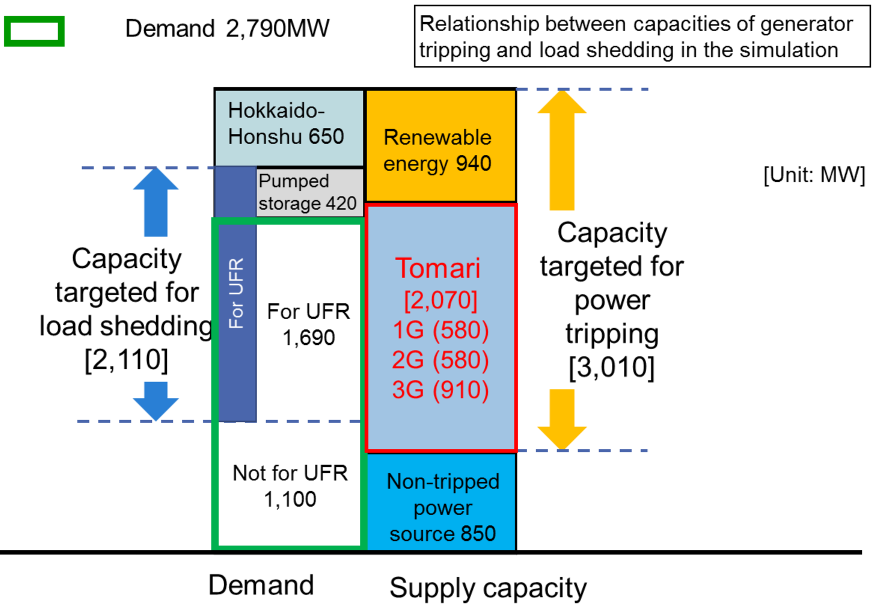
  After 3 Units of the Tomari power plant trip simultaneously, on one hand, tripping occurred due to solar power, wind power UFR, and the frequency drop was controlled by load shedding through UFR, the emergency AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power. The lowest point of frequency is 47.68Hz, and it exceeds 47.0Hz. The frequency recovered to about 50Hz.

  The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 672.0MW, and the adjusted reserve capacity of 183.0MW is secured against the transmission capacity of 855 MW.

  Note that the emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 1,317 MW. Considering the fact that the initial current flow is about 600 MW in the forward direction/ Honshu direction, it exceeds 744 MW of the maximum margin in the reverse direction/ Hokkaido direction.

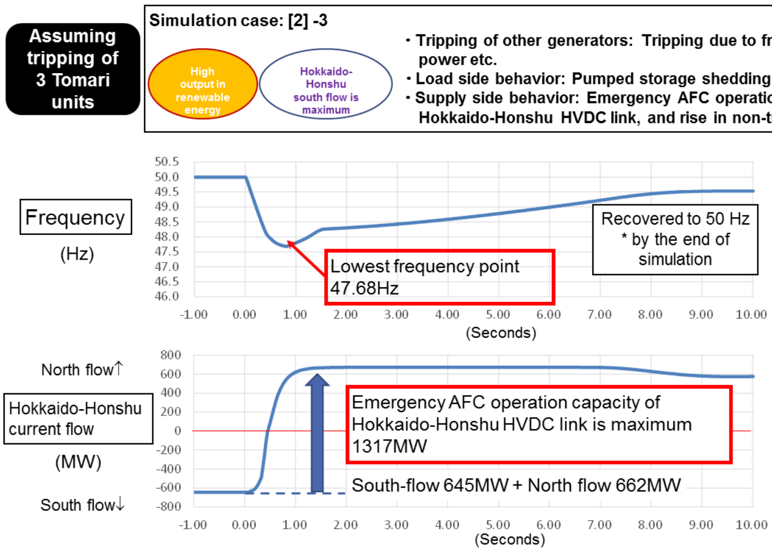
  Unlike Case [2]-1, in Case [2]-3 water pumping curtailing (420 MW) due to UFR is considered to be the main cause that can avoid blackout. The initial current flow of Hokkaido-Honshu HVDC Link is in the forward direction/ Honshu direction. The emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is believed to be substantial.

Fig. 4-37 Simulation results [1] of Case [2]-3: Three full-output Units of Tomari power plant trip simultaneously in the demand scenario of high-output renewable energy (2,790 MW, with water pumping, full output at 3 Units of Tomari power plant)



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-38 Simulation results [2] of Case [2]-3: Three full-output Units of Tomari power plant trip simultaneously in the demand scenario of high-output renewable energy (2,790 MW, with water pumping, full output at 3 Units of Tomari power plant)



Simulation result	
Result	O
Lowest frequency point (Hz)	47.68
UFR operation (MW)	725.5
Remaining UFR (MW)	959.9
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	1317.0
Hokkaido-Honshu current final value (MW)	672.0
Hokkaido-Honshu current final reserved capacity (MW)	183.0

*At the end of simulation, if the grid frequency is 49.86 Hz, it is within the frequency deviation target 50±0.3 Hz of the Hokkaido Electric Power Company.

- Case [2]-4: Demand scenario in the event of high-output renewable energy (demand size 3,440 MW, with water pumping, full output at 3 Units of Tomari Power Plant) (Refer to Fig. 4-39 and Fig. 4-40)

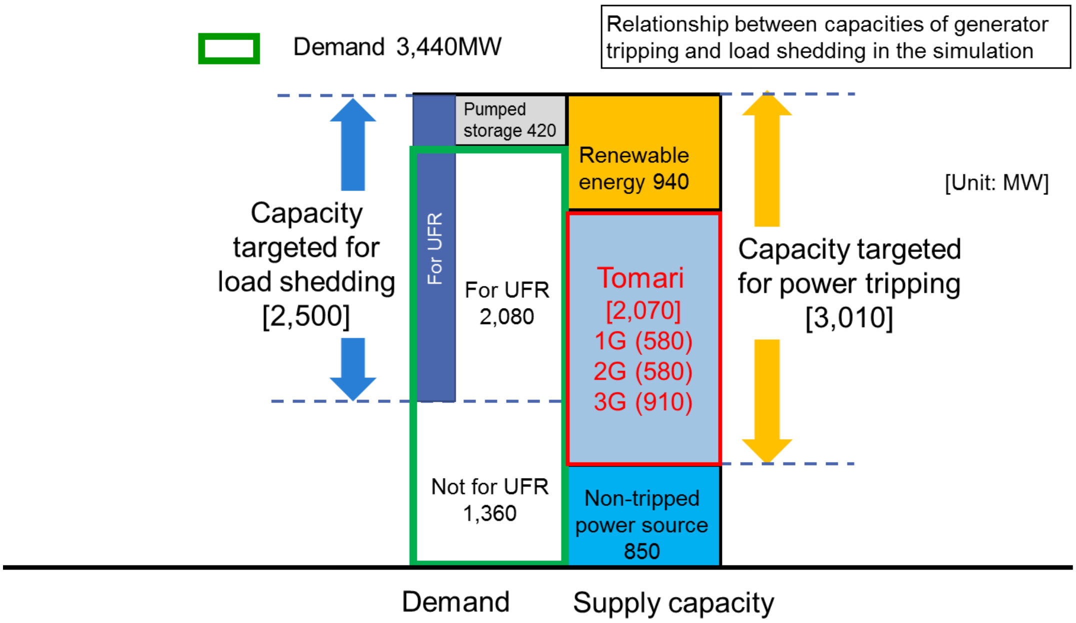
  After 3 Units of the Tomari power plant trip simultaneously, on one hand, tripping occurred due to solar power, wind power UFR, and the frequency drop was controlled by water pumping curtailing and load shedding through the UFR, emergency AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power. However, the lowest point of frequency is 47.44Hz, and it exceeds 47.0Hz. The frequency recovered to about 50Hz.

  The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 630.6 MW, and the adjusted reserve capacity of 224.4 MW is secured against the transmission capacity of 855 MW.

  However, the emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 855 MW. it exceeds 706 MW of the maximum margin in the reverse direction/ Hokkaido direction.

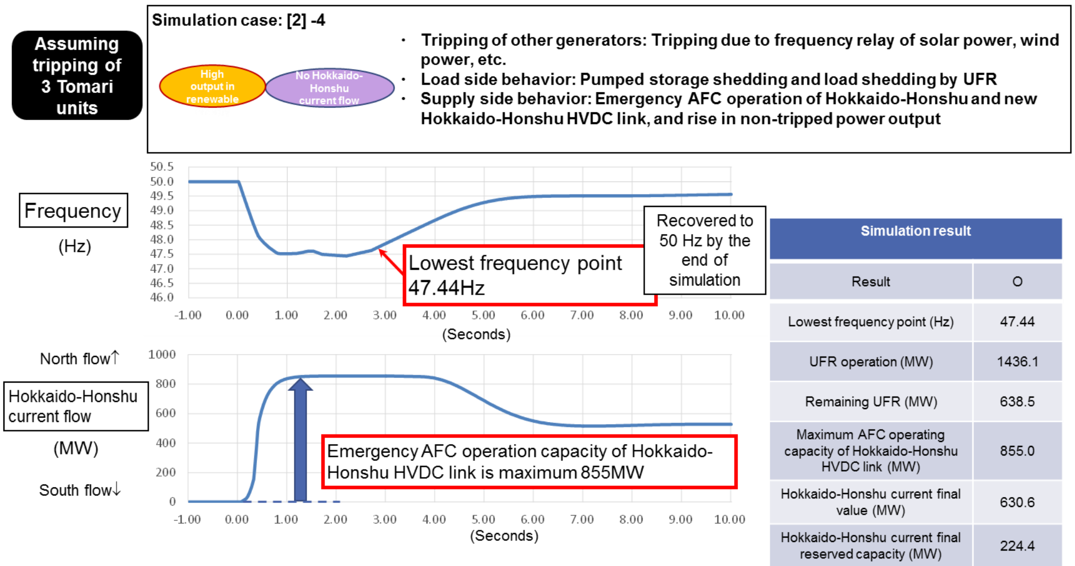
  Unlike Case [2]-1, in Case [2]-4, the water pumping curtailing (420 MW) due to UFR is considered to be the main cause that can avoid blackout.

Fig. 4-39 Simulation results [1] of Case [2]-4: Three full-output Units of Tomari power plant trip simultaneously in the demand scenario of high-output renewable energy (3,440 MW, with water pumping, full output at 3 Units of Tomari power plant)



Note) It is described that there is a risk of the renewable energy and other thermal power tripping with a frequency decrease of up to 47Hz. Tripping capacity may decrease depending on the lowest frequency point and duration in the simulation. Furthermore, for specific settings, simulation is performed based on Figure 4-43.

Fig. 4-40 Simulation results [2] of Case [2]-4: Three full-output Units of Tomari power plant trip simultaneously in the demand scenario of high-output renewable energy (3,440 MW, with water pumping, full output at 3 Units of Tomari power plant)



Simulation result	
Result	○
Lowest frequency point (Hz)	47.44
UFR operation (MW)	1436.1
Remaining UFR (MW)	638.5
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	855.0
Hokkaido-Honshu current final value (MW)	630.6
Hokkaido-Honshu current final reserved capacity (MW)	224.4

Even if the 3 Units or 2 Units of Tomari Power Plant at full output, trip simultaneously in the four most severe scenarios as mentioned above, we confirmed through simulations that blackout can be avoided assuming that necessary measures are taken to resolve certain reservations. However, additional measures are necessary for case [2]-1.

Moreover, among the cases in which blackout can be avoided, in all the cases it has been confirmed through simulation that the lowest point of the frequency exceeded 47.0Hz and the frequency recovered to about 50Hz.

Moreover, on the assumption that necessary measures are taken to resolve certain reservations, the final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is below a certain level of equipment capacity 855 MW. And, it has been confirmed through simulation that frequency adjusted reserve capacity is secured against the demand fluctuation. (Refer to Fig. 4-41).

However, in case [2]-2, the maximum operation capacity of emergency AFC of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is below the maximum margin in the reverse direction/ Hokkaido direction if the initial current flow is considered.

Fig. 4-41 Summary table of simulation results if the Tomari Power Plant, which is currently under long-term shutdown, tripped after resuming operations

Unit: MW

Case No.			[2]-1	[2]-2	[2]-3	[2]-4
Scenario			Late night zone scenario		Scenario of high output renewable energy	
			Tomari 3 units in operation	Tomari 2 units in operation	Tomari 3 units in operation	
Demand		Demand	3123	2507	2793	3438
		Pumped storage power	0	0	422	422
		Hokkaido-Honshu (Power transmission to Hokkaido is regular)	175	138	-645	0
Supply capacity	Generators simulated to be tripped	Tomari	2070	1491	2070	2070
		Other renewable energy	30	30	942	942
		Subtotal	2100	1521	3012	3012
	Generators simulated not to be tripped	Shiriuchi Unit 2	110	110	110	110
		Ishikariwan-shinko Unit 1	142	142	142	142
		Other	596	596	596	596
		Subtotal	848	848	848	848
Simulation result		Result	Measures are required (Note)	○	○	○
		Lowest frequency point (Hz)	45 or less	47.41	47.68	47.44
		UFR operation	1305	1047	726	1436
		Remaining UFR	580	466	960	639
		Maximum AFC operating capacity of Hokkaido-Honshu HVDC link *1	680	717 (762)	1317 (744)	855 (706)
		Hokkaido-Honshu current final value	855	547	672	631

(Note) Consider the blackout workaround separately.

*1 () indicates margin (Tripping of largest single unit)

(4) Mid-to-long term operational measures in Hokkaido area

The Investigation Committee examined the necessary medium-to-long term operational measures in the Hokkaido area in light of the simulation results for the tripping of the largest power plant (largest site) in the most severe scenario throughout a year that can be assumed currently, as described in point (3) (if the Tomari Power Plant, which is currently under long-term shut down, resumes operations and then trips in addition to the tripping of the Tomato-atsuma Power Plant, which is the largest power plant, after commercial operations of the Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link in February to March 2019).

However, it goes without saying that, in future, it is necessary to review the medium-to-long term measures related to the operations in the Hokkaido area in a timely and appropriate manner. These measures have been recommended by the Investigation Committee in its final report due to the major changes in the composition of power supply and the demand-supply balance in the Hokkaido area. Not only the Government and OCCTO, but Hokkaido Electric Power Company must also publish the necessary information, such as the review contents, their necessity, and the basis, including the data, in advance, and regardless of before or after review, must enable its external verification, after which they must review the following medium-to-long term operational measures in a timely and appropriate manner.

Therefore, especially, with reference to the case of the currently under long-term shutdown Tomari Power Plant, tripping after resuming operation, we believe that whenever the prospect of resumption of operations at the Tomari Power Plant is actually reached, it is necessary and mandatory to carry out simulation again, to examine the essential measures, and to take the required measures.

In addition, the Interim Summary of the Working Group on Electricity Resilience states that as one of the "medium-term measures", for which investigation must start immediately after compilation and specific conclusions be obtained by next spring, examine measures to improve emergency and restoration response, such as leaving even a partial isolated grid to avoid blackout if a major failure occurs in a transmission line etc. in light of the major blackout in Hokkaido and also from a broader viewpoint. It is necessary to pay attention to this study details and study results in the future.

(a) If the Tomato-atsuma Power Plant, which is the largest power plant, were to trip after the commercial operations of Ishikariwan-shinko Power Plant and the new Hokkaido-Honshu HVDC Link in February to March 2019

[1] The Under Frequency Relay (UFR) settings in the Hokkaido area

Regarding the idea of load shedding, as stated previously in (2. (2) (a)), though it cannot be said that there are inappropriate points in the approach based on route disconnection at the time of tripping of power supply from the major power source, it is necessary to reconsider the principle based on the blackout.

In addition, in the future, it is necessary to examine the medium-to-long term measures keeping in mind the major changes in the demand-supply balance in the Hokkaido area.

At this time, the following several steps should be considered in the context of the major changes in the demand-supply balance in the Hokkaido area. Moreover, it is also assumed that there will be progress in the introduction of renewable energy such as wind power generation.

February to March 2019 (Commercial operations of Ishikariwan-shinko power plant Unit 1 (LNG Thermal Power), and that of new Hokkaido-Honshu HVDC Link)

December 2026 (Commercial operations of Ishikariwan-shinko power plant, Unit 2 (LNG Thermal Power))

After FY2028 (Commercial operations of Kyogoku Unit 3 (Pumped-storage hydro power))

December 2030 (Commercial operations of Ishikariwan-shinko power plant, Unit 3 (LNG Thermal Power))

To be determined (Inspection and update of Hokkaido-Honshu HVDC Link)

To be determined (Resuming operations of Tomari Power Plant (Nuclear power) after the Nuclear Regulation Authority confirms that the station conforms to the New Regulatory Requirements[12])

To be determined (Introduction of renewable energy on a large scale)

Current UFR of the Hokkaido area is set assuming the supply capacity decrease (1,160 MW) due to the disconnection in the transmission line route from the Tomari Power Plant Units 1/ 2. Though UFR of the area with an early operation period has been increased to about 350 MW (for a demand of 3,090 MW) as measures for the winter 2018/19, the existing UFR operation period itself has not been reviewed.

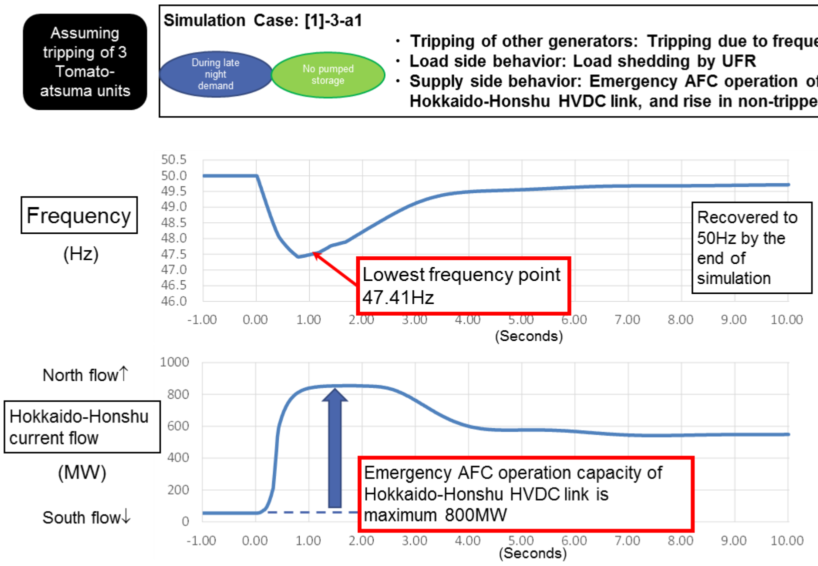
If the frequency significantly drop such as tripping of the largest site when water pumping is not carried out, the frequency drops below the lowest point of 47.0Hz, and there is a risk of chain tripping of the renewable energy.

Therefore, it is necessary to review the UFR settings so that the lowest point of frequency can be risen to 47.0Hz or higher.

An example of settings reviewing includes review of settings in which the frequency fluctuations rate element (df/dt) provided in the UFR terminal is used. Though the UFR of the frequency fluctuations rate element is currently set at 20%, only 10% settings are carried out. For this reason, we reviewed the settings that enable load shedding, which is a setting with a late operation period and cannot be used currently and confirmed the effectiveness of the measures. As a reference, a simulation was carried out for the use of a non-set part of the current facilities (Refer to Fig. 4-42).

[12] A consistent Government policy regarding Nuclear Power Plants stating "If the highly independent Nuclear Regulation Authority carries out a scientific and technical review and acknowledges that the power plant is in conformation with the New Regulatory Requirements which are the strictest in the world, that decision shall be respected, and the plant shall progress towards resuming operations while gaining the understanding of the local community".

Fig. 4-42 Simulation results when load shedding was targeted at about 20% of df/dt function in the current facilities



Simulation Results	
Results	O
Lowest frequency point (Hz)	47.41
UFR operation (MW)	1171.6
Remaining UFR (MW)	513.1
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	799.7
Hokkaido-Honshu current final value (MW)	641.8
Hokkaido-Honshu current final reserved capacity (MW)	213.2

[2]Operation of the largest capacity power plant generator

As stated earlier, at the time of the earthquake, one of the points of argument is the concentration of supply capacity at one site (3 generators) of the Tomato-atsuma Power Plant at the time of shutdown of the large scale pumped-storage hydro power plant (Kyogoku Power Plant, Units 1/ 2 (200 MW x 2)) in the Hokkaido area.

The operation of the largest capacity power plant generator is at present same as stated earlier (Chapter 4 2.(2)), however, it is necessary to study it in future as a medium-to-long term measure focusing on the major changes in the demand-supply balance in the Hokkaido area.

As stated earlier, several steps have been considered to deal with the major changes in the demand-supply balance in the Hokkaido area. As described in point (3) above, through simulation of the tripping of the largest power plant (largest site) in the most severe scenario throughout a year that can be assumed currently (if the Tomato-atsuma Power Plant, which is the largest power plant, trips after commercial operations of the Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link in February to March 2019), if 3 Units of Tomato-atsuma Power Plant trip simultaneously, in all the cases, it is possible to avoid blackout assuming that the necessary measures are taken to resolve certain reservations.

Based on the results of simulation, the measures for winter 2018/19 state that “it is possible to operate Units 1, 2, and 4 of the Tomato-atsuma Power Plant assuming that operations of Kyogoku power plant Units 1/ 2 are available”. However, even if an event similar to the Hokkaido Eastern Iburi earthquake takes place after the commercial operation of the new Hokkaido-Honshu HVDC Link, sufficient AFC reserved capacity can be ensured with the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and that will be sufficient to deal with the event.

Moreover, the measures for winter 2018/19 also state that "power of about 30~35% of demand can be supplied through coutinuousuly oparated power source, even if the frequency drops". However, as the simulation technique has been established, in future, the Hokkaido Electric Power Company must carry out simulation in advance and take the necessary measures as required if they estimate that percentage of continuously operated power source, such as thermal power, might drop below 30% of demand.

In Case [1]-3, it is desirable to consider measures through water pumping because the lowest point of frequency will be lower than 47.0Hz. For this reason, especially in case of Kyogoku Power Plant with a huge installed capacity for a single Unit, it is desirable to avoid a situation of simultaneous planned outage of 2 Units to the extent possible. However, this may not be applicable if the same measures are taken in the other pumped-storage power plants.

Therefore, in a demand-supply scenario (greater than expected demand decrease and the renewable energy connection capacity increase) where the three Units of Tomato-atsuma Power Plant are at full output and the frequency is expected to drop even below the most severe scenario assumed currently (the lowest point of frequency goes lower), and if the ratio of power sources that can continue operation, such as thermal power, is expected to fall below about 30% of the demand, the Hokkaido Electric Power Company must first carry out simulations for the tripping of the largest site, make sure that the situation does not lead to a blackout, and take the necessary measures as and when required (This is also applicable to shut down of equipment, such as Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, for frequency control adjustment).

After the commercial operations of the new Hokkaido-Honshu HVDC Link, when the greater available transmission capacity was used in the reverse direction/ Hokkaido direction, it limited the operation capacity of emergency AFC of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the time of simultaneous tripping of 3 Units of the Tomato-atsuma Power Plant. Thus, we also presumed cases that would be more severe than the present simulation case.

However, maximum north current flow and Tomato-atsuma Power Plant at full output are considered to be extremely rare in the minimum demand scenario.

Moreover, if such a case is assumed, it is necessary to carry out simulation in advance, and if there is a risk of blackout, it is necessary to take measures such as controlling the output at Tomato-atsuma Power Plant or water pumping operations.

[3] Relay settings for generators (wind power, solar power)

In the current Electricity Business Act or transmission and distribution business policy, nothing is specified in detail about the UFR settings for generators. The UFR settings for generators are specified by each general transmission and distribution company based on the grid interconnection technical requirements from the book of terms and conditions such as outsourcing and supply after agreement with the power producers.

For this reason, in the grid interconnection technical requirements of Hokkaido Electric Power Company, the operating limit frequency of extra high voltage grids is laid down as 47.0Hz as the lower limit, and 51.5Hz as the upper limit. If the frequency deviates from the operating limit frequency due to grid accident, a function is provided to automatically parallel off the grid, however, actually the setting is not always set at its lower limit. Currently, 70% of solar power generators and 50% of wind power generators activate output curtailment when the frequency is higher than 47.0Hz (Refer to Fig. 4-43). Moreover, in majority of the cases operation period is 1 second.

Fig. 4-43 UFR settings for solar power and wind power generators in Hokkaido area

[Simulation settings]

(Solar power)

Frequency	Shedding percentage
49Hz	14.2%
48.5Hz	27.3%
47.5Hz	26.9%
47Hz	31.7%
Total	100%

(Wind power)

Frequency	Shedding percentage
49Hz	33.8%
48.5Hz	1.9%
47.5Hz	15.7%
47Hz	48.6%
Total	100%

○Wind Power

Almost all the wind power generators (170 MW) shut down due to frequency drop immediately after the earthquake.

The immediate shutdown of the wind power generator after the earthquake is the result of demonstrating the function in the process where the frequency is dropped to 46.13Hz, and we believe that this does not necessarily indicate a problem.

However, in future, in order to not only avoid a significant impact on frequency maintenance of the whole grid when simultaneous parallel-off occurs at the time of frequency drop due to tripping of large power sources and grid isolation, but also to avoid blackout to the extent possible, first of all, starting from Hokkaido area, it is necessary to check whether UFR settings of individual wind power generator is set at the lower limit of the operating limit frequency, and whether latest FRT requirements (requirement to continue operation in the event of an accident) are satisfied. We believe that if these two conditions are not satisfied, then it is necessary to take proper measures.

In addition, we believe that it is necessary to examine the feasibility of the review of grid interconnection technical requirements from Hokkaido for the UFR settings and FRT requirements of wind power generators.

○Solar Power

The earthquake took place at night, therefore, there was no solar power generation. However, substantial capacity of solar power generates electricity during high-output renewable energy scenario, which is an extremely severe scenario assumed for examining the present recurrence prevention measures.

Therefore, similar to wind power generators, in future, in order to not only avoid a significant impact on frequency maintenance of the whole grid when simultaneous parallel-off occurs at the time of frequency drop due to tripping of large power sources and grid isolation, but also to avoid blackout to the extent possible, first of all, starting from Hokkaido area, it is necessary to check whether UFR settings of individual solar power generator is set at the lower limit of the operating limit frequency, and whether latest FRT requirements (requirement to continue operation in the event of an accident) are satisfied. We believe that if these two conditions are not satisfied, then it is necessary to take proper measures.

In addition, we believe that it is necessary to examine the feasibility of the review of grid interconnection technical requirements from Hokkaido for the UFR settings and FRT requirements of solar power generators.

Regarding the review and investigation of the above mentioned wind and solar power grid interconnection requirements, we believe that it is necessary to examine the response of agencies and the party concerned (operators, trade associations or OCCTO).

In the Interim Summary of the Working Group on Electricity Resilience, recurrence prevention measures (including above mentioned measures) related to major blackout in Hokkaido area suggested in the interim report of the Investigation Committee were listed as one of the “emergency measures” to be immediately undertaken after the summary is compiled. As one of the “medium-term measures”, for which investigation must start immediately after the summary is compiled and specific conclusions be obtained by next spring, the Interim Summary states that the parallel-off settings be reviewed along with the frequency fluctuations by solar power and wind power generators.

[4] Re-evaluation of the frequency control functions, such as governor-free systems, Automatic Frequency Control (AFC) function, and interconnection facility margin in the Hokkaido area

As medium-to-long term operational measures in the Hokkaido area, we believe that it is necessary to examine the required measures after re-evaluating the frequency control functions, such as governor-free systems, Automatic Frequency Control (AFC) function, and interconnection equipment margin in the Hokkaido area.

As described in point (3) above, through simulation of the tripping of the largest power plant (largest site) in the most severe scenario throughout a year that can be assumed currently (if the Tomato-atsuma Power Plant, which is the largest power plant, trips after commercial operations of the Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link in February to March 2019), if the three full-output Units of Tomato-atsuma Power Plant trip simultaneously, in all the cases, assuming that necessary measures are taken to resolve certain reservations, in case of governor free systems, it was confirmed that 2% power is ensured by generators simulated not to trip after the tripping of the largest site. Regarding Automatic Frequency Control (AFC), it was confirmed that adjusted reserve capacity remains in the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link in the final scenario at the end of the simulation.

Moreover, as described in (4)(a)[2] and according to the current way of thinking, the margin in the reverse direction/ Hokkaido direction of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, assumes the tripping of the largest single Unit, and even if the emergency AFC operation capacity increases beyond the north flow margin temporarily due to measures such as controlling the output of the Tomato-atsuma Power Plant generators and water pumping operations, the situation can be understood beforehand and blackout avoided.

Therefore, we believe that at present it is not necessary to review the governor-free system, Automatic Frequency Control (AFC) function, and the margin in the reverse direction/ Hokkaido direction of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link in the Hokkaido area.

In light of the above, in order to avoid a blackout more emphatically, the medium-to-long term operational measures (including matters to pay attention) (after the commercial operations of Ishikariwan-shinko power plant and the new Hokkaido-Honshu HVDC Link) for Hokkaido shall be as follows. Note that OCCTO shall check the implementation status of measures as and when necessary.

1. Review the UFR settings at the earliest so as to make it possible to increase the lowest point of frequency to higher than 47.0Hz (increase the ratio of settings already specified for df/dt from 10% to 20%). When reviewing the settings, review the approach to the places subject to load shedding while considering the impact of voltage rise and feasibility of forming an isolated grid.
2. In a demand-supply scenario (greater than expected demand decrease and the renewable energy connection capacity increase) where Units 1, 2, 4 of Tomato-atsuma Power Plant are at full operation and the frequency is expected to drop even below the most severe scenario assumed currently, and if the ratio of power sources that can continue operation, such as thermal power, is expected to fall below about 30% of the demand, the Hokkaido Electric Power Company must first carry out simulations for the tripping of the largest site, make sure that the situation does not lead to a blackout, and take the necessary measures (This is also applicable to shut down of equipment related to measures against frequency drop such as Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link).
3. Do not consider the operational status of Units 1, 2, 4 of the Tomato-atsuma Power Plant in the calculation of short circuit capacity required for the operation of Hokkaido-Honshu HVDC Link.

(b) If the Tomari Power Plant, which is currently under long-term shutdown, tripped after resuming operations

[1] The Under Frequency Relay (UFR) settings in the Hokkaido area

When 2 Units of Tomari Power Plant are operated, even though the current flow of Hokkaido-Honshu HVDC Link is not in the forward direction/ Honshu direction, or even though there is no water pumping operation, simulations confirmed that blackout could be avoided with the current UFR settings by load shedding through emergency UFR control capacity and AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase of generators simulated not to trip , such as hydro power.

Even when 3 Units of Tomari Power Plant are operated, if the water pumping operation 422 MW and current flow of the Hokkaido-Honshu HVDC Link is in forward direction/ Honshu direction, simulations confirmed that blackout could be avoided by load shedding through emergency UFR control capacity and AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase of generators simulated not to trip, such as hydro power.

On the other hand, we believe that there is a risk of blackout which cannot be avoided in spite of water pumping curtailment and load shedding through emergency UFR control capacity and AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase of generators simulated not to trip, such as hydro power, when there is no water pumping curtailment and when the emergency AFC control capacity of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link exceeds the largest margin in the reverse direction/ Hokkaido direction.

Though UFR of the area with an early activation period has been increased to about 350 MW (for a demand of 3,090 MW) as a measure for winter 2018/19, the existing UFR activation period itself has not been reviewed. As described in point (3), by the simulation for the tripping of the largest power plant (largest site) in the most severe scenario throughout a year that can be assumed currently (if the Tomari Power Plant, which is currently under long-term shutdown, tripped after resuming operations), as described in Case [2]-2, Case [2]-3, and Case [2]-4, the emergency AFC control capacity was expanded due to the commercial operations of the new Hokkaido-Honshu HVDC Link, and it was confirmed that there is a strong tendency that areas with a slow activation period of load shedding by UFR are not in operation.

Based on the above, we believe that it is necessary to review the UFR settings and period so as to ensure that when the frequency significantly drops (especially lower than 47.0Hz) as in the case of tripping of largest power plant (largest site) tripping, none of the must run power sources, used to operate the Hokkaido-Honshu HVDC Link stably, drop below 47.0Hz, which is the operable frequency level.

Moreover, based on Case [2]-1 where there is a possibility of a blackout if no additional measures are taken when the lowest point of frequency is less than 45.0Hz, we believe that it is necessary to raise the lowest point of frequency for the tripping of the largest site to the extent possible, and avoid cascading trip of power sources such as solar power and wind power.

First of all, water pumping curtailment is high-speed shedding (49.5Hz, period 0.1 second) and it is extremely effective, however, pumping up cannot be carried out beyond the conditions of upper reservoir capacity, therefore, it is not possible to carry out water pumping operations continuously for 24 hours.

Next, it is necessary to consider how early load shedding should be activated, for example, to raise the frequency level at which load shedding is performed. However, for ‘raising the frequency level at which load shedding is performed’, it is necessary to bear in mind that load shedding might be performed through UFR for an N-1 and N-2 accident of a generator.

For this reason, we believe that instead of activating UFR at a frequency detection level and period set in advance, it will be effective to take measures to activate load shedding through other detection methods, such as fluctuations frequency rate element, and to use a stabilization device to carry out load shedding rapidly by detecting the tripping of major power sources, such as tripping of the largest site.

Accordingly, simulation was conducted for examining the effectiveness of the following measures for Case [2]-1 where there is a high possibility of a blackout if additional measures are not taken.

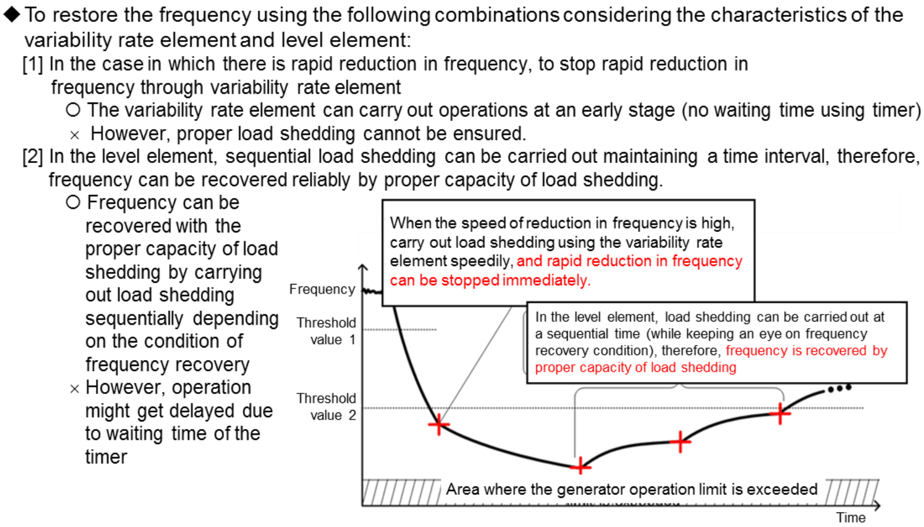
1. Measures through review of settings utilizing the frequency fluctuations rate element (df/dt) provided in the UFR terminal

Currently, UFR with frequency fluctuations rate element is only set to the extent of 10% of the whole, however, we reviewed the settings that enable load shedding, which is a setting with a late activation period and cannot be used currently, and examined the effectiveness of measures for 2 cases, namely when the unconfigured parts in the current facilities are used, and when all locations are updated.

Note that the simulation was conducted based on the proposal from TEPCO Power Grid. (Refer to Fig. 4-44).

If the entire UFR is updated based on the simulation results, the lowest point of frequency is 47.26Hz, and is greater than 47.0Hz.

Fig. 4-44 Approach to division of roles between the fluctuations rate element and level element



- Case[2]-1-a1: Case wherein all unconfigured parts of the df/dt function of the current facilities (about 20% of the current facilities) are subject to load shedding (Refer to Fig. 4-45)

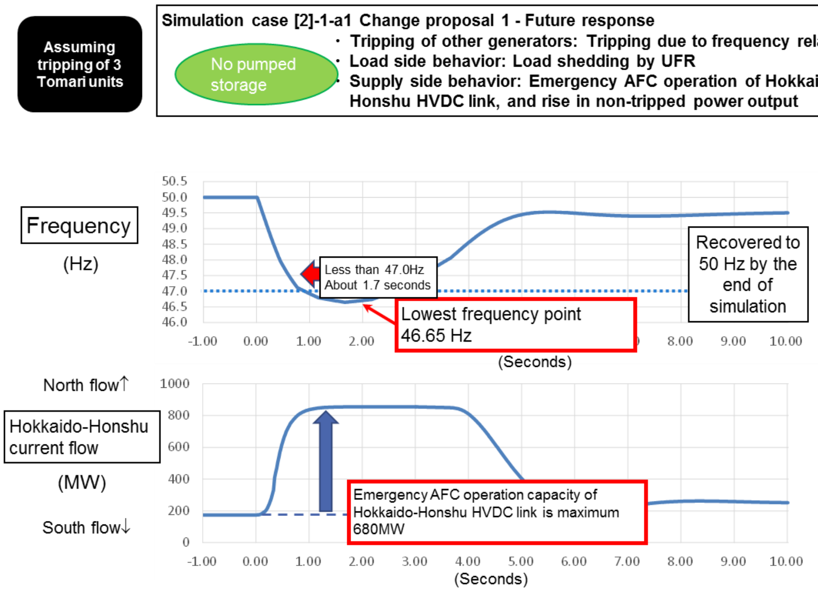
  After simultaneous tripping of 3 Units of the Tomari Power Plant, on the one hand tripping occurs due to wind power UFR, and although the frequency drop is controlled by load shedding through the emergency UFR, AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power, the lowest point of the frequency is 46.65 Hz, which is below 47.0 Hz. Moreover, the frequency recovered to about 50 Hz.

  However, such a situation did not lead to a blackout because the duration of frequency being lower than 47.0Hz was short for 1.7 seconds, and the generator UFR (less than 47.0Hz for 10 seconds) did not activate.

  The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation was 357.0MW, and the adjusted reserve capacity of 498.0MW is secured against the transmission capacity of 855 MW.

  Note that the emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 680 MW. If the initial current flow is considered to be little less than 200 MW in the reverse direction/ Hokkaido direction, Activated AFC is less than the margin of 725 MW in the reverse direction/Hokkaido direction.

Fig. 4-45 Simulation results of Case [2]-1-a1



Simulation Results	
Results	O*
Lowest frequency point (Hz)	*1 46.65
UFR operation (MW)	1835.7
Remaining UFR (MW)	48.8
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	680.0
Hokkaido-Honshu current flow final value (MW)	357.0
Hokkaido-Honshu current final reserved capacity (MW)	498.0

*1 Though it is below 47Hz, the situation does not lead to a blackout as there was no UFR load shedding at the power plant (47 Hz-10 seconds)

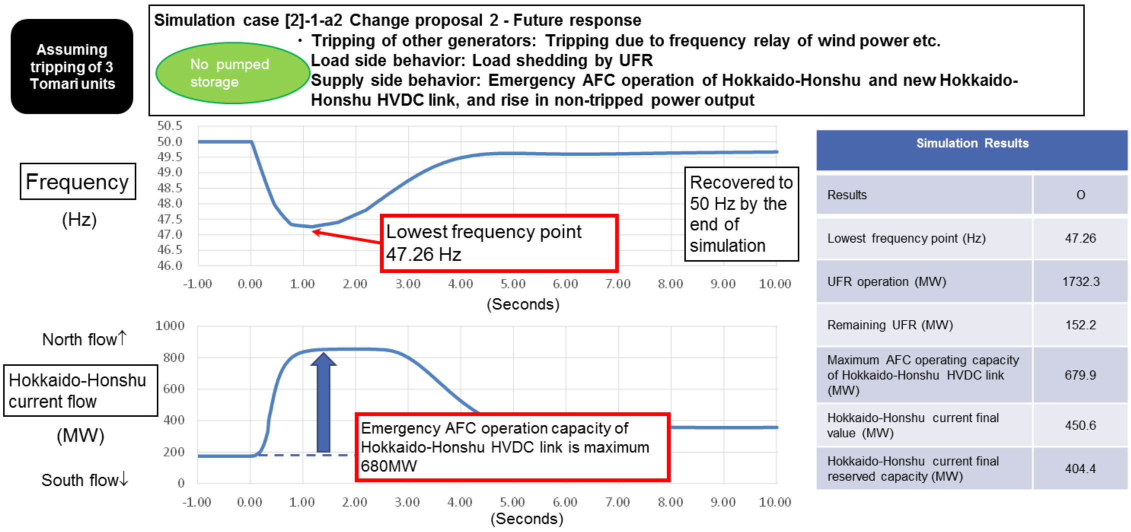
- Case [2]-1-a2: Case after all UFR facilities are updated with df/dt function (Refer to Fig. 4-46)

After simultaneous tripping of 3 Units of the Tomari Power Plant, on the one hand tripping occurs due to wind power UFR, and the frequency drop is controlled by load shedding through the emergency UFR, and AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power. The lowest point of the frequency is 47.26 Hz, which exceeds 47.0 Hz.

The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation is 450.6MW, and the adjusted reserve capacity of 404.4MW is secured against the transmission capacity of 855 MW.

Note that the emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 680 MW. If the initial current flow is considered to be little less than 200 MW in the reverse direction/ Hokkaido direction, Activated AFC is less than 725 MW of margin in the reverse direction/Hokkaido direction.

Fig. 4-46 Simulation results of Case [2]-1-a2



Simulation Results	
Results	O
Lowest frequency point (Hz)	47.26
UFR operation (MW)	1732.3
Remaining UFR (MW)	152.2
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	679.9
Hokkaido-Honshu current final value (MW)	450.6
Hokkaido-Honshu current final reserved capacity (MW)	404.4

In the Case where extended measures are applied to the frequency fluctuations rate element of UFR, after simultaneous tripping of 3 Units of the Tomari Power Plant, on the one hand tripping occurs due to wind power UFR, and the frequency drop is controlled by load shedding through the emergency UFR, and AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, and output increase from generators simulated not to trip such as hydro power. The lowest point of frequency was either higher than 47.0Hz or lower than 47.0Hz, yet it recovered to about 50Hz, and we confirmed that the situation does not lead to blackout.

The final current flow of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation was constantly below the equipment capacity of 855 MW, and we confirmed that frequency adjusted reserve capacity is secured for in demand fluctuations.

If the initial current flow is considered to be little less than 200 MW in the reverse direction/ Hokkaido direction, we confirmed that the maximum emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is below 725 MW, which is the margin in the reverse direction/ Hokkaido direction.

2. Measures through stabilization device to activate high-speed load shedding

Unlike the dispersed and distributed UFR, we examined the effectiveness of measures taken through a stabilization device that controls load shedding by pre-calculating the optimal control conditions to maintain demand-supply balance by using online data etc., or that controls load shedding based on detecting the accident and then carrying out post-calculation for an assumed accident like tripping of the largest site through main control (Refer to Fig. 4-47).

A simple simulation was carried out using the stabilization device for Case [2]-1 in which there is high possibility of a blackout if no additional measures are taken.

Note that if Hokkaido Electric Power Company decides to actually use the stabilization device, a separate and a detailed study will be necessary. However, here, we have assumed a stabilization device which uses online data to pre-calculate the optimal control conditions in order to maintain the demand-supply balance for an assumed accident like tripping of the largest site, and which controls load shedding based on the pre-calculation results when an accident is detected.

The calculation method of target control capacity has 2 patterns as given below:

Pattern 1:

Target control capacity= Capacity of tripped power supply - Grid constant (1% MW/Hz) x Demand in Hokkaido area x Allowable frequency deviation (Δ 3Hz)

= 2,070 - 0.01 x 3,123 x 3

= 1,976 MW

Pattern 2:

Target control capacity= Capacity of tripped power supply - Expected capacity of Hokkaido-Honshu HVDC Link

= 2,070 - 680

= 1,390 MW

Control time was assumed as 280ms.

The following two cases were implemented as described above:

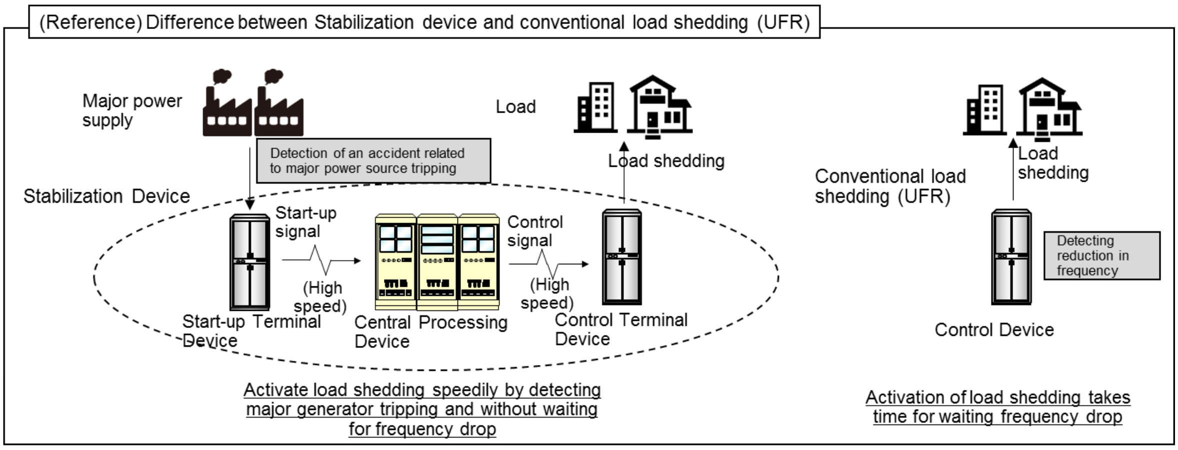
Case [2]-1-b1: Control capacity 1,976 MW

Case [2]-1-b2: Control capacity 1,390 MW

The simulation results showed that if a stabilization device is introduced to activate high-speed load shedding, the lowest point of frequency would be 48.65Hz, 48.52Hz, and in both cases, it exceeds 47.0Hz.

However, as in Case [2]-1-b1, for setting up the target control capacity, there is a possibility that coordination with emergency AFC of Hokkaido-Honshu HVDC Link cannot be achieved and the frequency might temporarily exceed 50Hz (overshoot) in the same capacity control considering the load characteristics of the grid, therefore, we believe that a detailed study is necessary at the time of introduction.

Fig. 4-47 Difference between stabilization device and conventional load shedding (UFR)



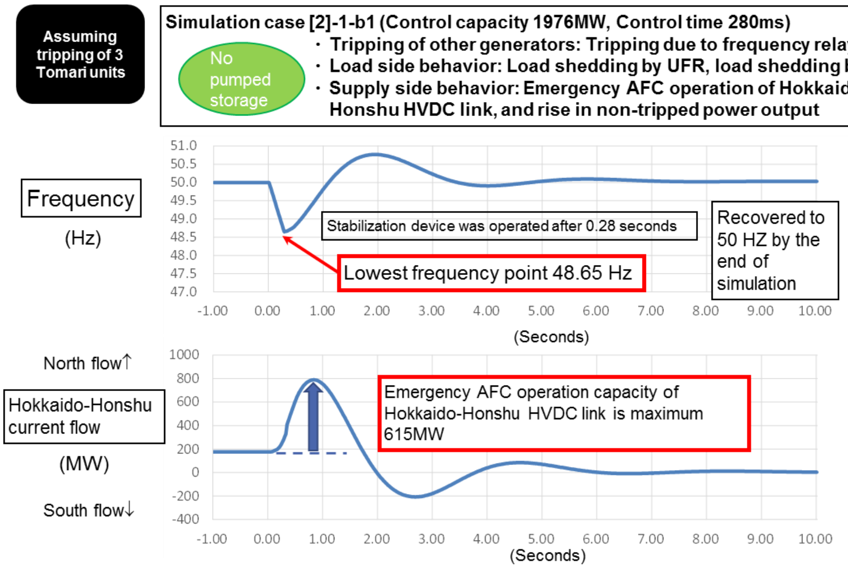
- Control capacity 1,976 MW, Control time 280ms: Case [2]-1-b1 (Refer to Fig. 4-48)

After simultaneous tripping of 3 Units of the Tomari Power Plant, on the one hand tripping occurs due to wind power UFR, and the frequency drop is controlled by load shedding through the emergency AFC and UFR operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, load shedding through the stabilization device (280ms), and output increase form generators simulated not to trip such as hydro power. The lowest point of frequency was 48.65Hz, and exceeded 47.0Hz.

The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation was 2.4 MW, and the adjusted reserve capacity of 852.6 MW is secured against the transmission capacity of 855 MW.

Note that emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 615 MW. If the initial current flow is considered to be little less than 200 MW in the reverse direction/ Hokkaido direction, Activated AFC is less than 725 MW of margin in the reverse direction/Hokkaido direction.

Fig. 4-48 Simulation results of Case [2]-1-b1



Simulation Results	
Results	O
Lowest frequency point (Hz)	48.65
Stabilization device operation (MW)	1976.0
UFR operation (MW)	187.5
Remaining UFR (MW)	1697.0
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	615.3
Hokkaido-Honshu current final value (MW)	2.4
Hokkaido-Honshu current final reserved capacity (MW)	852.6

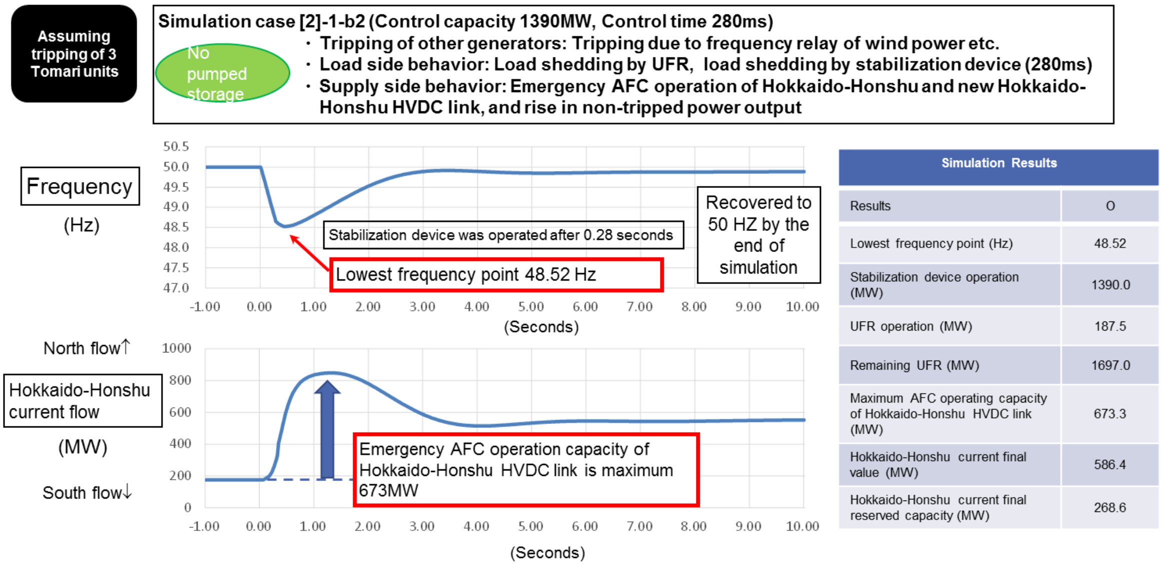
- Control capacity 1,390 MW, Control time 280ms: Case [2]-1-b2 (Refer to Fig. 4-49)

After simultaneous tripping of 3 Units of the Tomari Power Plant, on the one hand tripping occurs due to wind power UFR, and the frequency drop is controlled by load shedding through the emergency AFC and UFR operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, load shedding through the stabilization device (280ms), and output increase from generators simulated not to trip such as hydro power. The lowest point of frequency was 48.52Hz, and exceeded 47.0Hz.

The final current flow of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation was 586.4 MW, and the adjusted reserve capacity of 268.6 MW is secured against the transmission capacity of 855 MW.

Note that emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is maximum 673 MW. If the initial current flow is considered to be little less than 200 MW in the reverse direction/ Hokkaido direction, Activated AFC is less than the margin of 725 MW in the reverse direction/Hokkaido direction.

Fig. 4-49 Simulation results of Case[2]-1-b2



Simulation Results	
Results	O
Lowest frequency point (Hz)	48.52
Stabilization device operation (MW)	1390.0
UFR operation (MW)	187.5
Remaining UFR (MW)	1697.0
Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW)	673.3
Hokkaido-Honshu current final value (MW)	586.4
Hokkaido-Honshu current final reserved capacity (MW)	268.6

In the Case where measures are taken through the stabilization device to activate high-speed load shedding, after simultaneous tripping of 3 Units of the Tomari Power Plant, on the one hand tripping occurs due to wind power UFR, and the is drop controlled by load shedding through the UFR, and emergency AFC operations of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, load shedding through the stabilization device (280ms), and output increase from generators simulated not to trip such as hydro power. The lowest point of frequency was exceeded 47.0Hz, and recovered to about 50Hz. We confirmed that the situation does not lead to blackout.

The final current flow of the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link at the end of simulation was constantly below the transmission capacity of 855 MW, and we confirmed that frequency adjusted reserve capacity is secured for in demand fluctuations.

If the initial current flow is considered to be little less than 200 MW in the reverse direction/ Hokkaido direction, we confirmed that the maximum emergency AFC operation capacity of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link is below 725 MW, which is the margin in the reverse direction/ Hokkaido direction.

In the Case with measures related to utilization of the frequency fluctuations rate element (df/dt) of UFR, currently, though a blackout can be avoided as only about 10% of the whole UFR with the frequency fluctuations rate element (df/dt) is set, the lowest point of frequency is below 47.0Hz. If entire UFR is updated, the lowest point of frequency can be maintained at a level exceeding 47.0Hz.

In the Case where measures are taken using the stabilization device to activate high-speed load shedding, though a blackout can be avoided, for setting up the target control capacity, there is a possibility that coordination with emergency AFC of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link cannot be achieved and the frequency might temporarily exceed 50Hz (overshoot) in the same capacity control considering the load characteristics of the grid, therefore, we believe that a detailed study is necessary at the time of introduction (Refer to Fig. 4-50).

In light of the fact-finding by the Investigation Committee that the presumption that there was also an impact of increase demand due to voltage rise, was one of the events that occurred during the recent earthquake, and the fact that both, extended measures applied to the frequency fluctuations rate element of UFR and measures taken by using a stabilization device, can be accompanied by about 60~70% load shedding of the grid capacity (demand) for the entire Hokkaido area, and activate large-scale load shedding at once, we believe that it is necessary to consider the frequency drop due to demand increase.

We believe that, in future, at the time of examining detailed measures to activate load shedding, the Hokkaido Electric Power Company must consider the following points:

- Review the total approach to the places subject to load shedding while considering the impact of voltage rise and feasibility of forming an isolated grid when expanding the application of the frequency fluctuations rate element (df/dt)
- Incorporate the active power as well as reactive power information and control them simultaneously when measures are taken through a stabilization device

Moreover, we believe that at the time of introducing the stabilization device, it is necessary to examine the settings clearly specifying the segregation of control with UFR.

Fig. 4-50 Summary table of simulation results for measures utilizing the frequency fluctuations rate element (df/dt) and application of stabilization device in Case [2]-1

Unit: MW

Case No.		[2]-1-a1	[2]-1-a2	[2]-1-b1	[2]-1-b2
Recurrence prevention measures		UFR settings using df/dt		Stabilization device	
		UFR settings rate 20%	After the update of entire UFR	Load shedding 1980MW	Load shedding 1390MW
Simulation results	Results	O*	O	O	O
	Lowest frequency point (Hz)	*2 46.65	47.26	48.65	48.52
	UFR operation	1836	1732	188	188
	Remaining UFR	49	152	1697	1697
	Maximum AFC operating capacity of Hokkaido-Honshu HVDC link (MW) *1	680 (725)	680 (725)	615 (725)	673 (725)
	Hokkaido-Honshu current final value	357	451	2	586

***1 () margin (Tripping of largest single unit)**

***2 Though it is below 47Hz, the situation does not lead to a blackout as the duration is less than the UFR load shedding at the power plant (47 Hz-10 seconds)**

[2] Re-evaluation of the frequency control functions, such as governor-free systems, Automatic Frequency Control (AFC) function, and interconnection equipment margin in the Hokkaido area

As medium-to-long term operational measures in the Hokkaido area, we believe that it is necessary to examine the required measures after re-evaluating the frequency control functions, such as governor-free systems, Automatic Frequency Control (AFC) function, and interconnection equipment margin in the Hokkaido area.

As described in point (3) above, through simulation of the tripping of the largest power plant (largest site) in the most severe scenario throughout a year that can be assumed currently (if the Tomari Power Plant, which is currently under long-term shutdown, tripped after resuming operations), if the three Units of Tomari Power Plant trip simultaneously, in all the cases, assuming that necessary measures are taken to resolve certain reservations, in case of governor free systems, it was confirmed that 2% power is ensured by generators simulated not to trip after the tripping of the largest site. Regarding Automatic Frequency Control (AFC), it was confirmed that adjusted reserve capacity remains in the Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link in the final scenario at the end of the simulation.

Moreover, as described in (4)(a)[4] and according to the current way of thinking, the margin in the reverse direction/ Hokkaido direction of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link, assumes the tripping of the largest single Unit, and we believe that blackout is avoided by taking measures mentioned in (4)(b)[1].

Therefore, we believe that at present it is not necessary to review the governor-free system, Automatic Frequency Control (AFC) function, and the margin in the reverse direction/ Hokkaido direction of Hokkaido-Honshu HVDC Link and the new Hokkaido-Honshu HVDC Link in the Hokkaido area.

(5) Mid-to-Long-term measures for facility formation for the Hokkaido Area

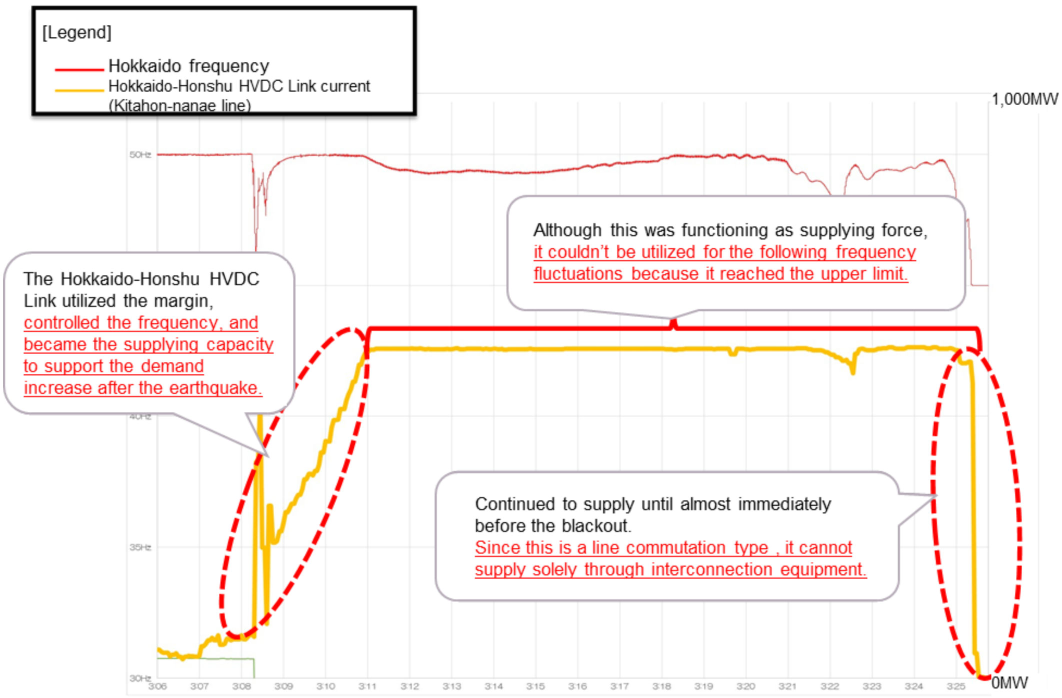
(a) Further reinforcement of the Hokkaido-Honshu HVDC Link etc.

Immediately after the occurrence of the recent earthquake, although the frequency dropped after Units 2 and 4 of the Tomato-atsuma Power Plant detected turbine vibrations and shutdown, we confirmed that the frequency did recover due to the emergency power transfer etc. from the Hokkaido-Honshu HVDC Link utilizing the transmission margin.

On the other hand, during this event, although the expected emergency power was transferred with the Hokkaido-Honshu HVDC Link when the demand rose and to the decrease in the supply capacity following the tripping of hydro power generation, the current flow remained at maximum after 3:11 on September 6, therefore, the originally provided function (AFC function) to adjust rapid demand fluctuations was lost.

Based on this event, as a result, it can be said that the ensured transmission margin capacity, fully utilizing the interconnection line performance, was inadequate (Refer to Fig. 4-51).

Fig.4-51 Frequency and Hokkaido-Honshu HVDC Link current flow from the occurrence of the earthquake to blackout



Moreover, the events from the second load shedding to blackout consist of the shutdown of other thermal power and hydro power plants to protect their own equipment due to the frequency drop, which in turn led to a complete loss of power supply within the Hokkaido area and we confirmed that due to this, the Hokkaido-Honshu HVDC Link which is of the line commutation type became unavailable.

In the Hokkaido area, as described above, the utility of the Hokkaido-Honshu HVDC Link having the AFC function is extremely high when there is a frequency drop due to power tripping and it can be expected to operate continuously even in times of a frequency drop if changed to a self-commutation type.

Moreover, based on the results of simulation, we believe that the possibility of avoiding this type of event is high if the new Hokkaido-Honshu HVDC Link starts its operation and presuming that the measures necessary to resolve certain reservations are taken.

On the other hand, as one of the points listed as a need for the developing of the new Hokkaido-Honshu HVDC Link, the existing Hokkaido-Honshu HVDC Link is configured at 300 MW x 2 (total 600 MW), it operates with only half, that is, 300 MW during times of equipment inspection. Moreover, when the equipment of the Hokkaido-Honshu HVDC Link is upgraded, there is also the possibility that the operations with 300 MW might be extended over a long period of time.

If the geographical features of Hokkaido, which is interconnected with the other areas only by direct current, are taken into account, it goes without saying that in order to prevent a blackout, further reinforcement of the Hokkaido-Honshu HVDC Link will be technically advantageous from the viewpoint of securing a stable supply.

Therefore, in order to facilitate a greater introduction of renewable energy and securing stable medium-to-long term supply/ balancing power in future for the Hokkaido area, as well as to prevent another blackout, we believe that we must not only develop the new Hokkaido-Honshu HVDC Link reliably, but also promptly investigate the feasibility of switching the existing Hokkaido-Honshu HVDC Link to a self-commutation type or further reinforcing the Hokkaido-Honshu HVDC Link after the new Hokkaido-Honshu HVDC Link is completed.

Specifically, the Government must promptly consider the cost allocation if further reinforcement of the Hokkaido-Honshu HVDC Link becomes necessary after the establishment of the new Hokkaido-Honshu HVDC Link. OCCTO must promptly undertake specific investigation of the feasibility of further reinforcing the Hokkaido-Honshu HVDC Link after the completion of the new Hokkaido-Honshu HVDC Link.

With regard to this, the Interim Summary of the Working Group on Electricity Resilience includes the study of further reinforcement of the Hokkaido-Honshu HVDC Link as one of the medium-term measures for which investigation must immediately start after compilation of the summary and specific conclusions be obtained by next spring.

Specifically, during the recent major blackout in Hokkaido, although the Hokkaido-Honshu HVDC Link functioned at a reasonable level after the earthquake till the point of blackout, the blackout could not be prevented, and in view of the fact that the power supply structure of Hokkaido largely consists of aged thermal power plants etc., and also considering the recommendations in the Interim Report of the Investigation Committee, it is imperative that OCCTO promptly undertakes a study regarding the further reinforcement of the Hokkaido-Honshu HVDC Link after the completion of the new Hokkaido-Honshu HVDC Link (after the total interconnection capacity is reinforced from 600 MW to 900 MW), and the feasibility of switching the existing Hokkaido-Honshu HVDC Link to a self-commutation type in order to facilitate a greater introduction of renewable energy and securing of stable medium-to-long term supply/ balancing power in future for the Hokkaido area, as well as to reduce the risk of recurrence of blackout in Hokkaido in the medium-to-long term period. As regards the further reinforcement of the Hokkaido-Honshu HVDC Link after the completion of the new Hokkaido-Honshu HVDC Link (after the total interconnection capacity is reinforced from 600 MW to 900 MW), after the effect of reinforcement is confirmed through simulation, the goals, including the routes and the scale of reinforcement, shall be achieved until next spring.

In view of this, in December 2018, at OCCTO, while deliberating upon the concept of making renewable energy sources the main source of energy by a subcommittee of experts under the supervision of the "“Cross-regional Network Development Committee” studying the methods of establishing grids in a wide area and the “Study Committee on Regulating and Marginal Supply Capability and Long-Term Supply-Demand Balance Evaluation” studying the methods of balancing power etc., it is expected that a new subcommittee concerning electricity resilience will be set up to study the electricity resilience in a cross-sectional and intensive manner.

It goes without saying that in order to prevent a blackout, further reinforcement of the Hokkaido-Honshu HVDC Link will be technically advantageous from the viewpoint of securing a stable supply, according to Government policy (Government’s response policy consolidated at the cabinet meeting on emergency inspection of important infrastructure, Interim Summary of the Working Group on Electricity Resilience), the Government and OCCTO shall conduct simulations to confirm the effectiveness of further reinforcing the existing interconnection link after the completion of the new Hokkaido-Honshu HVDC Link (after total interconnection capacity is reinforced from 600 MW to 900 MW), and the feasibility of switching the existing Hokkaido-Honshu HVDC Link to self-commutation type, and then work towards achieving the goals, including the routes and the scale of reinforcement, until next spring.

(b) Measures concerning the power generation equipment and power transmission equipment

During the earthquake, due to the damage to the boiler tubes of Tomato-atsuma Power Plant Unit 1 (rated output 350 MW), the output of that generator started to fall from 3:20 on September 6 and shutdown at 3:25.

Moreover, at 3:08 on September 6, due to the transmission accident on the Karikachi trunk line, the Shintoku-oiwake line, and the Hidaka trunk line (N-4), there was a power outage in the eastern Hokkaido and the Kitami areas, and the 370 MW hydro power generator shut down. The cause behind this is believed to be a ground fault which may have occurred due to the contact of the jumper wire with the line hardware.

As regards the safety of the power generation equipment or the power transmission equipment, the inspection of these equipment does not fall under the scope of the Investigation Committee, but mainly since the shutdown (N-3) of Units 1, 2 and 4 of the Tomato-atsuma Power Plant and the transmission accidents (N-4) on the Karikachi and 2 other transmission lines led to the shutdown of hydro power which in turn led to the loss of the frequency control function (mainly AFC), which became the compounding factor for the occurrence of the blackout, it is necessary that the Hokkaido Electric Power Company carries out a study of medium-to-long term measures based on comprehensive inspections including compliance with relevant regulations in order to prevent a recurrence of a blackout.

In this regard, according to the Interim Summary of the Working Group on Electricity Resilience, it was stated that as a result of investigation of N-4 transmission line accident, based on the fact that an N-4 accident occurred in a 275kV or lower voltage domain in the Hokkaido area, the Investigation Committee and the Second Working Group on Electricity Resilience assessed in their investigations and discussions that the Hokkaido Electric Power Company must examine proper recurrence prevention measures in the dense zone of transmission lines near important substations and that the situation will "not lead to a blackout" if necessary measures, including measures for the transmission lines adjoining important substations in the area, are taken.

Moreover, according to the Interim Summary of the Working Group on Electricity Resilience, it was stated that in case of equipment failure at the Tomato-atsuma Power Plant, specifically, the boiler tube damage at Units 1 and 2 and the fire in the vicinity of the turbine bearing at Unit 4 of the Tomato-atsuma Power Plant, considering that the tremors from the recent earthquake exceeded the usual earthquake tremors (intensity of about 5), it should be possible to evaluate whether there are any inappropriate points by comparing with the rules based on the standard "Comprehensively ensure the functioning of the system by means of ensuring substitution and multiplexing etc. such that there is no significant supply failure".

Although the N-4 transmission accidents are not within the scope of inspection of the Investigation Committee, we believe that the Hokkaido Electric Power Company must examine proper recurrence prevention measures in the dense zone of transmission lines near important sub-stations.

As one of the "Emergency Measures" to be undertaken immediately after the compilation of the summary, the Interim Summary of the Working Group on Electricity Resilience states recurrence prevention measures (including the measures mentioned above) for major blackout in Hokkaido as proposed in the Interim Report of the Investigation Committee.

Moreover, the following evaluations have been made in the Interim Summary of the Working Group on Electricity Resilience:

- There was boiler tube damage and fire in the vicinity of the turbine bearing at the Tomato-atsuma Power Plant due to the excessive stress etc. caused by the earthquake tremors. As strong seismic motion (intensity 6 lower) which exceeded the usual seismic motion is being witnessed at the Tomato-atsuma Power Plant, with regard to the aforesaid approach, it cannot be said that there was any problem with seismic resistance of these equipment. Further, as described later, the Tomato-atsuma Power Plant has been designed in accordance with the aseismic design regulations (Japan Electric Association (JEA) Standard JEAC3605. The same shall apply hereinafter) or the Building Standards Act for thermal power plants, hence, it is believed that it possesses the essential seismic resistance.
- In case of the equipment failure at the Tomato-atsuma Power Plant, specifically, the boiler tube damage at Units 1 and 2 and the fire in the vicinity of the turbine bearing at Unit 4 of the Tomato-atsuma Power Plant, considering that the tremors from the recent earthquake exceeded the usual earthquake tremors (intensity of about 5), we could assess that there were no inappropriate points by comparing with the rules based on the standard "Comprehensively ensure the functioning of the system by means of ensuring substitution and multiplexing etc. such that there is no significant supply failure".
- Based on the fact that an N-4 accident occurred in a 275kV or lower voltage domain, the Investigation Committee and the Second Working Group on Electricity Resilience assessed in their investigations and discussions that the Hokkaido Electric Power Company must examine proper recurrence prevention measures in the dense zone of transmission lines near important sub-stations and that the situation will "not lead to a blackout" if necessary measures, including measures for the transmission lines adjoining important substations in the area, are taken.

3. Countermeasures based on the problems involved in the sequence of events from the blackout to securing a certain supply capacity (Measures to shorten the restoration period after a blackout)

The Investigation Committee believes that the Hokkaido Electric Power Company must take the following measures based on the recent events as described in Chapter 3.

The creation of procedure manuals and drills etc. assuming a blackout was carried out reliably and even in the case of the recent accident restoration, it was done more or less in accordance with the procedures, but we believe that the restoration of power supply, although it was shortened by several hours, could have been done much earlier, had it been possible to avoid the first black start failure or the delay in the reception of power from the Hokkaido-Honshu HVDC Link etc.

It is believed that the time required for restoration from blackout in a real grid, which has never been experienced so far, was reasonable. However, improvements in the procedure manual and drill based on this event is desirable in order to shorten the restoration period. Moreover, it is expected that with the commercial operations of the new Hokkaido-Honshu HVDC Link, the restoration procedures will also be reviewed, hence it can contribute to the shortening of the time required for restoration.

We believe that the following measures or study based on the recent events as described in Chapter 3 are necessary for the Hokkaido Electric Power Company (Refer to Fig.4-52).

Fig.4-52 Items for which measures and study are necessary

[1] Review of restoration procedures for which the problems revealed during the recent inspections serve as lessons learned
[2] Improvement of drills or training for black start
[3] Assignment of the black start function using the new Hokkaido-Honshu HVDC Link and creation of a procedure manual at the same
[4] Equipment measures necessary for reinforcing the black start function

In the Interim Summary of the Working Group on Electricity Resilience, recurrence prevention measures (including above mentioned measures) related to major blackout in Hokkaido, suggested in the interim report of the Investigation Committee, were listed as one of the “emergency measures” to be undertaken immediately after the summary is compiled, and as one of the “medium-term measures”, for which investigation must start immediately after the summary is compiled and specific conclusions be obtained by next spring, the

Interim Summary lists sharing of know-how about restoration work.

Specifically, Interim Summary states that in order to share the know-how about restoration work, including black start, a study should be conducted regarding the creation or improvement of the manuals etc.

In response to the black start measures proposed in the Interim Report of the Investigation Committee, the Hokkaido Electric Power Company by setting up a domestic Investigation Committee namely, the Investigation Committee on Hokkaido Eastern Iburi Earthquake, has started a sequential study or execution of all the measures such as for instance, the review of restoration procedures scheduled for completion in the current month assuming damage/ failure at the power plants, substations, or the Load Dispatching Center to shorten the restoration period with a view to review those restoration procedures for which problems revealed during the recent inspections serve as lessons learned, and also, as equipment measures necessary for the reinforcement of the black start function, such as the starting of a study in the previous month scheduled to be completed in the first half of FY 2019 regarding the measures for the event of generation of a heavy electrical current at the time of power transmission to the Tomari power plant Unit 3 main transformer etc. (Refer to Fig. 4-53).

Fig. 4-53 Status of initiatives taken by the Hokkaido Electric Power Company for the black start measures proposed in the Interim Report of the Investigation Committee (Source: Final Report of the Investigation Committee for the Hokkaido Eastern Iburi Earthquake (Draft) (Summarized version))

2-5 Approach for the black start measures

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Action plan		Schedule				
		FY 2018				FY 2019
Measures	Approach	Dec.	Jan.	Feb.	Mar.	
Review of the restoration procedure learned from the issues that have come to light within this investigation	Toward shorter restoration period, we will immediately review the restoration procedure assuming damage and failure of power plants, substations, and Load Dispatching Center etc.	To be completed				
Enhancement of black start drills and trainings	Based on the procedure reviewed, we will plan and periodically carry out drills at the Load Dispatching Center and each grid control station so as to utilize this experience.	Started (Nov.2018)		To be implemented		Implementation periodically scheduled (once a year)
	In order to strengthen collaboration at black start, drills will be planned and periodically carried out between the Load Dispatching Center and each grid control station and periodically carried out.	Started (Nov.2018)			To be implemented	Implementation periodically scheduled (once a year)
Installing black start function using the new Hokkaido-Honshu HVDC Link and preparing a manual for the procedure	Utilizing the black start function of the new Hokkaido-Honshu HVDC Link, we will review the procedure and develop them as company rule for shortening the restoration period, such as concurrent execution of the black start by Niikappu and Takami power plant and the black start by the new Hokkaido-Honshu HVDC Link.	Started (Nov.2018)			To be completed	
Investment in equipment to enhance the black start function	For the auxiary power supply failure of Niikappu Power Plant, we will take countermeasures for early recovery from failure.	Started (Nov.2018)			To be completed	
	Against the inrush current to the main transformer of Unit 3 of Tomari Power Plant, we will consider necessary countermeasures in the future and will implement them.	Started (Nov.2018)				To be completed (first half)

Conclusion

For about three months, the Investigation Committee intensively studied the series of events concerning the major blackout that followed the 2018 Hokkaido Eastern Iburi Earthquake. The results of investigation are as described in the Interim Report and the Final Report and various facts were investigated through this investigation as well as the investigation which was carried out by the Government on the basis of the Interim Report.

On the basis of these facts, the Investigation Committee added some considerations and based on these, the blackout recurrence prevention measures were divided into three parts, namely, the short-term operational measures for winter 2018/19, the medium-to-long term operational measures, and the medium-to-long term equipment measures, and recommended them to the Government in the form of the Interim Report and the Final Report.

As already stated in this report, the event occurred mainly due to the simultaneous tripping (N-3) of the entire power supply of the same power plant and the transmission accident (N-4) of the main transmission lines (followed by the shutdown of hydro power which led to the loss of the frequency control function (mainly AFC function)), which became a compounding factor, and this caused the blackout.

According to the current facility formation rules, certain power outages are acceptable for risks with rare occurrence with respect to N-2 (failure associated with the loss of power equipment simultaneously at two places) or higher breakdowns and even internationally, for N-2 and higher events, cascading outage during operation are to be prevented as a rule although there are some differences in the approach to N-1 events (single failure of power equipment) (In other words, although power outages are acceptable, blackout must be avoided to the extent possible through operations).

Moreover, assuming all the events which may occur with power equipment accompanying such a major earthquake and requesting the generation or transmission side to take measures for all of these when there are more reasonable measures available on the demand side, may unnecessarily increase the redundancy and result in lower social benefits, and hence this is not reasonable.

Therefore, we did not find any inappropriate points in the facility formation of the Hokkaido Electric Power Company in the context of the current facility formation rules, and also after the investigation of the operations of the Hokkaido Electric Power Company, it cannot be said that the measures, including the operational measures assumed in advance, were necessarily inappropriate.

However, considering the social impact that these events bring, it is necessary to study and execute the operational measures to reduce the risk of power outages occurrence and the occurrence time in order to avoid blackouts in future to the extent possible.

As for the operational measures, we believe that initially it is necessary to take short-term measures for winter 2018/19 and then take the medium-to-long term measures.

Moreover, since it may be difficult to resolve the issue with the operational measures alone, the equipment measures must be studied simultaneously with the operational measures, and must be implemented as necessary after ascertaining the verification results of the operational measures.

Note that although the Investigation Committee mainly performs technical investigation, it has also proposed an Interim Report and Final Report regarding the matters which need to be studied again, but in particular, considering the risk with rare occurrence, that of simultaneous failure of all generators of the largest power plant in the Hokkaido area, it is desirable to implement the medium-to-long term operational and equipment measures from a technical viewpoint in order to avoid a blackout to the extent possible, but hereafter, the we believe that the Government must carry out a study and investigation from a comprehensive viewpoint including the economic efficiency.

The study and investigation from this viewpoint shall be carried out by the Government, specifically by the Working Group on Electricity Resilience and the Cabinet Meeting on emergency inspection of important infrastructure, on the basis of the Interim Report, and the Interim Summary of the Working Group on Electricity Resilience has requested that operations be thoroughly carried out winter 2018/19 on the basis of the Interim Report of the Investigation Committee as well as to begin the study immediately after the Interim Summary of the Working Group on Electricity Resilience is compiled. The Interim Summary has also consolidated the “medium-term measures” to prevent blackouts to the maximum possible extent as well as to minimize the damages or risks in the event of a blackout. At present, with reference to the "medium-term measures", the Government and OCCTO are moving to a stage where investigations will be carried out to obtain certain conclusions by next spring.

We strongly recommend that the contents of the Final Report which include the medium-to-long term measures proposed in the Final Report of the Investigation Committee, be incorporated appropriately in the study that will be carried out by the Government and OCCTO on the "medium-term measures" to obtain certain conclusions by next spring.

Additionally, we believe that the Government and OCCTO must focus on the following three points when studying these operational and equipment measures:

[1] It is an undeniable reality that this is the first time that a blackout has occurred in our country and in future also, there is a possibility of the occurrence of a blackout, so it is

necessary to conduct a fresh study.

[2]As for the various systems and measures, they have been established and set under various restrictions such as economic constraints, social constraints, historical constraints, regional constraints etc. in addition to the technical constraints. For example, even to take measures for technically feasible matters, it is necessary to comprehensively study the cost and the method of handling the responsibility etc.

[3] Measures should be considered from a medium-to-long term perspective and not just from a short-term perspective. For example, measures should be based on the progress of the power system reforms and needless to say that greater introduction of renewable energy is going to require time and cost, hence it is necessary to examine optimum measures for the overall power system from the medium-to-long term perspective.

Moreover, as mentioned above, the Investigation Committee intensively conducted investigation of a series of events concerning the major blackout associated with the 2018 Hokkaido Eastern Iburi Earthquake for about three months, but such investigation methods must be specified as emergency methods when there is an actual blackout.

As stated in Chapter 4.2(4), due to the major changes in the power supply composition and supply-demand balance in the Hokkaido area, it is needless to say that the medium-to-long term operational measures for the Hokkaido area, proposed in the Final Report of the Investigation Committee, should be reviewed in a timely and appropriate manner. Not only the Government and OCCTO, but Hokkaido Electric Power Company must also publish the necessary information, such as the review contents, their necessity, and the basis, including the data, in advance, and regardless of before or after review, must enable its external verification, after which they must review the following medium-to-long term operational measures in a timely and appropriate manner.

Therefore, especially, with reference to the case of the currently under long-term shutdown Tomari Power Plant, tripping after resuming operation, we believe that whenever the prospect of resuming operations at the Tomari Power Plant is actually reached, it is necessary and mandatory to carry out simulation again, to examine the essential measures, and to take the required measures.

Further, in addition to the conventional supply and demand verification processes, a process of regularly verifying the risk of blackout in a more accurate manner based on the method of comprehensive inspection of power infrastructure has been listed as one of the "medium-term measures", but while paying attention to the above mentioned points it is necessary to develop a sustainable and effective process so that it does not end up as investigation for the sake of investigation or confirmation for the sake of confirmation.

Finally, in order to prevent the recurrence of blackout and for a quick restoration from blackout, the concerned organizations such as the transmission system operators, the Government, and OCCTO must not merely stop at investigating the necessary measures, but it is strongly expected that the latest experiences and obtained findings or measures etc. are executed as early as possible, in other words, actual measures must be utilized as early as possible.

As mentioned above, through the investigation conducted by the Investigation Committee, the problems and lessons learned from the blackout and black start that occurred for the first time in Japan will, in future, be extremely valuable for improving the blackout recurrence prevention measures and the black start measures not only for the Hokkaido area alone, but also for areas other than Hokkaido. Therefore, it is believed that the latest experiences, obtained findings or measures etc. should be shared nationwide and in each area and wider areas, a feasibility study for the review of existing blackout recurrence prevention measures and black start measures should be carried out, and along with that it is necessary to enhance the training in order to improve the effectiveness of these measures.

In addition, regarding the measures obtained as a result of the investigations done by the Investigation Committee, it might not be possible to carry out these measures as they are since there is a difference in the characteristics of each area, but on the basis of the main points of considerations and recommendations in the Interim Report and the Final Report, we believe that these measures must be expanded in areas other than the Hokkaido area or across Japan.