Application of Risk Information on Various Hazards to Plant Operation at Onagawa Nuclear Power Station

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Abstract: Onagawa Nuclear Power Station (NPS) includes 3 BWRs original designed by GE owned by Tohoku Electric Power Co., Inc. (Tohoku EPCO) is the closest nuclear power plant on to the epicenter of the 2011 off the Pacific coast of Tohoku Earthquake and Tsunami. Now unit 2 is almost ready to restart, and we will continue risk management and utilization of risk information by utilizing the results of PRA evaluation incorporating these safety measures and the newly developed risk monitor for the plant operation status. In this paper, we report on the efforts to utilize risk information for various hazards such as internal and external events at Onagawa NPS unit 2.

Keywords: PRA, RIDM, Risk Management

1. INTRODUCTION

Onagawa Nuclear Power Station (NPS) includes 3 BWRs original designed by GE owned by Tohoku Electric Power Co., Inc. (Tohoku EPCO) is the closest nuclear power plant on to the epicenter of the 2011 off the Pacific coast of Tohoku Earthquake and Tsunami.
In Japan, the Nuclear Regulation Authority (NRA) has implemented new regulatory standards in 2013, and Onagawa NPS has been working on the restart of unit 2, which was the first unit to comply with the new regulatory standards in Tohoku EPCO's plants. In parallel with these efforts to restart operations, Onagawa NPS has been utilizing risk monitor to evaluate the risk of fuel damage in the plant shutdown state and in the spent fuel pool as a reference for process management during periodic inspections. In addition, various safety improvement measures introduced to comply with the new regulatory standards have been incorporated into various unit 2 PRA models for internal and external events.
Now unit 2 is almost ready to restart, and we will continue risk management and utilization of risk information by utilizing the results of PRA evaluation incorporating these safety measures and the newly developed risk monitor for the plant operation status. Referring to the details of the PRA modeling status for unit 2, the evaluation of each PRA for internal and external events is currently being conducted sequentially. Specifically, we are proceeding with scopes for level 1 (at power operation), level 2 (at power operation), level 1 (shutdown), earthquake, tsunami, internal fire, and internal flooding.
In addition to hazards that can be quantified probabilistically, we also conduct risk management using qualitative or semi-quantitative assessment results for other external hazards and various risks including occupational safety.
In this way, Onagawa NPS aims to conduct rational and effective plant operation and management by using risk information.
Furthermore, in Japan, a new inspection system for nuclear power plants by NRA (so-called Japanese ROP) has been introduced in 2020, and Japanese utilities are using the information obtained from the PRA model for Mitigating System Performance Index (MSPI) and Significance Determination Process (SDP), etc., and utilizing it in plant inspections.
In this paper, we report on the efforts to utilize risk information for various hazards such as internal and external events at Onagawa NPS unit 2.

2. Various risks considered at Onagawa NPS

At Onagawa NPS, natural and human-induced events that could affect the plant were extracted based on domestic and foreign standards and literature, taking into account national standards and other factors as shown in Table 1. Specifically, at the design stage of the plant modification for this restart, the following events were extracted based on the environment and conditions at and around the Onagawa site, taking into consideration overseas selection criteria.

(Must consideration under the regulatory standards)
Internal events, earthquake, tsunami, internal flood, internal fire, etc.

(Natural phenomena)
Tornado, volcanic effect, forest fire, wind (typhoon), precipitation, lightning, biological event, freezing, snow accumulation, landslide, storm surge, external flood

(Human-caused events)
Explosions, fires in nearby factories, toxic gases, ship collisions, electromagnetic disturbances, flying debris (falling aircraft), dam collapses

Onagawa NPS has responded to these events using probabilistic or deterministic approaches, or a combination of both. The status of the response is described below.

Table 1. Main Phenomena Approach

Phenomena	Approach		Special Note
	Deterministic	Probabilistic	
Internal event	○	○	Analysis of accident scenarios using internal event PRA
Earthquake	○	○	Refer to earthquake hazard and conduct earthquake PRA when developing earthquake ground motions
Tsunami	○	○	Tsunami hazard is referenced and tsunami PRA is conducted when developing the reference tsunami
Flood	○	○	Internal flood PRA is currently being evaluated.
Fire	○	○	Fire PRA is currently being evaluated. Design is based on deterministic evaluation
Tornado	○	○	Calculate hazard curve for maximum tornado wind speed. Maximum wind speed for design tornado is 100 m/s.
Volcanic effects	○	-	Design values are calculated based on literature review, existing values, and empirical values.
Forest fire	○	-	
Wind (typhoon)	○	-	
Precipitation	○	-	
Lightning	○	-	
Freezing	○	-	
Snow	○	-	
Fires in neighboring factories	○	-	
Toxic gas	○	-	
Ship collision	○	-	
Electromagnetic interference	○	-	
Aircraft fall	○	○	The probability of aircraft fall is evaluated to be less than 10-7/y in addition to the restricted flight over the nuclear power plant, and it is confirmed that no consideration is required in the design. Intentional aircraft collision is responded by the Large Scale of Damage or the specialized safety facility.

In addition, a systematic approach called "risk management activity"[1] is also implemented in the operational phase of plants. This activity is based on the establishment of a process to identify/evaluate work risks from a broader perspective, including occupational safety, when planning work, and to take countermeasures to reduce risks before implementing the work. This is an initiative that enables comprehensive consideration of risk.

3. EXAMPLES Of RISK INFORMATION UTILIZATION

3.1. Design Phase

Onagawa NPS is designed not to be inundated by a standard tsunami of 23.1m in height by installing a sea wall[2] 29m above sea level surrounding the site and a sea wall to prevent uprising of water from the auxiliary intake and discharge pit on the site. All safety-critical facilities, including the seawall, are designed to withstand a design base earthquake motion of 1,000 gals (approx. 1.02 G). In addition to the existing mitigation equipment using ECCS and various permanent facilities through accident management, several portable facilities such as water pumps have been newly deployed in light of the accident at the Fukushima Daiichi Nuclear Power Plant. However, analysis using PRA and other methods indicates that the effectiveness of the response by portable facilities is highly uncertain in the event of a tsunami impact on the site, and therefore, it may not be possible to respond to an event that progresses quickly, such as the TBP (Loss of all AC power + SRV open sticking) sequence. Therefore, a new DC-driven Low-pressure water Injection pump (DCLI) was installed to address this risk. This pump operates under the control of another DC power source, and is designed to drive the electric motors from a different DC power source than the RCIC and HPAC (TWL™ pump), which are also steam-driven, to ensure versatility. See Figure 1 for these facilities.
Thus, PRA has been utilized in the design study phase of the modification for this restart.

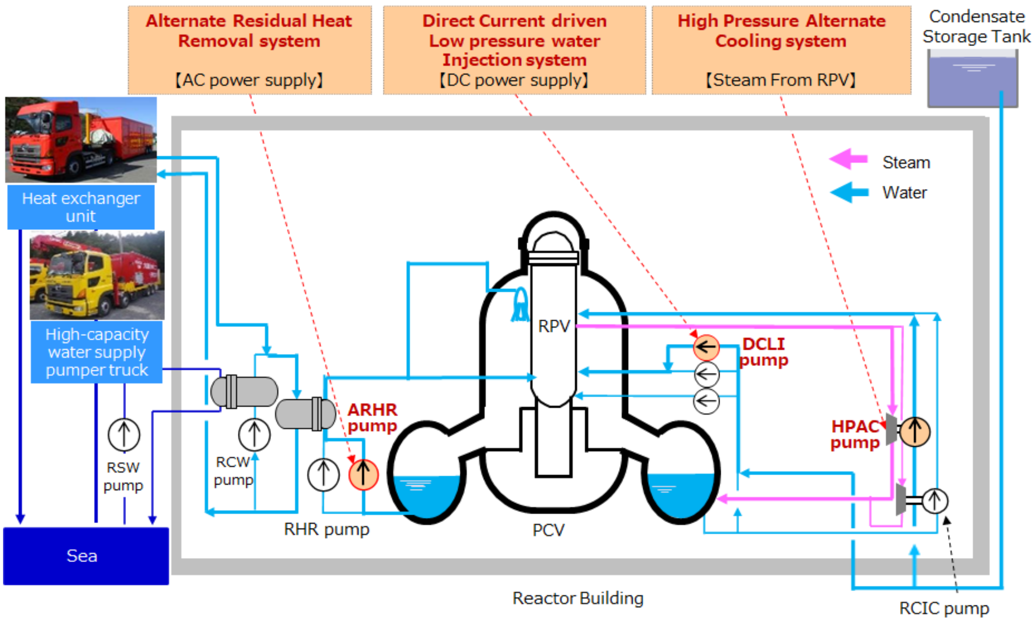

Figure 1. Overview of newly installed water injection or heat removal facilities

3.2. Operation Phase

In Japan, the introduction of risk monitor has been slower than in other countries because on-line maintenance, etc., has not been introduced, and the increase in risk associated with scheduled work is kept low by strict safety regulations and deterministic safety management efforts during plant operation and shutdown. Therefore, the full-scale introduction of risk monitor, etc., was implemented at a slower pace than in other countries. Onagawa NPS introduced risk monitor on a trial basis in the 2000s, and has been working to enhance risk management, especially during shutdowns. As shown in Table 2, risk monitors introduced have been selected based on the software used for PRA modeling at that time and the way the risk monitors were used. Incidentally the latest PRA model for Unit 2 is being developed using CAFTA which is the Computer Aided Fault Tree Analysis system code developed by the Electric Power Research Institute.

For Unit 2, an internal event PRA model is being developed that incorporates the latest findings from Japan and other countries, as well as plant conditions modified by safety measures for the restart of the plant. Examples are shown below.

Table 2. Transition of Risk Assessment Tool for Onagawa Unit 2

Generation	PRA tool	Risk Monitor	Remarks
1st	Toshiba	Toshiba	Originally developed by Toshiba.
2nd	RiskSpectrum PSA[3]	RiskSpectrum RiskWatcher	
3rd (Present)	CAFTA	Phoenix Risk Monitor	Risk monitor is currently being prepared for introduction.

3.2.1. Actions taken by utilizing the outage risk monitor

At Onagawa NPS, several mitigation facilities have been excluded from standby in various combinations due to modification work and other reasons. Therefore, risk assessment has been conducted by utilizing the outage risk monitor.
As shown in Figure 2, Onagawa NPS has established a management guideline for ensuring safety during plant shutdowns as an internal document. In this document, safety management measures during plant shutdowns are defined from both deterministic and probabilistic perspectives. In risk management by risk monitoring, risk assessment results consistent with the latest plant status are always shared within the plant, and risk assessment by risk monitoring is conducted whenever there is a change in the construction process or when a standby exemption occurs for a facility subject to risk monitoring.
If the Core Damage Frequency (CDF) or Fuel Damage Frequency (FDF) exceeds a certain value shown in Table 3, the process is changed or countermeasures are taken.

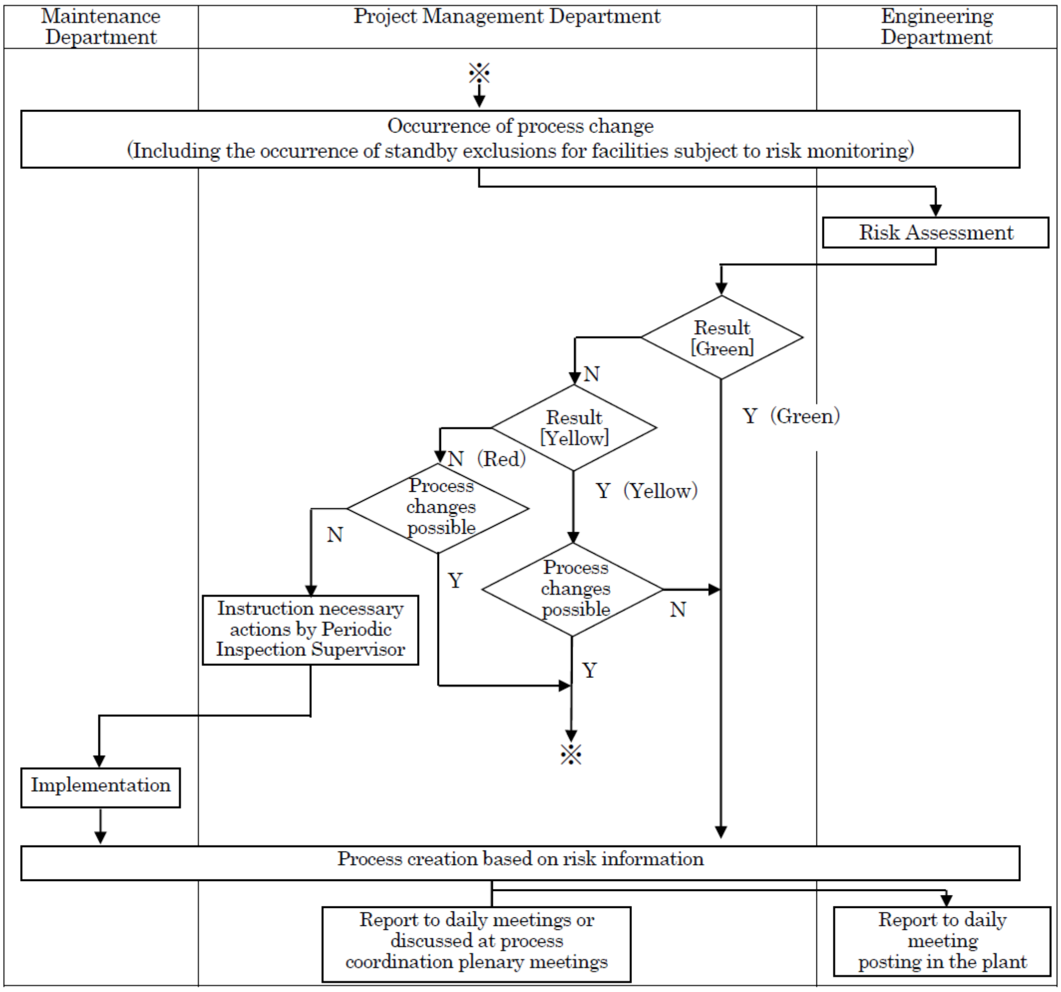

Figure 2. Overview of Outage Risk Management Process

Table 3. Risk Reference Values

Value(X)	Risk Color	Risk Status
X< 1/10 of CDF in operation	Green	Risk is sufficiently low that no special measures are required
1/10 of CDF in operation ≦X ＜Less than CDF in operation	Yellow	A state in which the risk is somewhat high and process changes are recommended to the extent reasonably feasible.
CDF in operation ≦X	Red	A high-risk condition in which process changes should be implemented whenever possible. If process change is not possible, necessary compensation measures should be implemented.

One specific example was the plan to inspect a fire truck, which is a portable water injection system (work of the disaster prevention group), during the same period when the fuel pool cooling and purification system was fully shut down (work of the reactor management group). This resulted in a risk assessment result of level "red," so the reactor management group streamlined and shortened the work process, and the disaster prevention group avoided an increase in risk by performing maintenance on the fire truck after the completion of FPC's fully shut down.
In this way, we are taking risk-conscious measures even during plant shutdowns.

3.2.2 Improvement and upgrading of facilities to be patrolled and patrol perspectives

In order to comply with the new regulatory standards, Onagawa NPS has introduced various new facilities through this modification work. Therefore, it is necessary to properly detect safety-critical equipment malfunctions and to allocate operator resources to these facilities in order to improve plant safety. In view of this, the operation department of Onagawa NPS is working to optimize the targets and frequency of patrols by utilizing risk information obtained from the PRA in addition to determinism.
The operation department is mainly responsible for ensuring that the plant continues to operate stably during normal times. Therefore, the following points of view are taken into account in the patrols

Dynamic equipment in constant operation that is necessary for the stable operation of the plant and that corresponds to the following;

- Equipment related to reactivity control
- Equipment that violates safety regulations when tripped
- Equipment that requires output fluctuation or output suppression operation due to equipment failure

In addition to the above, from the viewpoint of PRA, the target facilities were selected by referring to the recommended values of EPRI and NEI, and considering the values of FV importance and RAW. In addition, during plant operation, the focus is generally placed on the risk of power outage before the risk of core damage. From the PRA perspective, this corresponds to the so-called level 0 PRA, but we have not conducted a level 0 PRA for Onagawa Unit 2. However, it is thought that indirect considerations can be made by utilizing the evaluation of level 1 PRA.
In the level 1 PRA, loss of external power supply, LOCA, and other events are extracted as initiating events, and accident scenario analysis is performed for these events to evaluate the frequency of core damage. Since preventing the occurrence of these events can lead to avoiding reactor shutdowns, the CDF evaluation results for each event are used to select important equipment from the viewpoint of avoiding plant shutdowns. The room temperature exceeded the design conditions of the installed equipment (mainly power supply panels) due to the loss of air conditioning, etc., leading to the loss of multiple mitigation functions, and the auxiliary cooling system, chillers, and air conditioning equipment are important for the plant operation continuity. This indicates that the auxiliary cooling system, chillers, and air-conditioning systems are critical to the plant's operational continuity.

These results are consistent with the selection criteria for priority patrolling areas established by the operation department based on its past experience, and the appropriateness of the operation department's considerations is supported from a risk assessment perspective.
The results of this study are used for the stable operation of the Onagawa NPS through discussions between the operation department and the engineering department, and the locations and contents of patrols are organized and utilized for the stable operation of the plant.

3.2.3. Risk recognition using risk maps

Based on the results of PRA evaluation, efforts are being made to color-code and visualize equipment on equipment layout maps according to risk severity. This provides the risk assessment department to the operation and maintenance department with information on systems and facilities that should be protected because loss of function causes a large increase in CDF, and systems and facilities that should be strengthened through patrol inspections, etc. because improved reliability contributes greatly to reducing CDF.

3.2.4. Others

Modeling of the MAAP[4] code for Unit 2 was conducted for use in Success Criteria Analysis. We have also developed our own system, "Integrated Analysis System for Disaster Prevention"[5] using this model, and are promoting its use in disaster prevention drills and other activities.

4. CONCLUSION

Onagawa NPS is scheduled to restart this year for the first time in 13 years. It is the responsibility of those of us engaged in nuclear power generation to keep a close watch on various risks and continue our efforts to improve plant safety. In the future, we will not only continue to utilize the various types of risk information reported in this paper, but also broaden the scope of risk information utilization to achieve further safety improvements.

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