Offsite Power Supply Security at Nuclear Power Stations and Reprocessing Plants

May 16th, 2011

The Tokyo Electric Power Company, Incorporated

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1. Preface

Due to the Tohoku-Chihou-Taiheiyou-Oki Earthquake which occurred on March 11th 2011, TEPCO's facilities including our nuclear power stations were severely damaged. We deeply apologize for the anxiety and inconvenience caused. We are currently making our utmost effort with the close coordination and corporation of relevant organizations such as the national government, local municipalities and Electric Utility operators including TEPCO to bring the situation under control.

Meanwhile, due to the Miyagiken-Oki Earthquake which occurred on April 7th 2011, the electric power system supplying the entire northern Tohoku area was knocked out starting from the ground fault at a major Tohoku Electric Power Company substation. This also led to the cut off of offsite power supply systems to nuclear facilities.

In light of the lessons learned from this incident that cast a cloud of uncertainty over the reliability of the power systems, this report covers the implementation status of the countermeasures regarding offsite power supply security based on the directive on "Offsite power supply security of nuclear power stations and reprocessing plants" from the Minister of Ministry of Economic Trade and Industry on April 15, 2011.

1.1 Requirements based on the order from the Minister of Ministry of Economy, Trade and Industry

Deal with and report the implementation status of the following;

[Concrete requirements]

1. In light of the fact that power outages due to earthquakes etc. could affect the offsite power supply to nuclear power stations etc., the analysis and evaluation of the reliability of power supply of your company's power systems which could affect power supply to nuclear power stations etc, and the consideration of measures to further improve the reliability of power supply to such nuclear power stations (including enforcement of on site power in nuclear power stations etc.) is required. As for the processing facilities, consideration towards improving equipment within such facilities which corresponds to the measures above pertaining to the reliability of power systems which supplies power to such facilities is required.

2. In order to improve the reliability of power supply to each unit in your nuclear power stations, connect all the transmission lines which are connected to multiple power lines to each unit to enable power supply.
3. Concerning the power line towers of your nuclear power stations, evaluate seismic adequacy, the stability of the foundation against earthquakes and depending on the results execute necessary countermeasures such as reinforcement work.
4. Concerning electrical facilities such as the switchyards of your nuclear power stations etc., consider countermeasures such as installing them indoors and making them watertight to ward off any impact to the tsunami.

1.2 Intended Nuclear Power Stations and Reprocessing Plants

In addition to the Kashiwazaki Kariwa Nuclear Power station, this report dealt with the countermeasures regarding the Tokai Daini Nuclear Power Station of the Japan Atomic Power Company and Nuclear Fuel Cycle Engineering Laboratories (Tokai Reprocessing Facility) of the Japan Atomic Energy Agency.

However, regarding the Tokai Daini Nuclear Power Station and the Nuclear Fuel Cycle Engineering Laboratories, we dealt with just Order1 and Order3 since each Operator deals with Order2 and Order4.

2. Analysis and Evaluation of offsite power supply security (Order 1)

2.1 Procedure for Evaluation

Under the current policy of establishing facilities, we basically make up the off site power supply system including the power transmission lines of nuclear power stations in light of the following;

(1) We accept a“N-2 fault (a fault that loses two pieces of equipment simultaneously)”, since such an accident is a rare occurrence. However, we will consider taking countermeasures if the outage scale is wide and the social impact is a concern.
(Excerpt from “The Rules of Electric Power System Council of Japan”)

(2) Offsite Power Supply is designed to have connections to the Electric Power System with more than one transmission line.
(Excerpt from “The Guide for Safety Design Review of Water-Cooled Type Power Generating Nuclear Reactor Facilities”, stipulated as the same in “The Guide for Safety Review of Reprocessing Facility”)

In light of the lessons learned from the incident that some of the nuclear facilities lost power supply at the time of the Miyagiken-Oki Earthquake, we have decided to evaluate the reliability of the offsite power supply at nuclear power stations etc. in consideration of the following (3),(4) in addition to the (1),(2) above;

(3) In case an“N-2 fault” occurs, the reliability of offsite power is secured.
That is to say, the loss of offsite power supply doesn’t accompany the fault or offsite power supply is immediately restored even when we are forced to implement the emergency measure with on site power supply at the nuclear power stations.

(4) We will evaluate more severe accidents to take account of the reliability of offsite power supply further and consider countermeasures as necessary.

Furthermore, the following case was chosen for evaluation. The Ground fault accident in the major substation occurred in the Tohoku area at the time of Miyagiken-Oki Earthquake is a fault of one class voltage in one substation. Hence, that is ranked as the (2)[severe case]. However, in this report, we have evaluated the (1)[super severe case] that exceeds the (2)[severe case].

[Evaluation case]

(1) Super severe case:

One substation (including switch station) entirely lose power

(2) Severe case:

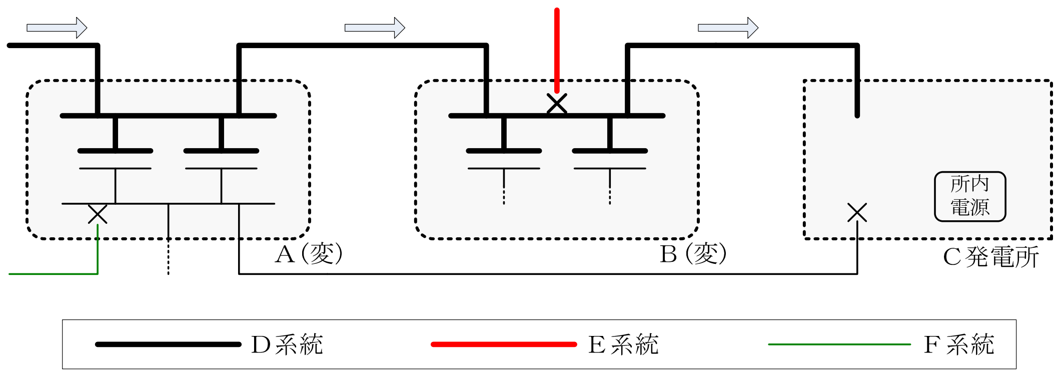
Bus line of one voltage class in one substation lose power

(3) Other:

Other than (1)(2)(including the“N-2” fault)

(Reference) Evaluation image ((2)[severe case])

<Normal power system>



（変）：substation

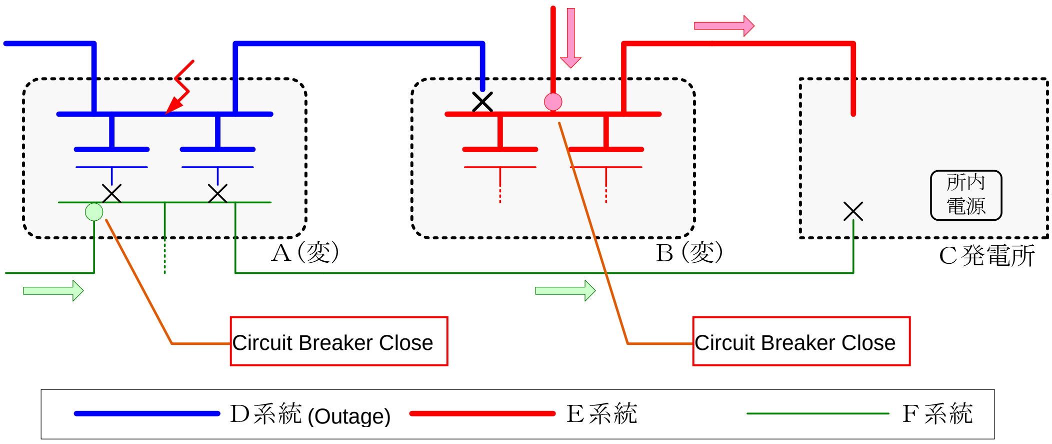
発電所：power station

所内電源: on site power

系統：power system

- Power station C receives off site power from power system D under normal operations.

<Bus fault in upper level voltage of Substation A occur (transmission line and transformer outage) >



-Immediately after the fault power station C loses offsite power temporarily (manage by on site power).

-And then, the offsite power of power station C is restored quickly from power system E by switching the power system. (Further, it could be supplied by power system F)

2.2 Evaluation Results (Trunk Transmission System)

First, we evaluated our trunk transmission system.

Specifically, we evaluated the supply reliability of the electrical power system in the case of (1) regarding all 500kV substations except those covered in 2.3~2.5. This evaluation encompasses the evaluation of case (1) to case (3) regarding all substations and transmission lines of 500kV or lower voltage levels.

As a result of the evaluation, we conclude that the supply reliability of the electrical power system for case (1) regarding the above 500kV substations is sufficient. In our trunk transmission system, we form a multiple-route/grid power system that consists of double or triple transmission routes which encircle Tokyo, a high demand area, from east to west and multiple transmission routes which run through north to south mutually interconnected. The conclusion above is obtained through the enhancement of the supply reliability by the loop operation of this trunk transmission system.

2.3 Evaluation Results (Kashiwazaki Kariwa Nuclear Power Station)

We evaluated the transmission facilities installed on the supply route from a 500kV substation as a starting point to Kashiwazaki Kariwa Nuclear Power Station.

As a result of the evaluation, we conclude that the supply reliability of the electrical power system through case (1) to case (3) is sufficient due to no loss of offsite power*.

*Some cases require the implementation of the switching operation (within 30 minutes) at Kashiwazaki Kariwa Nuclear Power Station to receive power from intact lines. Even if by any chance all AC power including on site power is lost during the switching operation, control power for the Reactor Core Isolation Cooling System (RCIC) is designed to continue 8 hours.

The power supply lines of Kashiwazaki Kariwa Nuclear Power Station consists of four 500kV transmission lines of two routes and one 154kV transmission line from the electrical power system of Tohoku Electric Power Company. The evaluation result above is due to the availability of offsite power from two independent power systems.

2.4 Evaluation Results (Tokai Daini Nuclear Power Station)

We evaluated the transmission facilities installed on the supply route from a 500kV substation as the starting point to Tokai Daini Nuclear Power Station.

As a result of the evaluation, we conclude that the supply reliability of electrical power system is sufficient, because although offsite power is temporarily lost, which requires temporary handling by onsite power, offsite power is restored* immediately by switching the power system.

*Even If by any chance all AC power including on site power is lost, the control power for the Reactor Core Isolation Cooling System (RCIC) is designed to continue 8 hours. Offsite power is restored quickly enough compared to this duration (for maximum case, approximately 80 minutes for switching the power system plus 30 minutes for the power receiving operation at Tokai Daini Nuclear Power station).

The power supply lines of Tokai Daini Nuclear Power Station consist of two 275kV transmission lines of one route and one 154kV transmission line. The above evaluation result is due to the availability of offsite power by the switching operation as a result of securing two independent transmission routes as a power supply line.

2.5 Evaluation Results (Nuclear Fuel Cycle Engineering Laboratories)

We evaluated the transmission facilities installed on the supply route from a 500kV substation as a starting point to the Nuclear Fuel Cycle Engineering Laboratories.

As a result of the evaluation, we conclude that the supply reliability of the electrical power system is sufficient, because although offsite power is temporarily lost except in some cases which requires temporary handling by onsite power, offsite power is restored* immediately by switching the power system and multiple transmission routes are available in the most severe case furthermore

*There is a reprocessing plant for spent fuels which is used for research, development and operations at Nuclear Fuel Cycle Engineering Laboratories. If by any chance all AC power including on site power is lost, decay heat removal functions etc, are planned to be restored based on emergency safety measures. However, the high radioactive waste solution and plutonium solution which require AC power for necessary cooling, takes over 30 hours to reach the boiling state. Offsite power is restored quickly enough compared to this (for max case, approximately 12 hours to connect 6kV power line).

The power supply lines of Nuclear Fuel Cycle Engineering Laboratories consist of two 154kV transmission lines of one route. The above evaluation result is due to the availability of offsite power by switching operations including switchovers to 6kV power systems, since the necessary amount of electric power for cooling is minor at Nuclear Fuel Cycle Engineering Laboratories.

In this regard, however, in considering the specific restoration time or power supply lines consisting of two transmission lines of one route, we evaluate that building a new measure of enhancing the restoration of offsite power or cutting the restoration time has a certain meaning.

2.6 Evaluation Results (Summary of Evaluation Results)

From the evaluation results obtained through 2.2 to 2.5 above that indicate that the supply reliability of the electrical power system for every case is sufficient, we conclude that the reliability of our electrical power system for the intended facilities listed on 1.2 is sufficient based on the policy described in 2.1. Based on that acknowledgement, we evaluate that building a new measure of enhancing the restoration of offsite power or cutting restoration time has a certain meaning regarding the Nuclear Fuel Cycle Engineering Laboratories.

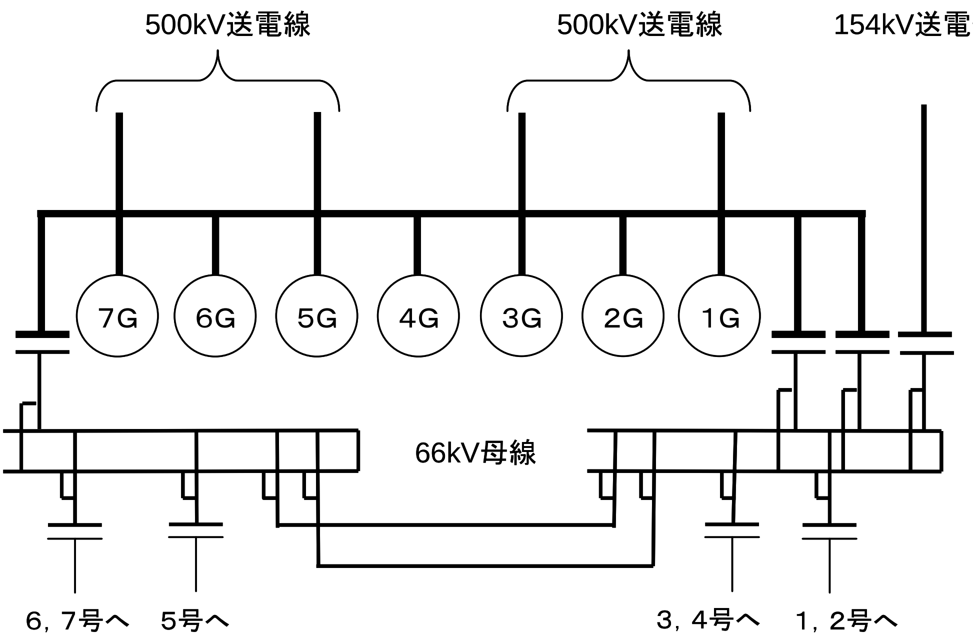
Therefore, regarding the Nuclear Fuel Cycle Engineering Laboratories, we will implement the task of building a new 66kV transmission route to further strengthen the reliability of offsite power and consider doing this in cooperation with the Laboratories.

In parallel, establishing an onsite facility in Laboratories for connecting the 6kV power line will be implemented by around September, 2011.

3. Connection of Power Line to each unit (Order 2)

3.1 Station Power Supply System at Kashiwazaki Kariwa Nuclear Power Station

Safety regulation requires the supply system of nuclear power stations to be connected to power systems with more than one transmission line. All the power supply systems of Units 1～7 at Kashiwazaki Kariwa NPS are connected to four 500kV transmission lines and one 154kV transmission line. Moreover, the power pool is available among all Units of NPS. Thus, we feel that additional countermeasures are not necessary.



送電線：Transmission line
66kV 母線：66kV bus line
号：Unit

【Schema of power supply system at Kashiwazaki Kariwa NPS】

4. Seismic Adequacy of Steel Tower for Offsite Power（Order 3）

4.1 Seismic Adequacy of Transmission Facilities

Based on the “Basic Disaster Prevention Plan” which was decided at the central disaster prevention council on July, 1995, the report of the “Electrical equipment disaster prevention study commission”, published on November 24th, 1995, shows a basic policy to secure the earthquake-proof performance of electrical equipment.

(1) Against general earthquake motion,

Serious obstacles shall not occur in each facility

(2) Against high level earthquake motion,

In order to prevent notable (long term and wide range) power outages, a comprehensive system function shall be maintained by securing alternative methods or multiplexing.

The report analyzed whether or not the earthquake motion and scale of damages of Hyogo-ken South Earthquake were within assumptions at the design stage, and also studied the validity of the current earthquake resistance standard based on empirical studies.

The results of the study confirmed that the current earthquake resistance standard was appropriate enough to stipulate the earthquake-proof performance of electrical equipment. Namely, the current earthquake resistance standard was considered valid; it had secured a necessary degree of earthquake-proof performance and the comprehensive system function was maintained against high level earthquake motion by securing alternative methods or multiplexing to prevent a notable (long term and wide range) power outage

In addition to the aforementioned evaluation, earthquake occurrences were evaluated for 7 transmission lines (510 steel towers) directly connected to the nuclear power station as offsite power in consideration of the damages of the Tohoku-Chihou-Taiheiyou-Oki Earthquake (hereafter “this earthquake”).

[Targeted transmission facilities for seismic adequacy]

Voltage	Line name	Number of steel towers
500kV	Shin-Niigata-Kansen	214
500kV	Minami-Niigata-Kansen	201
275kV	Tokai-Genshiryokusen	44
275kV	Genkennakasen	4
154kV	Genshiryokusen	8
154kV	Muramatusen	38
154kV	Muramatukitasen	1

4.2 Seismic Adequacy of Steel Towers

(1) Damage conditions caused by this earthquake and probable causes

[Damage Conditions]

・The number of collapsed towers was one including the offsite lines for the nuclear power station and other transmission lines.

・Many support insulator breakages installed on the transmission steel towers occurred. Transmission failures occurred in some lines due to insufficient insulation distances.

[Estimated Causes]

・ The tower collapse is currently estimated to have occurred due to the earth pressure caused by the fact that a large portion of the embankment collapsed and was shifted over to the steel tower site by the earthquake motion.

・ The support insulator breakage is estimated to have occurred due to the earthquake motion.

(2) Evaluation of Seismic Adequacy

[Steel Tower]

・ The earthquake motion did not directly cause the collapse of any tower belonging to Tohoku Electric Power Company and Tokyo Electric Power Company.

・ The number of steel tower collapses from past huge earthquakes (Hyogo-ken South Earthquake, Chuuetsu Earthquake) total three. All the damages were caused by the effect of nearby tower sites. (Hereafter “Secondary damage”) Earthquake motions did not cause any steel tower collapses.

- Thus, as the report (in 1995) mentioned, steel towers were estimated to be sufficiently earthquake-proof.
- However, one steel tower collapsed due to the collapse of a large portion of the embankment adjacent to the site. It is necessary to evaluate the stability of the foundation at the site

[Support Insulator]

- It is difficult to say whether or not seismic adequacy is secured, because many breakages were caused by earthquake motions.
- Thus, it is necessary to conduct countermeasures such as changes for newer ones exhibiting higher earthquake-proof qualities.
- The outage occurred due to the breakages of jumper support insulators using long rod insulators. Therefore, similar facilities were investigated concerning the offsite lines for the nuclear stations.
- We will study the countermeasures such as the replacement of long rod support insulators with suspension insulators or organic insulators.

[Targeted lines for evaluation and the number of similar facilities]

Targeted line name	The number of targeted towers	Period for measure
500kV Shin-Niigata-Kansen (The number of all towers: 214)	0	Temporary measure : ― Measure : ―
500kV Minami-Niigata-Kansen (The number of all towers:201)	0	Temporary measure : ― Measure : ―
275kV Tokai-Genshiryokusen (The number of all towers:44)	16	Temporary measure : ― Measure : 2011.5 ～ 2011.12
275kV Genkennakasen (The number of all towers:4)	0	Temporary measure : ― Measure : ―
154kV Genshiryokusen (The number of all towers:8)	0	Temporary measure : ― Measure : ―
154kV Muramatusen (The number of all towers:38)	1	Temporary measure : ― Measure : 2011.5 ～ 2011.12
154kV Muramatukitasen (The number of all towers:1)	0	Temporary measure : ― Measure : ―

[Schedule]

Items	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seismic design	■							
Performance test								
Manufacture		■	■	■	■	■	■	
Repair work								■

4.3 Foundation Stability

In general, transmission routes are selected from the viewpoint of avoiding landslide regions from the route selection stage in order to minimize the damage caused by the effect of a nearby site around steel towers due to earthquakes. Even in those cases where a transmission line is obliged to pass through landslide regions, we take countermeasures such as selecting a foundation after subjecting it to a detailed investigation and evaluation of its stability.

However, a tower collapse occurred due to secondary damage regarding this earthquake. In order to improve the reliability of transmission facilities, the foundation stability against the impact of sites around steel towers should be studied as evaluated in Section 4.2.

(1) Items for evaluation

Secondary damages are estimated to be caused by several factors such as landslides or mudflows on steep slopes as well as the collapse of embankments caused by this earthquake. Thus, the following three items have been evaluated.

[1] Collapse of the Embankment

Places having a large portion of an embankment near a transmission steel tower are selected for risk assessment.

[2] Landslides

Based on the information of landslide prevention regions, landslide hazard areas, and landslide geographical distribution diagrams, potential sites to cause landslides are selected for risk assessment.

[3] Mudflow on steep slope

Potential sites to cause mudflows on steep slopes are selected for risk assessment.

(2) Targeted Lines for Evaluation and the Number of Towers

Targeted Line Name	The number of targeted towers	Period of Evaluation ※
500kV Shin-Niigata-Kansen (The number of all towers: 214)	214	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～
500kV Minami-Niigata-Kansen (The number of all towers:201)	201	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～
275kV Tokai-Genshiryokusen (The number of all towers:44)	44	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～
275kV Genkennakasen (The number of all towers:4)	4	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～
154kV Genshiryokusen (The number of all towers:8)	8	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～
154kV Muramatusen (The number of all towers:38)	38	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～
154kV Muramatukitasen (The number of all towers:1)	1	Evaluation period : 2011.5 ～ 2011.8 (Period for measures) 2011.9 ～

(3) Schedule

Items	May	Jun	Jul	Aug	Sep	Oct~
Selection of targets						
Confirmation of sites etc.						
Risk assessment						
Design of countermeasures						

5. Countermeasures to Protect Facilities such as Switching Yards in Nuclear Power Stations against Tsunamis(Order 4)

5.1 Countermeasures against Tsunamis to Protect Facilities such as Switching Yards at Kashiwazaki Kariwa Nuclear Power Station

In order to protect electrical facilities such as switching yards in nuclear power stations from Tsunamis, we will take measures such as installing them indoors or making them watertight.

We are now implementing emergency countermeasures for safety according to the order from the Minister of Economy, Trade and Industry on March 30th, 2011. The reliability of power for cooling each reactor is estimated to be secured because power-supply cars were already deployed. From the perspective of further improvements to reliability, we will study and implement them as well as countermeasures against Tsunamis.

5.2 Targeted Facilities regarding Countermeasures to Protect them from Water

The facilities necessary for receiving electricity from offsite power and gas turbine power-supply cars to be deployed in future have been targeted.

However, facilities, which are installed on a hill and expected not to be affected by Tsunamis, have been excluded from targeted equipment.

Specific electrical facilities are shown as follows;

(Switching yards providing offsite power are installed on a hill, and are more than 13.2 meters above sea level. Gas turbine power-supply cars will also be installed on a hill.)

ａ． Switching yard facilities
    500kV GIS，154kV Switchgear，66kV GIS
ｂ． High start up transformers
ｃ． Transformers for construction
ｄ． Distribution panels for emergency (M/C etc.)（We plan to install）

5.3 Countermeasures against Flooding of Electric Facilities

Concerning countermeasures against flooding of electric facilities, TP +13.2m is now regarded as the “inundation level to be considered after the accident of Fukushima Daiichi Nuclear Power Station”. (ＴＰ＋13.2ｍ is obtained by adding 9.5m to TP +3.7m, the evaluated Tsunami level at Kashiwazaki Kariwa Nuclear Power Station in 2002 by Japan Soc. of Civil Engineers.

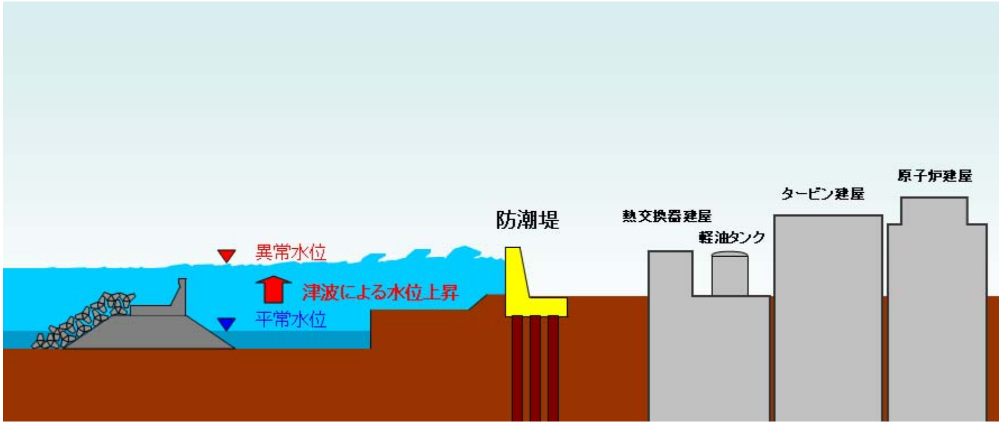
Switching yards supplying offsite power are located on a hill, which are more than 13.2 meters above sea level. We are going to conduct studies to secure further reliability.

（including Kashiwazaki Kariwa Nuclear Power Station）

	Targeted facility	Countermeasure	Period for countermeasure
Units １～７	Whole power station	Installation of seawalls in front of the sea shore	First quarter, 2013
	Switching yard	Installation of seawalls at the switching yard (66kV、500kV）	The second half of 2012
	Transformer	Installation of seawalls at high start up transformers（to be implemented with the switching yard）	The second half of 2012
	Power panel (M/C)	Making reactor buildings watertight	The second half of 2012
	Medium voltage distribution panel and cable for emergency （Newly installed）	Installation of a medium voltage distribution panel for emergency, and installation of cables connected to the distribution panel in the reactor building for emergencies	The first half of 2012

（１）Installation of seawalls

Seawalls located in front of the sea shore prevent Tsunamis from flooding the site and protect the buildings and structures on the premises (including switching yards).



[Image of protection against Tsunami]

異常水位：Abnormal water level

津波による水位上昇：Water level raising due to Tsunami

平常水位：Normal water level

防潮堤：Seawall

熱交換器建屋：Heat exchanger building

軽油タンク：Light oil tank

タービン建屋：Turbine building

原子炉建屋：Reactor building

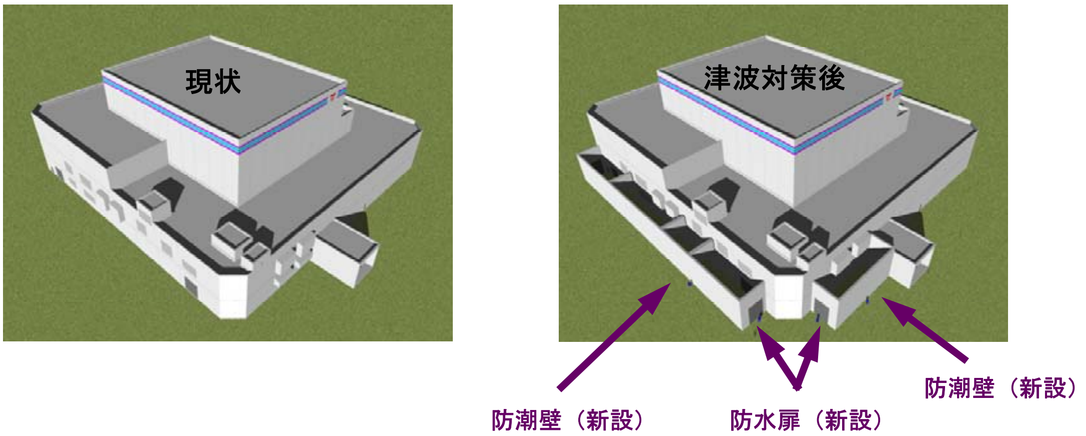
（Retaining wall type）

（Embankment type）

[Image of seawalls]

（２）Installation of water proofing gates

Install water proofing gates to prevent Tsunamis from flooding the reactor buildings containing important facilities for safety such as power facilities and emergency diesel generators.



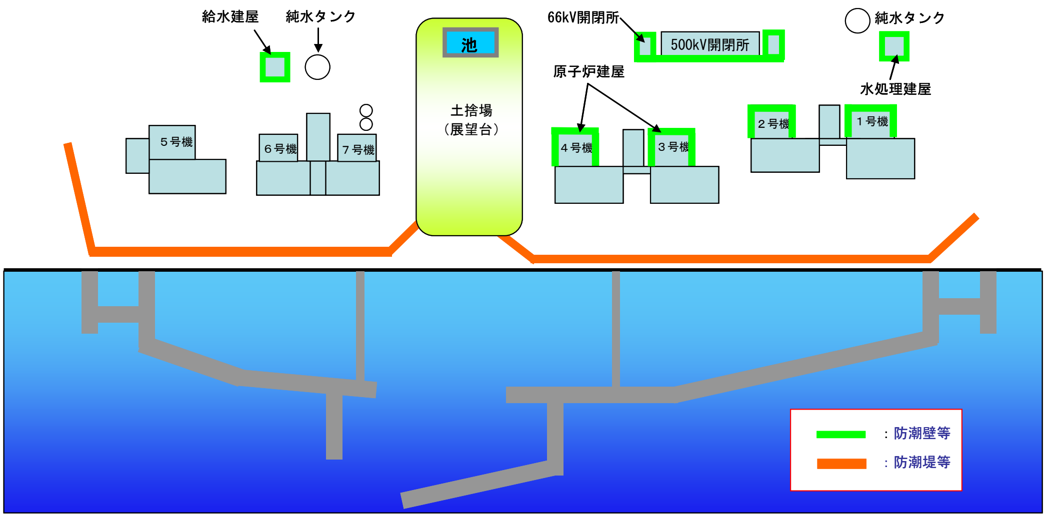
[Image of water proofing gates for a reactor building]

現状：Before taking countermeasures against Tsunamis

津波対策後：After taking countermeasures against Tsunamis

防潮壁（新設）：Seawalls (new)

防水扉（新設）：Water proofing gate (new)



[Image of seawalls (plain figure)]

給水建屋：Feed water building

純粋タンク：Fresh water tank

池：Pond

土捨場（展望台）：Spoil area (observation platform)

原子炉建屋：Reactor building

66kV 開閉所：66kV switching yard

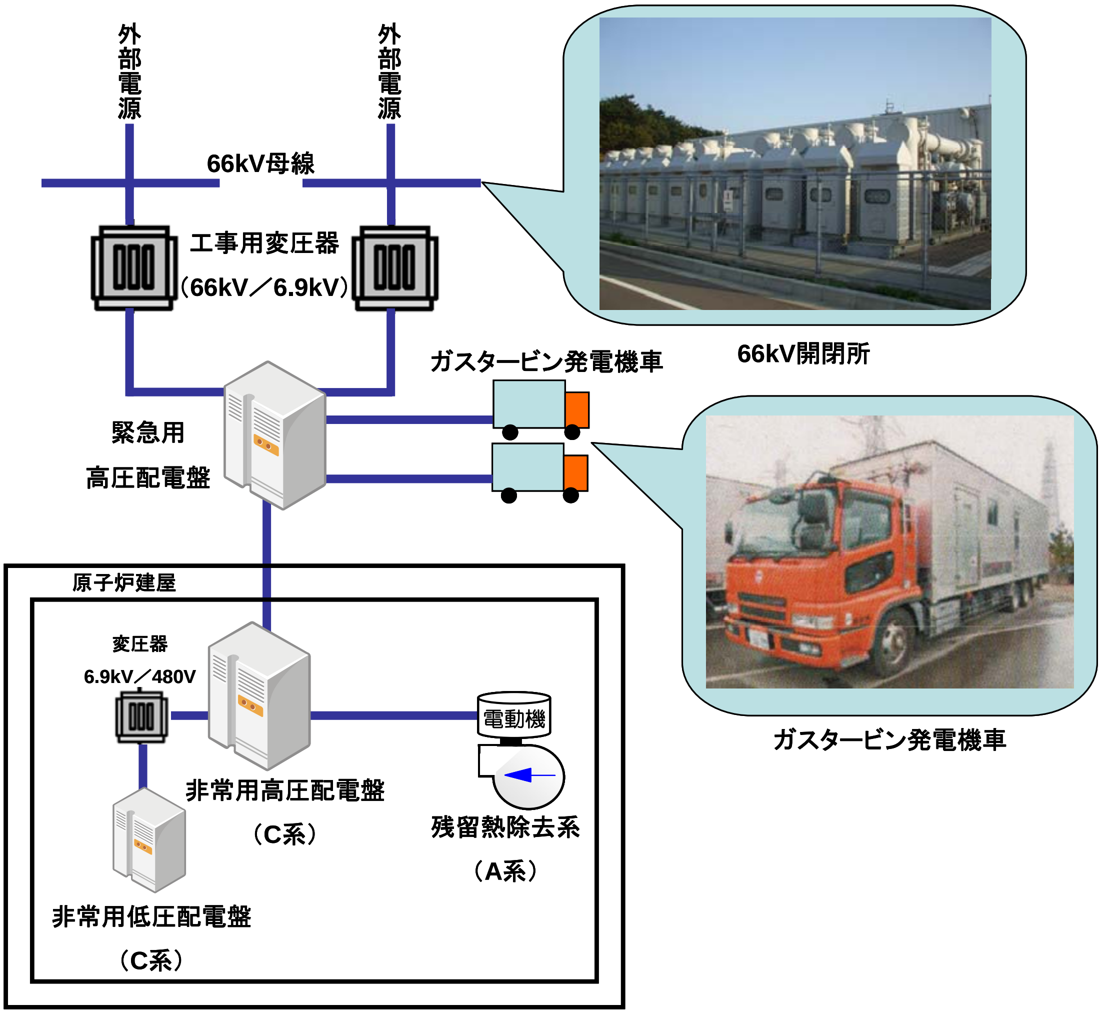
500kV 開閉所：500kV switching yard
水処理建屋：Water treatment building
1 号機：Unit 1

（3）Watertight Level of Reactor Buildings

Making facilities such as reactor buildings watertight to prevent Tsunamis from flooding the medium or low voltage distribution panel for emergencies needed to achieve cold shutdown.

（4）Installation of emergency medium voltage distribution panel （hereafter “Emergency M/C”, and installation of permanent cables connected to the medium voltage distribution panel for emergency use (hereafter “M/C for emergency use”)

In order to conduct quick restoration work in case of all power failure, permanent cables connected to M/C for the emergency use of each Unit (Units 1～7) are installed to secure power in emergencies and provide stable power with a residual heat removal system. Places where the cable passes through the building will be made watertight. Since the emergency M/C is located on a hill, it is estimated that it will not be affected by a Tsunami.



[Image of securing power through emergency medium voltage distribution panel]

外部電源：offsite power
66kV 母線：66kV bus line
66kV 開閉所：66kV switching yard
ガスタービン発電機車：Gus turbine power supply car
工事用変圧器：Transformer for construction
緊急用高圧配電盤：Emergency medium voltage distribution panel
非常用高圧配電盤：Medium voltage distribution panel for emergency use
非常用低圧配電盤：Low voltage distribution panel for emergency use
原子炉建屋：Reactor building
変圧器：Transformer
電動機：Electric motor
系：system

In addition to installing seawalls and water proofing gates to prevent Tsunamis from flooding the site, we also plan to implement countermeasures to secure a power supply to a residual heat removal system by establishing a power supply line between the 66kV switchyard, emergency M/C, and M/C for emergency use for each unit.

６． Summary

This report explains the countermeasures needed to secure the reliability of offsite power.　We will continue to work on implementing measures to improve the reliability of offsite power.

End