Tsunami PRA Standard Development by Atomic Energy Society Japan (AESJ) (4) Unresolved Issues and Future Works

Akira Yamaguchi[a*], Yukihiro Kirimoto[b], Katsumi Ebisawa[c]
[a]Osaka University, Osaka, Japan
[b]Central Research Institute of Electric Power Industry (CRIEPI), Tokyo, Japan
[c]Japan Nuclear Energy Safety Organization (JNES), Tokyo, Japan

Abstract: Following the Fukushima Dai-ichi nuclear power plant accident on March 11, 2011, the Atomic Energy Society of Japan (AESJ) started to develop the standard of Tsunami Probabilistic Risk Assessment (PRA) for nuclear power plants in May 2011. The tsunami PRA standard development has been completed and published in December, 2011. As is known, tsunami PRA standard has never been developed worldwide. The AESJ has decided to start the tsunami PRA standard development from the base line. Apparently there exist significant uncertainties in every step of the tsunami PRA and some assumptions and premises are introduced. However, a rough estimate of the tsunami risk is essential for the nuclear safety and our group has decided to take multi-stage development of the tsunami PRA standard. In the first stage, the root cause of tsunami is assumed to be earthquakes. Although the nuclear power plant will be influenced by the tsunami as well as earthquake in advance, it is assumed that the safety-related structures systems and components are not damaged by the earthquake. Questions and discussions are brought up and several unresolved issues have been identified with regard to the tsunami PRA technology. The authors discuss in the present paper the unresolved issues and future works in the tsunami PRA standard and related technologies.

Keywords: Tsunami PRA, PRA Standard, .

1. INTRODUCTION

Facing the Fukushima Dai-ichi nuclear power plant accident on March 11, 2011, the Atomic Energy Society of Japan (AESJ) recognized urgent necessity of the tsunami Probabilistic Risk Assessment (PRA) for nuclear power plants. Urgent request is to develop the tsunami PRA standard immediately so as to certify currently operating NPPs have enough capacity to manage the tsunami risk. Accordingly, the Tsunami PRA Subcommittee has been established under the Risk Technology Committee (RTC) of the Standard Committee (SC) in May 2011. The RTC requested the Tsunami PRA Subcommittee to develop the standard by the end of 2011. At the same time, we have noticed that there are many unresolved issues in the tsunami PRA methodology and data. The tsunami PRA standard cannot be perfect in the first version within the limited short time period. The Tsunami PRA Subcommittee has decided to develop the base line standard for the Tsunami PRA, which involves, however, all the essential engineering and scientific aspect of nuclear safety for extreme external events. Through eight-month investigation and discussion, the tsunami PRA standard has been completed and published in December, 2011 as requested by the RTC and as most of us expected. [1]

We ask for comments from the RTC and SC after the draft version of the Tsunami PRA standard is completed. In response to the comments, the draft standard was modified and updated. As to some essential points that cannot be solved concurrently, the Subcommittee discussed and presented the near-term and mid-term processes for solution. It mentions in the first stage of the tsunami PRA development, it deals with a single tsunami risk alone. No load combination with an earthquake is considered as well as other earthquake initiated event loads is considered. Putting the premises, the improvement of the standard is completed in response to the comments. Then, it moved to the voting process in the RTC and SC. The next step is to accept public comments. According to the AESJ rule, every standard issued by the AESJ is opened to public and subject to public comments. It is the final process for the standard publication.

The members of Tsunami PRA Subcommittee discussed the scope and the boundary condition of the standard. As is known, tsunami PRA standard has never been developed worldwide. Limited experience has been accumulated on tsunami PRA as a part of the seismic PSA (see JNES reports [2], [3]). Apparently there exist significant uncertainties in every step of the tsunami PRA and some assumptions and premises are introduced. However, an estimate of the tsunami risk even if it may be preliminary is essential for the nuclear safety and our group has decided to take multi-stage development strategy of the tsunami PRA standard.

Premises used in the first stage are: the root cause of tsunami is assumed to be earthquakes; although the nuclear power plant will be influenced by a tsunami as well as an earthquake in advance, it is assumed that the safety-related structures systems and components (SSCs) are not damaged by the earthquake itself. During the discussions on the premises, questions and discussions are brought up and several unresolved issues have been identified with regard to the tsunami PRA technology.

In the development tsunami PRA standard, a commentary chapter is prepared, in which the premises, assumptions and future works, i.e. the unresolved issues are described and discussed. In the process of the standard development, the combination of earthquake load and the tsunami is one of the most critical issues. Although the standard for the seismic PRA [4] has already been developed, almost no investigation on the plant response and fragilities from the view point of the tsunami scenario that follows. It is a matter of course that there are several engineering and technological issues that requires simplification to assume that the seismic effect and tsunami effect are independent each other.

Apparently there exist significant uncertainties in every step of the tsunami PRA and some assumptions and premises are introduced. However, a rough estimate of the tsunami risk is essential for the nuclear safety and our group has decided to take multi-stage development of the tsunami PRA standard. In the first stage, the root cause of tsunami is assumed to be earthquakes and the safety-related SSCs and other major equipment are kept functional after the earthquake. The nuclear power plant will be influenced by the tsunami as well as by the preceding earthquake. As a matter of course, several unresolved issues are brought up. The authors discuss in the present paper the unresolved issues and future works in the tsunami PRA technology.

The background of the tsunami PRA standard development is described in the Preface of the standard. It is cited in Appendix.

2. SCOPE OF APPLICATION OF THE TSUNAMI PRA STANDARD

The Tsunami PRA Standard defines the scope of application in one of the opening chapters. It covers the core damage scenarios in the commercial light water reactors in operation. The initiator of the accident is a tsunami that is caused by earthquakes. The nuclear power plant is in power operation condition when an earthquake occurs.

According to the earthquake and/or tsunami alarms, it is considered that the reactor is in a safe shutdown. The first important assumption is that the earthquake itself does not influence the safety function of the NPP. In other words, the safety-related SSCs for the reactivity control, core cooling, and containment of the fission products are all intact. It is the premise, “no direct effect by earthquakes.”

However, we consider one exception. The seismic capacity of the off-site power grid system is not so high as most of us expect in comparison to the safety-related SSCs. In the 2011 earthquake off the Pacific coast of Tohoku, the off-site power of the Fukushima Dai-ichi nuclear power plants were lost by the earthquake although the safety-related SSCs had successfully operated and the safety functions were intact. The fact tells us that some earthquakes that may cause a significant tsunami possibly deteriorate the off-site power supply system. Therefore, the standard requires a additional assessment of the tsunami risk on condition that the availability of the off-site power is lost before the tsunami attacks the NPP site.

The standard is applicable to the sodium-cooled reactor as well. The Japanese nuclear energy policy is that the closed nuclear fuel cycle with the fast reactor development. A sodium cooled fast reactor Monju is waiting for the restart-up and power escalation to the rated power 714MWth or 280MWe. It should be noted that the specific design features of the sodium cooled reactor are different from those of the light water reactor. Major difference is the front line systems which use liquid sodium as the coolant and the coolant pressure is approximately only several times of the atmospheric pressure. AC power is not required for the decay heat removal because of high natural circulation capability. The boiling point of the liquid sodium is higher than 1100K. Therefore the coolant injection and system depressurization are not the essential part of the accident mitigation. On the other hand, the functions of the support systems are similar to those of the light water reactors. At any rate the safety characteristics of the sodium cooled reactor and the location arrangement of safety-related SSCs are to be taken into consideration carefully to apply the standard to another type of reactor.

3. DISCUSSION OF SCOPE AND LIMITATION OF TSUNAMI PRA STANDARD

3.1 Multi-Step Approach in Response to the Fukushima Dai-ichi NPP Accident

We have many lessons-learned from the Fukushima Dai-ichi NPP accident. The most important one from the viewpoint of the risk assessment is the necessity of the tsunami consideration and investigation of other external events in the PRA. In addition, we have learned that the earthquake and loss of the off-site power preceded the tsunami. The most probable cause of tsunami is undersea earthquakes in near or far field. Therefore, it is a matter of course to consider the coupling effect of the earthquake and tsunami.

Another point is earthquake and tsunami risk in reactor shutdown conditions. The unit 5 and 6 are in shutdown for refueling on Marh11, 2011. The unit 4 was also in a shutdown condition. What is different is all the fuel assemblies are unloaded and transferred to the spent fuel pool to replace the reactor vessel shroud. In the shutdown condition for refueling and maintenance, some safety systems may be out of service. Watertight doors and openings may not be closed. It is well understood that the internal event risk in reactor shutdown conditions is not recognized and sometimes comparable to the risk of reactors in power operation. Similarly, the external event risk in reactor shutdown conditions should be investigated in detail.

Spent fuel pool risk is another safety concern. Generally, the decay heat in the spent fuel pool is quite small and the maintenance of water level in the pool is sufficient for the cooling the spent fuels. However, the inventory of the fuel and fission products is much larger than in the reactor core. It is necessary to estimate the spent fuel pool risk in the framework of the PRA.

In the Onagawa nuclear power plant of Tohoku Electric Power Co. Inc., a fire was induced by the earthquake in a transformer in 2011 earthquake off the Pacific coast of Tohoku. Five years ago in 2007, the Tyuetsu Offshore Earthquake triggered a fire of a station service transformer of Kashiwazaki-Kariwa nuclear power plant. It is well understood that the possibility of the seismic induced fire especially of non-safety grade equipment is not excluded. In addition, an earthquake can trigger not only a fire but also other secondary events such as flooding and so on.

As we discussed, we have to establish a framework of the full scope PRA for external events. Narumiya and Kuramoto[5] discuss how to select risk-dominant external events in a systematic way. Several external events are mutually related. For example, the RTC has completed the draft standard of the internal flooding PRA. However, it mentions that the earthquake-induced flooding is the out of scope of the standard. The seismic-induced flooding is the cross-point of the seismic risk and internal flood risk. Since some external events may induce multiple failure and another external event.

On the basis of the consideration mentioned above, the RTC of the AESJ has decided to take a multi-stage approach for the development of the external event PRA standards.

(1) The first sage is to develop the tsunami PRA standard in which coupling of the earthquake and the tsunami is not considered (no direct effect of earthquake).
(2) The second stage is to develop or modify the PRA standard for the coupled earthquake and tsunami.
(3) The third stage is to develop other external event PRA standard such as fire, volcano and so on according to the risk significance. If an external event is less significant, other simplified approach may be developed.
(4) The fourth stage is the consideration of the coupled external event risk. Examples are seismic induced fire and seismic-induced flooding. At the same time, level 2 and level 3 PRAs, shutdown PRA,spent fuel pool consideration are the tasks in this stage.

In parallel, the necessity of the shutdown PRA, level 2 and level 3 PRAs for the external events is under discussion. The other points are the spent fuel pool risk and multi-unit consideration. These points are under discussion presently and will be the task in the fourth stage.

Another point is that the Japanese regulatory authority, NISA required the utilities to implement Emergency Safety Measures for currently operating nuclear power stations on March 30, 2011, three weeks after "the March 11". [6] Additional vital power and alternative cooling equipment and others have been introduced already, which contributes considerably to reduce the risk fot the station black out and the loss of ultimate heat sink caused by earthquake and tsunami. The emergency measures have to be taken into account in the current level 1 PRA and seismic PRA. Therefore, the level 1 PRA standard [7] and seismic PRA standard [4] must be updated so that the up-to-date safety are appropriately evaluated.

3.2 No Direct Effect by Earthquake

The premise is that the three fundamental safety functions are maintained after the earthquake. First of all, the control rods are inserted and the reactor power is under control. Secondly, systems for cooling the reactor core are functional. Lastly, the containment capability is intact. In addition to them, supporting systems such as the power supply and ultimate heat sink are also available. It is considered that the reactor is automatically shut down by the excessive earthquake signal when a tsunami attacks the NPP because the reactor protection system is required to be actuated within a few seconds. In general, it takes more than ten minutes for a tsunami reached the NPS and a tsunami alarm will be activated. Therefore, it is reasonable to assume that there is sufficient time to actuate the reactor protection system. Accident sequences in which the reactor shutdown fails are already counted in the seismic PRA. Therefore, it is accepted to assume that the reactor is already shut down when the tsunami attack the NPS.

Reactor core cooling function and the containment function are based on the safety-grade design and seismic importance class is high. Thus the systems are supposed to survive earthquakes. If the earthquake is extremely significant, safety-related SCCs may fail. However, the risk induced by the extreme earthquake in which those safety functions would be lost should have been already considered in the seismic PRA. It is the basic idea that we consider the earthquake and tsunami are separately treated in the PRA.

Based on the premise, the following points are to be taken into consideration in the tsunami PRA. Since one may have sufficient time to be prepared for the tsunami attack. Usually, after an earthquake, tsunami alarm is generated and they can foresee when the tsunami is expected to come and what the magnitude of the tsunami is. Making the most use of the time, they may perform accident management actions for the power supply, water source, confirmation of water-tightness and so on. On the other hand, if the available time is not large enough, the evacuation of the workers and operators to a safe place may be considered. Consideration of preparation and management for the risk reduction of coming tsunami is largely dependent on the available time. In the first step of Tsunami PRA standard development, no preparation and management in advance is taken into account.

The coupling of the earthquake and the tsunami should be considered only when supporting systems and equipment which may fail at relatively low intensity earthquake and some added equipment and structures to enhance the water-tightness. In this case the coupled seismic and tsunami PRA is necessary.

3.3 Consideration of Loss of Off-site Power

Once a large earthquake occurs, the likelihood of the loss of offsite power is not always low. We remind that the offsite power in Fukushima Dai-ichi NPP was lost for all the units. Various causes are considered such as the ceramic insulator failure, circuit breaker failure, and so on. Although some of the failures can be protected on site, the root causes of others are attributed to the off-site factors such as substations and transmission line with regards to the power distribution grid. Therefore, it is not appropriate to rely on the offsite power excessively.

In the previous section, we assumed no direct effect by the earthquake. However, it seems reasonable to consider a loss of function as far as the offsite power is concerned. It is required in the tsunami PRA standards to perform the comparative analysis by assuming that the offsite power is lost by the earthquake. The comparative study will give us important insights concerning the robustness of the electrical power supply system of the NPP. It is not allowed to depend on the availability and the recovery of the offsite power excessively.

It is noted that the seismic fragility of the offsite power system is evaluated in the seismic PRA. We can use the seismic PRA result to judge the availability of the offsite power after an earthquake. However, the hazard curve for the seismic PRA is evaluated as a function of the intensity of the ground motion such as the peak ground acceleration. On the other hand, the hazard parameter for the tsunami PRA is the tsunami height. The tsunami height is a function of the earthquake magnitude, and distance from the epicentre, characteristics of the tsunami generation and propagation. A small earthquake can generate a tsunami of large magnitude. No matter how large an earthquake is, the tsunami height is not always significant. Therefore, the seismic fragility of the offsite power system cannot be used as the tsunami fragility. It is the reason that the tsunami PRA standard requires an additional evaluation of tsunami risk assuming loss of offsite power.

3.4 External Event Combination

An earthquake may be a cause of various secondary dependent events. A seismic event induces multiple failures of safety systems. Currently the Japanese Regulatory Guide[i] defines and requires the consideration of two seismic-induced secondary events. One is the possible collapse of the surrounding ground above the foundations. The other is the tsunami which is reasonably postulated during the service period.

The RTC of the AESJ considers the fire PRA and the flooding PRA are of great importance for external events. Seismic-induced fire and seismic-induced flooding would be considered as well. If we perform the seismic induced fire and flooding PRAs, we need to complete independent fire PRA and internal flooding PRA in advance. The internal flooding PRA standard is to be published in 2012. The fire PRA standard subcommittee will start the activity in 2012. However at present, the PRA standards for all the external events have not been completed. Taking into consideration of the current situation of PRA standard development, it is practical to develop the independent external event PRA standards and perform the individual external event PRA first of all. Our approach is to establish the line-up of the external PRA standards followed by the consideration of the coupled phenomena of the earthquake and other secondary events. Accordingly the earthquake and tsunami combination are excluded from the present tsunami PRA standard.

The necessity of other external event PRAs is to be judged on the basis of the occurrence frequency and the importance from the viewpoints of risk. Then the likelihood of the concurrency of external events will be studied to identify the dominant multiple external event scenario. The first priority is to be placed on the combined effect of the earthquake and tsunami. Then we develop the internal flooding PRA and fire PRA standards. The combinations of earthquake and flooding and fire are considered in the combined PRA. Furthermore, the necessity of other external event PRAs will be investigated. According to the investigation, the strategy of the standard development will be established. The coupled external event PRAs are to be investigated

Major concerns of the combined earthquake and tsunami PRA are possibilities of the seismic failure of SSCs, loss of function or deterioration of infrastructure such as the power supply system and communication system. Furthermore, the deterioration of the accessibility for the operators and workers is to be considered in case that the human recovery actions are taken into account.

3.5 Level 2 PRA, Level 3 PRA and Shutdown PRA

The tsunami PRA standard describes the level 1 PRA for reactors in power operation. However, it does not mean the level 2 and level 3 PRAs specific to the external events are excluded or merged to the level 2 and 3 PRAs for internal events. The AESJ has published AESJ-SC-P009 [7] for the level 2 PRA standard and AESJ-SC-P010 [8] for the level 3 PRA standard caused by internal events, respectively. The RTC of the AESJ will discuss to decide the necessity to develop standards for the tsunami initiated level 2 PRA and level 3 PRA. If the level 2 and level 3 PRA standards for the internal events are applicable to the external events, they are to be referred as the citation standards in the tsunami PRA standard. It depends on the consideration if the tsunami has specific features in terms of the fission product release, containment performance and the off-site emergency preparedness.

The shutdown PRA methodology for internal events has been developed and described in AESJ-SC-P001.[9] Shutdown PRA for tsunami is probably needs to be considered. One of the practical and efficient tsunami protections is to keep the safety-related SSCs away from the tsunami water. For this purpose, watertight, water-resist and water-proof concepts are introduced in the safety design of the nuclear power plant. However, during the shutdown situations, the equipment hatch and watertight doors may be open although the little thermal power is generated in the core. It is noted that currently operating nuclear power plant in Japan has equipped back-up AC power and heat sink that is very independent from the safety -grade equipment such as emergency diesel generators and seawater pumps. In general, the shutdown PRA for external events is questionable issue and the necessity of the shutdown PRA standards for external events is to be discussed continuously.

3.6 Risk Assessment of Spent Fuel Pool

It has been recognized that the risk caused by the spent fuel pool should be taken into account. At the same time, it is considered that the spent fuel pool risk is less significant than the reactor itself. In the Fukushima Dai-ichi NPP accident, we have experienced the difficulty in the spent fuel pool cooling. The difficulty comes from the hydrogen explosion and the accessibility were extremely deteriorated. It is considered that the spent fuel pool risk is well supressed to a low level if the core damage risk in the reactor is in a low level. Furthermore, the technological requirement, quantification methodology, and data are scare to complete the spent fuel pool risk assessment. Therefore, the risk assessment of the spent fuel pool is not included in the present standard.

3.7 Applicability to the Generation IV Reactor

Although the tsunami PRA standard is developed for the commercial light water reactors, basic idea and methodology is common to the generation IV reactors such as the sodium cooled reactor and gas cooled reactors. It is noted the characteristics from the safety viewpoints specific to the reactor type should be investigated carefully and taken into account in the evaluation of the tsunami fragilities and the systems analysis. For example, the sodium cooled fast reactor Monju has the capability of completely natural circulation cooling and no vital power equipment is necessary for the decay heat removal. On the other hand, it has sodium tanks on the basement and sodium loops exists in the auxiliary building. The liquid sodium freezes at the room temperature. Hence the coolant temperature must be kept above ~150C. However, the severe accident scenarios initiated by tsunamis depends on the location of the safety-related SSC and the tsunami effect propagation root basically. It is the reason that the standard can applicable to the generation IV reactors.

4. CONCLUSION

The Tsunami PRA standard has been established by the AESJ in December 2011. It is based on the up-to-date knowledge and methodologies for the tsunami characteristics and the NPP response and fragility to the tsunami. However, new findings are being obtained from the 2011 East Japan Great Earthquake and the Fukushima Dai-ich NPP accident. Because of the limited knowledge and less experience in the tsunami PRA, some simplifications are made in the PRA procedure. In the present paper, the authors summarize the limitation and the future works on the tsunami PRA standard. The AESJ continues the activity of the Tsunami PRA Subcommittee and the standard is in the process of update.

In the process of the Tsunami PRA standard, many question and comments are raised from members of the Standards Committee (SC), the Risk Technical Committee (RTC) and the Tsunami PRA Subcommittee of the AESJ as well as other researchers in various fields such as earthquake and tsunami engineers, seismologist, nuclear and safety engineers, etc. It comes from the premises and assumption that the nuclear power plant is not damaged nor deteriorated by the earthquake. We continuously perform the activity of the Tsunami PRA Subcommittee even after the completion of the standard. We need to answer to the questions raised. One example of such is the combination of earthquake and tsunami since a tsunami follows an earthquake.

The authors hope the tsunami PRA standard is to be made most use of by licensees as well as the regulatory body to ensure that the emergency preparation[5] that is ordered by the regulator immediately after the accident is effective protect the accident progression and practically suppress the risk of severe accident considerably. Also our expectation is that the PRA be the communication tool to other stakeholders such as public, local government, and specialists with expertise in individual field. The authors discuss in the present paper the unresolved issues and future works in the tsunami PRA standard and related technologies. According to the insights, the tsunami PRA standard is to be updated.

Acknowledgements

The authors appreciate the contribution from the members of the Tsunami PRA subcommittee of the AESJ.

References

[1] AESJ-SC-RK004:2011, A standard for Procedure of Tsunami Probabilistic Risk Assessment (PRA) for nuclear power plants, December 2011 (in Japanese)

[2] Improvement of seismic PSA methodology - Preliminary analysis of severe accident sequence for recent 3 loop-type PWR, Japan Nuclear Energy Safety Organization (JNES) report, Dec. 2010 (in Japanese)

[3] Improvement of seismic PSA methodology - Preliminary analysis of severe accident sequence for BWR, Japan Nuclear Energy Safety Organization (JNES) report, Dec. 2010 (in Japanese).

[4] AESJ-SC-P006, A Standard for Procedures of Seismic Probabilistic Safety Assessment for Nuclear Power Plant, the Atomic Energy Society of Japan, September 2007 (in Japanese).

[5] Narumiya, Y. and Kuramaoto, T., a paper presented in PSAM11

[6] AESJ-SC-P008, The Standard for Procedures of Probabilistic Safety Assessment of Nuclear Power Plants during Power Operation (Level 1 PSA)：2008, AESJ, March 2009 (in Japanese).

[7] AESJ-SC-P009, The Standard for Procedures of Probabilistic Safety Assessment of Nuclear Power Plants during Power Operation (Level 2 PSA)：2008, AESJ, March 2009 (in Japanese).

[8] AESJ-SC-P010, The Standard for Procedures of Probabilistic Safety Assessment of Nuclear Power Plants (Level 3 PSA)：2008, AESJ, March 2009 (in Japanese).

[9] AESJ-SC-P001, A Procedures Guide for Probabilistic Safety Assessment of Nuclear Power Plants during Shutdown Conditions：2002, AESJ, February 2002 (in Japanese).

[10] On Implementation of Emergency Safety Measures at Other Nuclear Power Stations Based on Accident at Fukushima Dai-ichi and Dai-ni NPSs, the Nuclear and Industrial Safety Agency, March 30, 2011

Appendix

The following is citation from the Tsunami PRA Standard which describe the background and contents of the standard briefly.

FORWARD OF TSUNAMI PRA STANDARD

A standard for Procedure of Tsunami Probabilistic Risk Assessment (PRA) for nuclear power plants 2011 has been established and issued by the Atomic Energy Society of Japan (AESJ) through the discussion at the Tsunami PRA Subcommittee under the Risk Technical Committee of the Standards Committee. The standard defines the procedure which specifies the requirement and the concrete method of the PRA regarding incidents resulting from tsunamis as the initiating events at nuclear power plants during power operation.

The mission of the Standards Committee (SC) and the Risk Technical Committee (RTC) is the establishment and publication of criteria/guidelines with regard to probabilistic assessment of the risk caused by incidents. In this respect, March 11 of 2011 is the day that should be engraved in the heart of the committee members. The 2011 earthquake off the Pacific coast of Tohoku occurred at 14:46:18 Japan Standard Time on March 11. Approximately in 40minutes, the first tsunami struck the Fukushima Dai-ichi Nuclear Power Station (NPS). Consecutively, other tsunamis rushed one after another, which resulted in the station black out and loss of ultimate heat sink in the units 1-4 of the Fukushima Dai-ichi NPS. Without recovery of the AC power, the reactor cores were seriously damaged and the nuclear fuel melted which lead to the radioactive material release to environment. To make the matter worse, the hydrogen detonation in the reactor building took place which provoked the continuous loss of cooling capability and controllability in the reactor core as well as the spent fuel pool.

The SC and the RTC of the AESJ has announced the press release in light of the serious accident to establish the Tsunami PRA Subcommittee and to develop a standard for Tsunami PRA procedures. It indicates the understanding of the SC and the RTC that the tsunami risk should be emphasized and developed with the highest priority. Japanese nuclear facilities are subject to the external hazard risk such as an earthquake and associated incidents with the earthquake. It is noticed that a comprehensive risk assessment related to both the internal and external events should be required.

The PRA for nuclear power plants evaluates the safety of a nuclear power plant in a comprehensive and quantitative manner using the probabilistic methodology. As mentioned above, the PRA for nuclear power plants can be roughly classified into two groups according to the characteristics of the initiating events; one for internal events, which result from equipment failure occurring inside of the power generation system and human errors and the other for external events, which result from earthquakes and fires, etc. The PRA focuses on the events which lead to core damage or large amount of fuel failure, identifies the accident scenarios which result in failure and development of events following the failure, and estimates frequencies of each event and its effect. The PRA methodology has been recognized as the effective mean which can support the decision making process in the fields of safety design, operation management and safety regulations.

As Japan is one of the countries with frequent earthquakes, a great deal of efforts has been made in the field of seismic research since the early stage. By association, researches on the tsunami generation, propagation and induced damage have been published. The accumulation of seismic research results has been incorporated in the seismic design of nuclear power plants and analytical methods have been improved accordingly and "**AESJ-SC-P006** A standard for Procedure of Seismic Probabilistic Safety Assessment (PSA) for nuclear power plants 2007" has been published in March 2007. The Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities has been published by the Nuclear Safety Commission in September 2006 in which the residual risk quantification is strongly suggested. The Japan Society of Civil Engineers issued a report that sets up the re-evaluation of design tsunami height of the nuclear power plants. To our regret, the PRA procedures guide for tsunami has not yet been developed although the importance is held in mind of the PRA community.

Accordingly, we hereby institute a standard to specify the standardized procedure for tsunami PRA considering the results of investigation into the concept, the requirements which should have and the concrete methods regarding tsunami PRA referring the opinions of experts in the associated fields.

---

[i] NSCRG: L-DS-I.02 Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities, The Nuclear Safety Commission of Japan, 1978 (latest update in 2006)