DESIGN FOR PROTECTION AGAINST EXTERNAL EVENTS IN TEPCO'S KASHIWAZAKI-KARIWA NUCLEAR POWER STATION

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ABSTRACT

Protection against external events has been improved in Tepco's Kashiwazaki-Kariwa Nuclear Power Station since the accident at Tepco's Fukushima Daiichi Nuclear Power Station in 2011 with consideration for lessons learned from the accident. In this paper, protection of the 2nd and 3rd layer of defense in depth against external events excluding earthquake and tsunami is discussed in particular. Systems, structures and components classified as class 1 to 3 in "(Japanese) Safety review guideline for classification of safety function of light water reactor facility" are designed such that they shall not lose their function due to external events.

External events were selected as follows to confirm conformity to this design requirement. Documents investigation was conducted to identify the external events to be addressed in design. Among these events ones that have possible effects to the power station were selected. Magnitude of each event was assumed to be maximum value among (1) Requirements from applicable industrial codes and standards or regulatory guidelines, (2) The most severe hazard in the records, (3) Hazard analysis on the basis of extreme values (the magnitude corresponding to annual probability of exceedance of 1E-04/yr in general). In considering protection for combination of external events magnitude of leading events were assumed to be the same as one assumed in the design for protection against single events and magnitude of accompanying events were assumed to be the magnitude corresponding to annual probability of exceedance of 1E-02/yr. Countermeasures to protect class 1 to 3 SSCs in safety classification have been taken based on the assessment of influence of the external events.

1. Introduction

Safety functions including water injection into the core using safety and non-safety systems were lost concurrently except reactor shutdown function because of the beyond design tsunami in the Fukushima Daiichi accident. Protection against tsunami that is beyond design basis had not been implemented based on the principle of defense in depth (DID) since the probability of beyond design tsunami had been judged as infinitesimal in spite of insufficient knowledge about tsunami. Based on this lesson learned from the accident it is important that each level of defense in depth against external events must be enhanced so that accidents do not readily escalate to higher levels even if the assumptions for design standards are exceeded. The basic policy of enhancing DID therefore was to prepare safety measures focusing on diversity and physical separation based on the assumption that multiple failure could happen, and to adopt and deploy the policy to each layer of DID. Overall strategies to ensure safety for ABWRs in Tepco's Kashiwazaki-Kariwa Nuclear Power Station and specific additional safety measures taken after the accidents are described in the reference[1].

This paper mainly focuses on protection of the second and third layer of DID against external events in Kashiwazaki-Kariwa ABWRs.

2. Design requirement for protection against external events

Design requirement is that systems, structures and components classified as class 1 to 3 in "(Japanese) Safety review guideline for classification of safety function of light water reactor facility" are designed such that they shall not lose their function due to external events. These SCCs were divided into two categories by their function as shown in Fig. 1. Firstly, the SCCs that have the safety function needed in safety shut down, core cooling, decay heat removal and spent fuel pool cooling as well as the buildings which contain those SCCs were examined as to whether they are adequately protected against the external events which should be considered in design (Design basis hazard). Countermeasures will be taken if they cannot maintain their safety function. The other SCCs were examined as to whether they can maintain their function or be replaced by another SCC or be recoverable even if they may lose their safety function during and after the impact from each design basis external hazard. Otherwise, countermeasures will be taken to protect those SCCs against the external events.

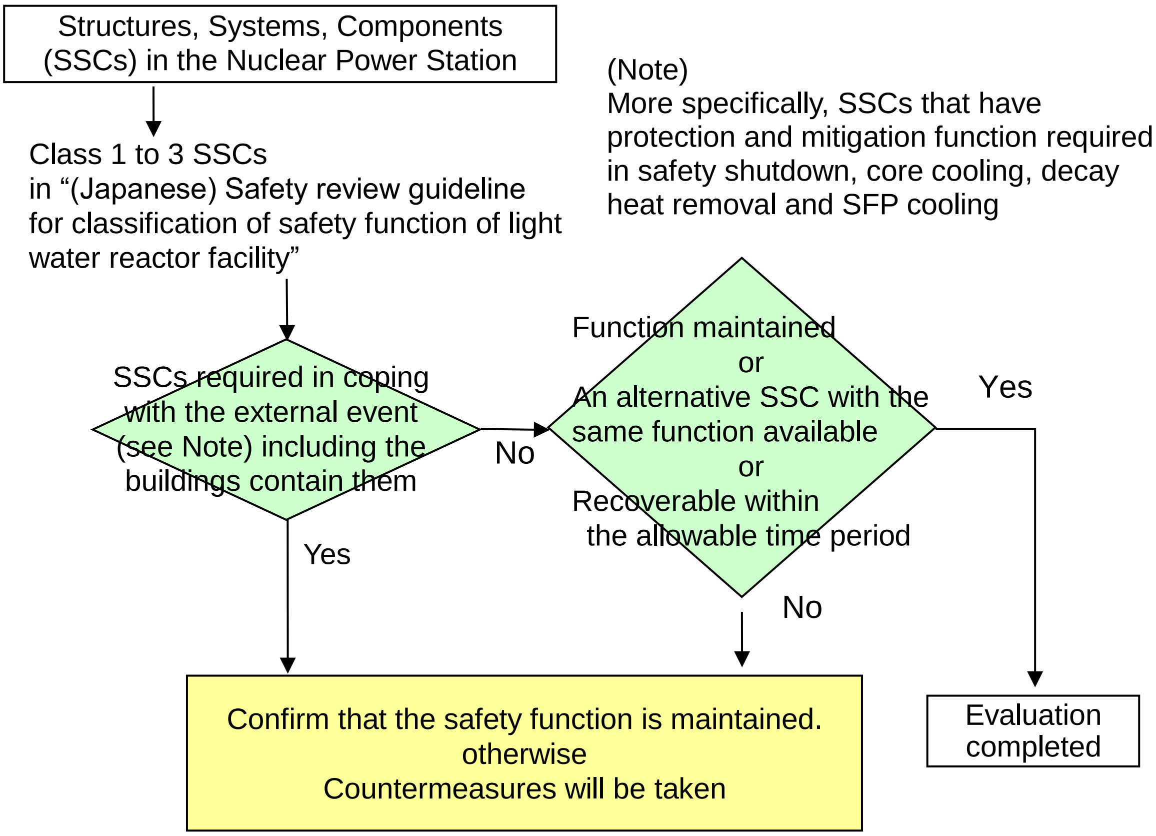

Fig. 1. Flow diagram for safety evaluation of class 1 to 3 SSCs for each external event

3. Identification of external events considered in design

At first 83 external events excluding earthquake and tsunami were collected comprehensively from both domestic and international codes and standards as well as documents [2]-[7]. Note that protections against earthquake including the effect on the ground foundation, tsunami, internal fire and internal flooding are designed in different ways and hence excluded from the scope of this paper. Then, those events which have the effect similar to that of another event (or other events) or which is triggered by another event were put together into the same group to get 62 events shown in Table 1 and Table 2. For example, extreme wind and tropical cyclone have the similar effect on the plant and they are called as "extreme wind" in the list in Table 1 and Table 2. Also, steam and natural toxic gas are both considered to be triggered by volcanic activity and described as "volcanic phenomena".

These 62 external events were screened with following criteria to identify the safety significant events at the site for further detailed evaluation. The result of screening is shown also in Table 1 and Table 2.

Criteria A. The external event does not occur close enough to affect the plant.
Criteria B. The impact from the external event can be prevented since the development of the external event is moderate and predictable.
Criteria C. The impact from the external event is less severe than that from the events considered in the original plant design.
Criteria D. The impact from the external event is less severe than that resulting from another external event in the list.

Table 1 List of natural event and screening criteria

No.	Natural event	Screening Criteria	No.	Natural event	Screening Criteria
1	Extreme rain	Screened in	21	Wind induced wave	D (Tsunami)
2	Extreme snow	Screened in	22	Flooding	A
3	Avalanche	A	23	Low water level	A
4	Hail,	D (No. 10)	24	River Diversion	A
5	Ice storm	D (No. 2, 26)	25	Drought	A
6	Ice crystals	D (No. 2, 26)	26	Volcanic phenomena	Screened in
7	Frost	C	27	Landslide	Screened in
8	Ice floe	A	28	Underwater landslide	Out of scope
9	Extreme wind (incl. tropical cyclone)	Screened in	29	Land rise	D (earthquake)
10	Tornado	Screened in	30	Karst	B
11	Sandstorm	A	31	Soil shrink-swell	C
12	Mist	C	32	Coastal erosion	B
13	High air temperature	B	33	Groundwater	D (No.27, 34)
14	Low air temperature	Screened in	34	Erosion by groundwater	C
15	High water temperature	B	35	Wild fire	Screened in
16	Low water temperature	C	36	Biological event	Screened in
17	Extreme pressure	D (No. 10)	37	Seiche	D (Tsunami)
18	Lightning	Screened in	38	Salt damage	C
19	Storm surge	D (Tsunami)	39	Meteorite	A
20	Waves	D (Tunami)	40	Solar flare	C
			41	Debris flow	A
			42	Mud volcano	Out of scope

Note) The events considered in design for protection against combination of events are marked with underlines (explained later in chapter 6). Wild fire is treated as human induced event.

Table 2 List of human induced events and screening criteria

No.	Human induced event	Screening criteria	No.	Human induced event	Screening criteria
1	Aircraft impact	A	11	Cyber terrorism*	-
2	Dam failure	A	12	Accident in industrial facilities	D (No. 3, 4)
3	Fire, Explosion	Screened in	13	Transportation accident	D (No. 3, 4)
4	Toxic gas	Screened in	14	Missiles from military activity*	Screened in
5	Ship collision	Screened in	15	Digging in the site	C
6	Electromagnetic disturbance	Screened in	16	Internal flooding*	Screened in
7	Pipeline accident	A	17	Turbine missile	A
8	Illegal intrusion*	-	18	Transportation of heavy goods	C
9	Airplane crash (intentional)*	-	19	Water pollution by chemical release	B
10	Deliberate attack (incl. Sabotage)*	-	20	Oil spill	D (No. 3, 5)

Note) The events considered in design for protection against combination of events are marked with underlines (explained later in chapter 6). *Intentional human induced events are out of scope for protection against DBA equipment

The screened in events are listed in Table 3, whose impacts on the plant were evaluated later in more detail. Design basis hazard, that is, magnitude or intensity of each safety significant event in Table **3** is discussed in the next chapter.

Table 3 External events considered in the design for protection against single event

No.	Natural event
1	High wind
2	Tornado
3	Low air temperature (freeze)
4	Extreme rain
5	Extreme snow
6	Lightning
7	Landslide
8	Volcanic phenomena
9	Biological event

No.	Human induced event
1	Fire, Explosion (Wild fire, industrial facility, aircraft fire)
2	Toxic gas
3	Ship collision
4	Electromagnetic disturbance

4. Determination of design basis hazard for each safety significant external event

Design basis hazard for each safety significant natural event identified in the chapter 3 was assumed to be the maximum among following 3 values. Class 1 to 3 SSCs are designed to withstand the load from design basis hazard.

(1) Requirements from applicable industrial codes and standards or regulatory guidelines
(2) The most severe hazard in the records
(3) Hazard analysis on the basis of extreme values

In (3) hazard curves were evaluated according to the same method as that applied in “severe weather risk map[8]" of Japan Meteorological Agency. The basic procedure in the method is as follows. At first available data sets of each natural events for the region around the site are collected. Then, the most appropriate probabilistic distribution for the data set is selected from those probabilistic distributions that have been used in hazard analysis on the basis of extreme values such as Gumbel distribution, generalized extreme value distribution, and squared exponential type distribution of maximum and so on. Statistical parameters for the distribution functions is estimated by method of moments or maximum likelihood estimation. It is worth noting that available data sets of each natural event for the region showed no significant changes in trend over years. Although climate change generally takes place in much longer term than lifetime of nuclear power plants there is some concern for the risk of climate change. Therefore, design basis hazard will be reviewed according to future trends when necessary.

Once hazard curves (magnitude of events versus annual probability of exceedance) were obtained a certain annual probability of exceedance for each natural event was specified to determine to what extent Class 1 to 3 SSCs are designed to be protected against each natural event. In general, design basis hazards were determined to be those events that have annual probability of exceedance of 1E-4 /yr in consideration of safety goal for operation of nuclear power plant established by Japan’s Nuclear regulation authority (NRA), that is, core damage frequency (CDF) of less than 1E-4 /yr. If Class 1 to 3 SSCs are protected against design basis hazards that have annual probability of exceedance of 1E-4 /yr, initiating even frequency is less than 1E-4 /yr. This means that CDF is much less than 1E-4 /yr because of mitigating measures. Followings were also taken into consideration in establishing design basis hazard.

1) Design basis seismic acceleration and tsunami height required from codes and standards correspond to annual probability of exceedance of 1E-4 to 1E-5 /yr
2) The previous guideline for safety assessment review in Japan required to conduct safety assessment for anticipated operational occurrences and design basis accidents. Anticipated

operational occurrence is defined as those conditions that are expected to occur once or more times during the life of the plant (probability of exceedance of 1E-1 to 1E-2/yr) while design basis accident is defined as those accidents that are not expected to occur during the life of the plant but still need to be evaluated, which is considered to correspond to probability of exceedance of 1E-3 to 1E-4.

3) Design basis hazard in other countries includes annual probability of exceedance of 1E-2 to 1E-5 /yr (according to the report on stress test in European countries.) though it depends on countries.

Table 4 shows design basis hazard of each safety significant natural event. Design basis hazard of landslide and biological events cannot be determined in the way mentioned above. Hence, specific source of danger were identified for each event. Also, in the evaluation of influences from human induced events specific sources of potential danger around the site such as human activities and hazardous materials were identified and whether or not they could affect the plant was examined.

Table 4 Design basis hazard of safety significant natural events

No.	Natural event	Design basis hazard	(1) Codes and standards	(2) Record	(3) Probabilistic hazard analysis
1	High wind (wind speed)	40.1 m/s (2)	30 m/s Building standard law of Japan[9]	40.1 m/s Niigata city (80 km NNE from the site)	39.0 m/s Niigata city (80 km NNE from the site)
2	Tornado (instantaneous wind speed)	92 m/s F3 upper limit	No applicable codes and standards	69 m/s Japan sea coast region	58.3 m/s (probability of exceedance of 1E-5 /yr)
3	Low air temperature	-15.2℃ (3)	-13.0℃ Design requirement in original construction	-11.3℃ Kashiwazaki city	-15.2 ℃ (probability of exceedance of 1E-4 /yr)
4	Extreme rain	101.3 mm/h (3)	51.1 mm/h Nagaoka city (30 km ENE from the site)	52 mm/h Kashiwazaki city	101.3 mm/h Kashiwazaki city (probability of exceedance of 1E-4 /yr)
5	Extreme snow	167 cm (3)	100 cm Building standard law of Japan (incl. snow removal)	103.1 cm (maximum daily snow fall 72 cm/d + average snow depth 31.1cm)	167 cm (maximum daily snow fall 135.9 cm/d (probability of exceedance of 1E-4 /yr)+average snow depth 31.1cm)
6	Lightning (current)	200 kA (3)+margin	150 kA JEAG4608-2007[10]	460k A Niigata pref. and inland area of Honshu mainland (during winter)	560 kA (w/o lightning protection) 156 kA (w/ lightning protection by lightning rod)
7	Volcanic phenomena (ash fall)	35 cm (2)	No applicable codes and standards	35 cm (maximum ash fall layer)	Probabilistic hazard analysis not applicable

(Note) design basis hazard for tornado and lightning have some margin to the maximum value among (1) to (3) because of uncertain nature of the events

5. Evaluation of influence from design basis hazard on SSCs

The summary of the results of evaluation for the influence from the safety significant external events on the SSCs required in coping with external events (see Fig. 1) are described in Table 5. Further detailed information are available in the reports for the review meeting on conformity to the new regulatory requirements held by Nuclear Regulation Authority in Japan (available only in Japanese). [11].

The specific SSCs to be evaluated were identified as follows. First of all the buildings which contain these SSCs are designed to withstand the loads from design basis hazards. Some countermeasures are implemented to ensure that the buildings are well protected such as snow and volcanic ash removal for continuous snow and volcanic ash fall. In this way the SSCs installed in these buildings can be well protected except for the following cases.

(1) The SSCs which have openings to the atmosphere can be affected by atmospheric pressure change and missiles due to tornado, blockage by accumulated snow or volcanic ash and contamination from volcanic ash (Diesel generator (D/G), D/G intake system, D/G blowers, air-conditioning systems and RSW).

(2) The SSCs installed near doors that can open during the events or be perforated by missiles due to tornado etc. can be affected (SSCs located at D/G area, emergency electric power distribution system room and staircase at heat exchanger area).

(3) Some external events such as lightning, toxic gas and electromagnetic disturbance can affect the SSCs installed in buildings. The influence from these events on the SSCs inside of the buildings are examined.

Finally, the SSCs located outside of the buildings excluding the buildings themselves (D/G fuel oil system, light oil tanks) are examined as to whether they remain functional during and after the external events and countermeasures are taken.

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Table 5 Evaluation of influence from design basis hazard

External event	Influence on the SSCs which should be protected and countermeasures
High wind	The buildings are not affected because wind load on the building is less than design seismic load for the buildings. Light oil tanks and Diesel generator fuel oil (DGFO) pumps are designed to withstand design basis wind load. Note that design basis wind is less intense than that for tornado.
Tornado	The buildings withstand the loads from tornado wind, atmospheric pressure change, missiles impact. SSCs that have openings to the atmosphere withstand atmospheric pressure change. Tornado missile sources such as construction equipment and materials within the radius of maximum travelling distance of each missile from the SSCs have been either removed if possible or fixed. Doors to D/G rooms have been replaced to the ones with thicker steal material. Protection nets or plates have been installed to the openings near the SSCs such as ventilation louvers on the buildings. Light oil tanks have been replaced by ones with thicker steel material. Protection walls against missiles will be installed around DGFO.
Low air temperature	The SSCs inside of the buildings are not affected because of air-conditioning systems. Light oil for diesel generators have been replaced by one with lower clogging point.
Extreme rain	No roof load is imposed because design basis rain can be drained from roofs with drainage pipes. Rainwater to the ground is drained with drainages. Even if rainwater to the ground is not drained flooding to the buildings is protected by water proof treatment to the openings of the building such as doors and penetrations of pipes and cables.
Extreme snow	Roof snow load is less than allowable load capacity. Intakes for air-conditioning systems are not blocked because they are installed higher than design basis snowfall. Snow removal will be needed for the continuous snow fall or combination of extreme snow and earthquake. Snow removal program is under consideration.
Lightning	No influence because of lightning rods. The SSCs in the building are not affected even if design basis lightning strikes the exhaust stack.
Land slide	SSCs which are necessary for coping with the external event have sufficient separation distance to any slopes.

External event	Influence on the SSCs which should be protected and countermeasures
Volcanic phenomena	Volcanic ash load on the roofs is less than allowable load capacity. Pieces of volcanic ash is easy to break into smaller pieces and particle size of volcanic ash is so small that it doesn't cause any wear and blockage on sea water intake screens as well as pumps and strainers in the sea water systems. Intakes for D/G and air-conditioning systems are installed with filters to prevent volcanic ash from going inside. Filter exchange is necessary. Volcanic ash removal will be needed for continuous ash fall.
Biological event	Intrusion of small animals such as mice into the buildings is prevented with water proof treatment. Intrusion into exposed equipment is prevented with sealing of cable penetration. Jellyfishes are removed from sea water intake with screen.
Fire, Explosion	Sufficient separation distance is secured to fire, explosion and missile from explosion resulting from wild fire, petrochemical complexes, industrial facilities with hazardous materials, transportation accidents and ship collision (except that separation distance for missile resulting from ship collision is not sufficient but probability of missile reaching the buildings is negligible small.) Temperature of the buildings, light oil tanks and DGFO resulting from the fire of light oil tank, main transformer and transformer for recirculation internal pumps and aircraft crash is less than allowable temperature. Change in concentration of O_2 and CO_2 resulting from fire do not affect habitability in the main control room and technical support center. 20 to 22m of firebreak have been constructed around the plant. Fire resistant walls will be installed around DGFO.
Toxic gas	Toxic gases from outside of the site don't affect habitability in the main control room and technical support center because of sufficient separation distance. The influence of toxic gases from inside of the site on habitability in the main control room and technical support center can be prevented by air-conditioning systems.
Ship collision	Sufficient separation distance is secured to the sea routes with which ships are regularly operated. Drifting small ships and boats don't reach the plant because of breakwaters.
Electromagnetic disturbance	Reactor Protection System (RPS) is designed to withstand electromagnetic disturbance.

Note) Countermeasures are shown with underbars.

6. Combination of external events

Class 1 to 3 SCCs are adequately protected against each single design basis hazard once countermeasures are taken according to the flowchart in Fig. 1. In considering protection against combinations of external events the combinations of events that have enhanced influence on the plant compared to that of single events should be identified. Hence, the screening criteria B and C applied in the design for protection against single external events cannot be applied for combination of the events. As a result 32 external events including earthquake and tsunami were screened in and addressed in the design for protection against combinations of events. Those events are shown in Table 1 and Table 2 with underbars.

The number of the events combined in the design for protection was basically two (each referred to as “leading event” and “accompanying event” hereafter) because the probability of more than two independent events happening at the same time is quite small. However, those groups of events which have correlation with each other such as extreme snow, hail, frost, low air temperature and low water temperature (their frequency of occurrence is not independent with each other) should be combined with another independent event as shown in Fig. 2 and their effect on the plant should be examined because the probability of dependent events occurring at the same time is bigger than the simple product of probability for each event.

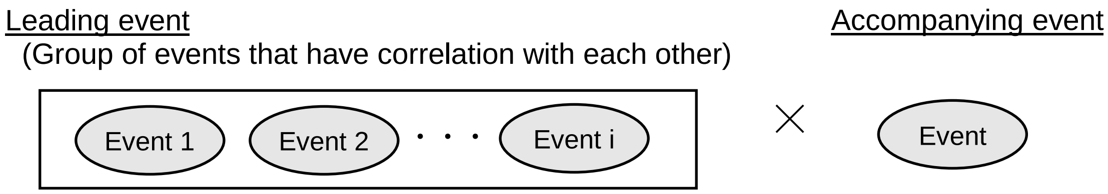

Fig. 2 Combination for correlated events

After consideration for each correlated group of events it turned out that effect on the plant from the events in each correlated group combined is not enhanced compared to the single event because they don’t share the same effect mode (An example is shown in Table 6).

Table 6 Group of events that have correlation with each other (caused by low air temperature)

External event	Effect mode
Extreme snow	Accumulated load
Hail	Impact load
Frost	No effect mode
Low air temperature	Freeze
Low water temperature	No effect mode

Also, the load resulting from frequent events such as extreme rain and extreme snow was added to every combination of events.

Magnitude of leading events was assumed to be the same as that of design basis hazard (events that have annual probability of exceedance of 1E-4 /yr in general) and magnitude of accompanying events was assumed to be the magnitude corresponding to annual probability of exceedance of 1E-02/yr. Although Turkstra’s rule states that the arbitrary-point-in-time intensity of the other (secondary) load effects should be considered lifetime of the plant was taken into consideration and the magnitude corresponding to annual probability of 1E-2 /yr was applied for securing safety margin.

32 external events identified in this chapter were further broken down into their effect modes (for example tornado has following effect modes; wind load, load from pressure change, load from missiles and blockage of sea water intake by tornado debris). The influence of combination of every effect mode of 32 event on Class 1 to 3 SSCs were examined (Table 7 shows a part of the combinations).

Influence of combinations of events were categorized into following four groups.

a. Effect on the plant is not enhanced
b. The combination of events highly unlikely to happen

c. Enhanced effect do not exceed the effect of single event nor safety margin in design
d. the others

The combinations of events fall into group “d”, which need to be examined in more detail, were further divided into the four groups shown in Fig. 3. Every combination of effect modes of 32 external events were categorized in this way as examples are shown in Table 7. As a result of evaluation for the influence countermeasures were extracted as shown in Table 8.

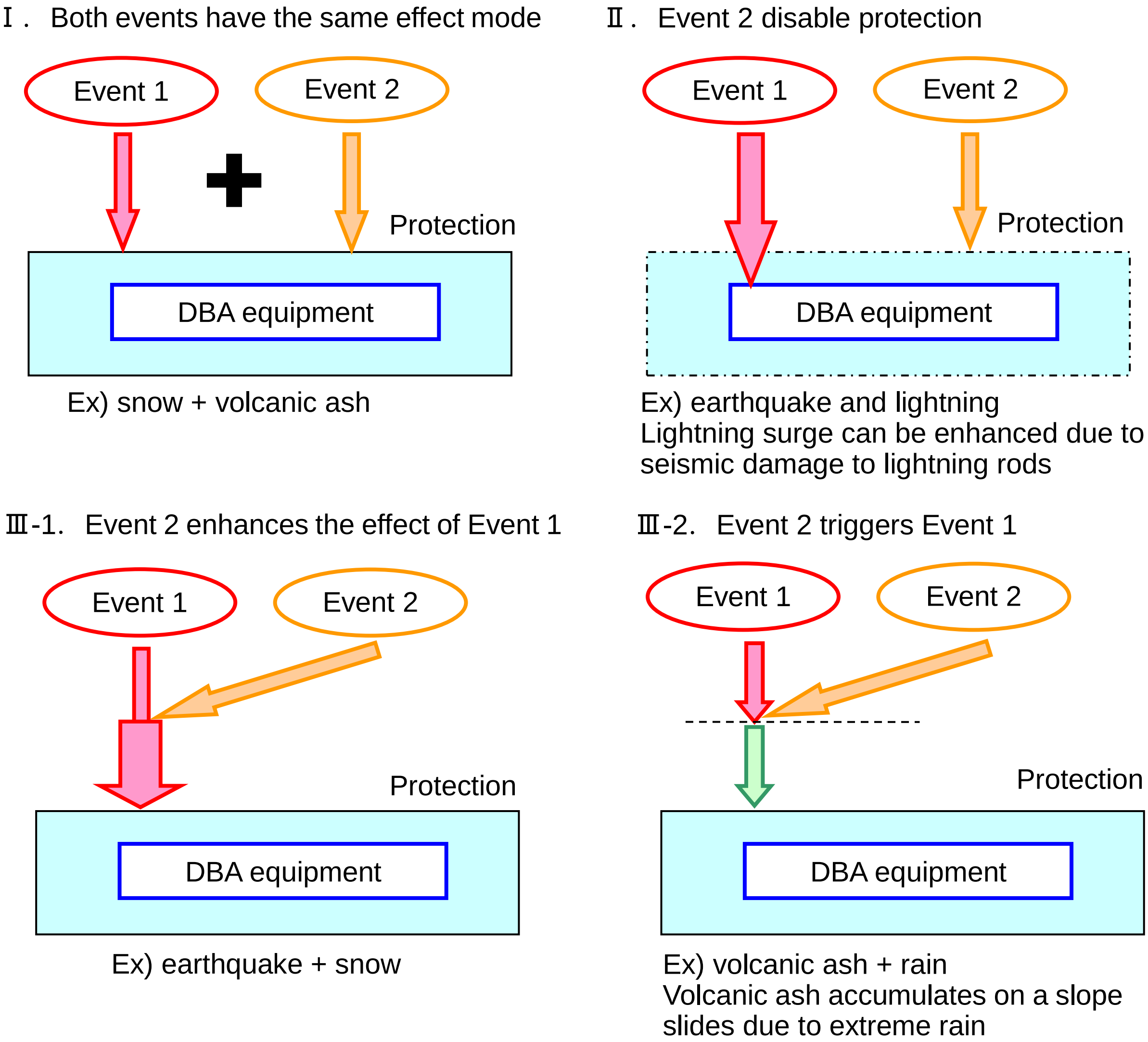

Fig. 3 Categorization of enhanced effect mode

Table 7 Categorization of combinations of effect modes

accompanying event \ leading event		No.	1	5				6
		event	earthquake	tornado				lightninfg
		failure and effect mode	seismic load	wind load	load from pressure change	load from missiles	blockage of sea water intake by debris	lightning surge
No.	event	failure and effect mode						
1	earthquake	seisimic load		b	b	d（Ⅱ）	b	d（Ⅱ）
		land subsidence		a	a	a	a	a
		land rise		a	a	a	a	a
		mud volcano		a	a	a	a	a
8	extreme snow	accumulated load	d（Ⅲ-1）	b	a	a	a	a
		short circuit of transformer	a	a	a	a	a	a
		blockage of ventilation openings	a	a	a	a	a	a
9	frost	none	a	a	a	a	a	a
10	low air temperature	freeze	a	a	a	a	a	a
11	low water temperature	none	a	a	a	a	a	a
12	high air temperature	degradation of air conditioning	a	a	a	a	a	a
13	high water temperature	degradation of thermal efficiency	a	a	a	a	b	a
14	mist	none	a	a	a	a	a	a
15	volcanic activity	accumulated load	d（Ⅲ-1）	b	a	a	a	a
		blockage of sea water intake by ash	a	a	a	a	b	a
		blockage of ventilation openings	a	a	a	a	a	a
		erosion	a	a	a	a	a	a
		short circuit of transformer	a	a	a	a	a	a
		water pollution	a	a	a	a	a	a
		aire pollution	a	a	a	a	a	a

(Note) a. Effect on the plant is not enhanced, b. The combination of events highly unlikely to happen
c. Enhanced effect do not exceed the effect of single event nor safety margin in design, d. the others
Also see Fig. 3 for explanation on roman numerals.

Table 8 Examples of evaluation for the influence of combination of events

Combination	Effect mode	Influence and countermeasures (if necessary)
volcanic ash and snowfall (accumulated load)	Ⅰ	The buildings withstand load from 35 cm of ash fall and 84.3 cm/day of snowfall (1E-2/yr) +31.1cm (average snow depth)
Earthquake (seismic load) and lightning (lightning surge)	Ⅱ	Lightning surge can be enhanced due to the seismic damage to lightning rods. 156 kA of lightning current resulting from the lightning that has annual exceedance of probability of 1E-4/yr with lightning rods can be enhanced to 216kA without lightning rods. It is confirmed that this lightning surge don't exceed the dielectric resistances of power supply panels, control panels and Instrument and control systems.
Earthquake (seismic load) and snow (accumulated load)	Ⅲ-1	Load from design basis seismic motion and 84.3 cm/day of snowfall (1E-2/yr) +31.1cm (average snow depth) can damage the buildings. Snow removal will be required.
Volcanic ash and extreme rain (landslide)	Ⅲ-2	Volcanic ash accumulates on a slope may slide due to extreme rain. No influence because sufficient separation distance is secured between Class 1 to 3 SSCs and slopes.
Earthquake (seismic load) and tornado (missile load)	Ⅱ	Missile load can be enhanced due to seismic damage to prevention measures for tornado missiles. Inspection after earthquake will be needed.

7. Protection of SA equipment

Class 1 to 3 SSCs, which are required in coping with design basis accidents (DBA) and hence referred to as DBA equipment in this chapter, are adequately protected against external events with the scheme mentioned so far. On the other hand severe accident (SA) equipment should be also ensured to work properly in beyond design basis accidents including severe accidents, where multiple pieces of DBA equipment that perform the same safety function fail at once due to external events. Here, SA equipment refers to the SCCs that required in coping with beyond design basis accidents including severe accidents. Design requirement for SA equipment when being in standby were established as follows (See also Fig. 4). The external events considered here is design basis hazards in Table 3 as well as missiles from aircraft crash and terrorism.

(1) SA equipment which has prevention function shall not lose its function simultaneously with DBA equipment.
(2) SA equipment which does not have prevention function shall be able to be replaced by alternative equipment or recover from its failure within the duration where its failure does not affect safety of the plants.
(3) Primary safety functions, that is, safety shut down, core cooling, containment cooling and spent fuel pool cooling shall be achieved only with SA equipment.

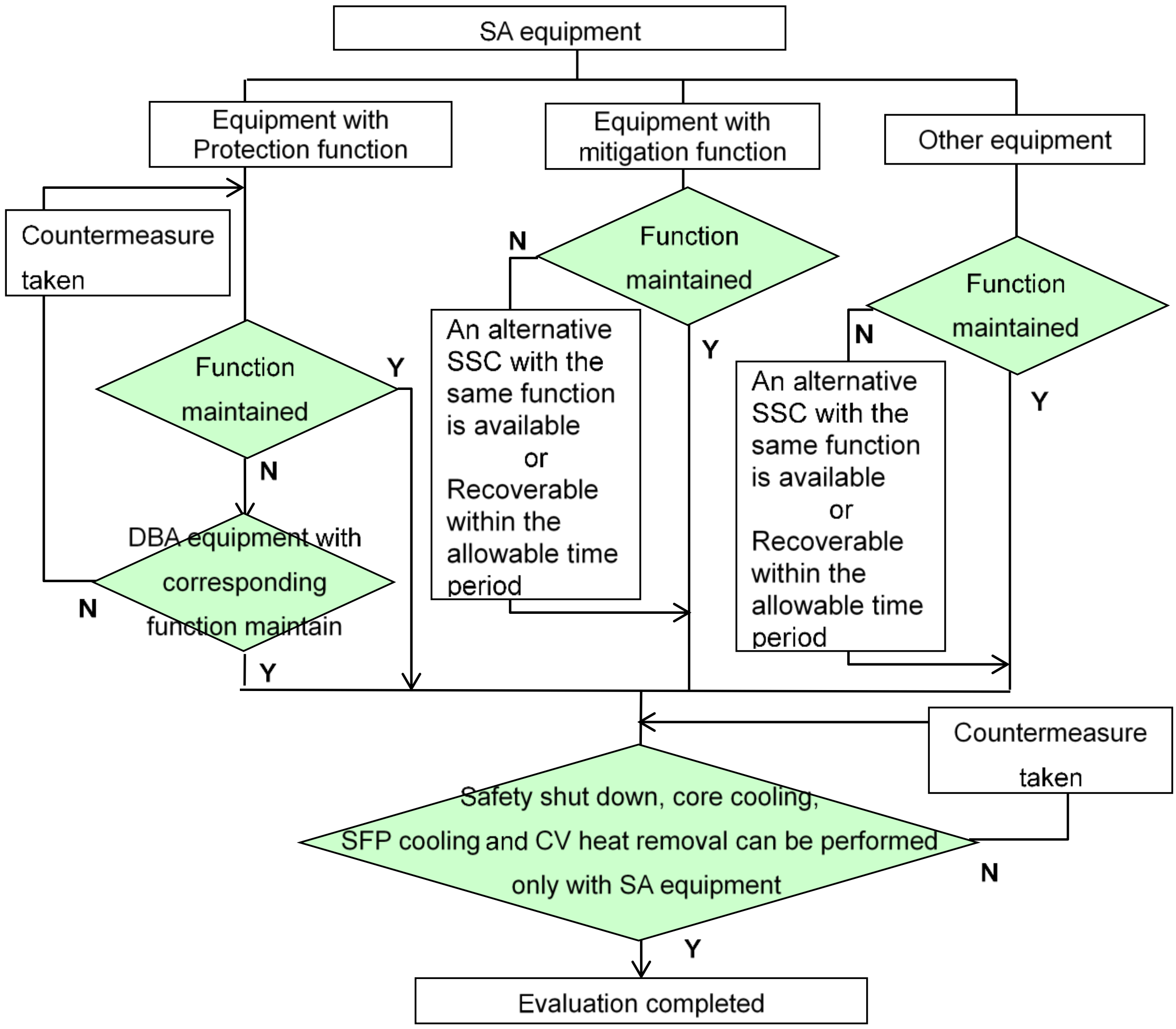

Fig. 4 Flow diagram for safety evaluation of SA equipment against each external events

This requirement is met because SA equipment have been designed putting focus on securing diversity (in driving mechanism, power and water source and cooling equipment) and independence (physical separation with physical protection and spatial separation) to prevent common-cause failure between DBA and SA equipment and among multiple pieces of SA equipment.

Also, SA equipment have been designed to withstand loads from environmental condition of severe accident (pressure, temperature and so on) and external events when being in service. Magnitude of events whose loads is considered in combination with the loads from SA environmental conditions is assumed to be whichever is bigger between the average annual maximum and the magnitude corresponding to annual probability of exceedance of 1E-01/yr.

8. Conclusion

Design for protection against external events in ABWRs of Tepco's Ksashiwazaki-Kariwa Nuclear Power Station were described mainly focusing on the 2nd and 3rd layer of DID. The external events that could affect the site were identified and the magnitude of each of those events addressed in the design (design basis hazard) was determined with consideration of hazard analysis on the basis of extreme values as well. Countermeasures to protect class 1 to 3 SSCs in safety classification have been taken based on the evaluation for the influence of the external events. Tepco will continue efforts to improve safety in our nuclear power plants.

9. Reference

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