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# STRATEGY OF AESJ FOR PRA STANDARDS DEVELOPMENT AND MAINTENANCE

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*The Risk Technical Committee (RTC) in the Standards Committee of Atomic Energy Society of Japan has developed and revised many implementation standards related to the PRA methods and its application. RTC published 13 standards until the end of 2015. L1PRA standard, L2PRA standard, L3PRA standard, Estimation Standard of PRA Parameters and Shutdown PRA Standard were published. In addition, the external events, i.e. the earthquake, the tsunami, the internal fire, the internal flooding, PRA standards were published. And Methodology selection standard for the external hazards was developed for considering lots of external events other than earthquake or tsunami. Ensuring PRA Quality standard and Terms & Definitions standard were developed in the first step for PRA application.*

*Now, RTC tries to progress next step. It is second phase for expansion of PRA standard category to compound events, external events L2PRA, SFP and multi-units PRA. However lots of matters are noticed in the development of these PRA Standards. In this report, the strategic plans to find out solution of each matter are provided.*

## I. INTRODUCTION

The paper presents the achievements of the PRA standards development by RTC in the Standards Committee (hereafter, SC) of Atomic Energy Society of Japan (hereafter, AESJ) and the improvement strategy of PRA standards for future risk-informed activities of Japanese utilities. RTC has been positively promoting the formulation of various kinds of PRA Standards to provide "technical basis" which plays an important role in ensuring the quality of PRA. The numbers of PRA standards reached 13. Precisely, 12 standards and one case study were released, but in this paper they are called "standards" in a simple manner. The scope of PRA standards covers from L1PRA to L3PRA. Initiating hazards include almost main ones, e.g. internal events, earthquake, tsunami, internal fire and internal flooding. The plant operational states are at-power and shutdown. These PRA standards were referred in safety analysis reports for applications of new regulatory requirements. On the other hand, PRA standards are advancing to the next stage. RTC has a plan to improve PRA standards to be performance requirements.

## II. DEVELOPING SHORT HISTORY OF PRA STANDARDS

### II.A. Organization of AESJ Standard Committee

Japanese three academic societies, the AESJ, the Japan Society of Mechanical Engineers (JSME), and the Japan Electric Association (JEA) developed the organizations aimed to formulate nongovernmental standards and began to define them. This approach was practiced with the principle of fairness, impartiality, and transparency. In September 1999, the AESJ developed SC to formulate "standards" describing the consented matters about techniques used in a wide range of activities of design, construction, operation, and decommissioning measures for the nuclear power plants.

The development of PRA Standards was originally conducted by Power Reactor Technical Committee, but after revision of the organization in 2008, RTC was founded under SC to specifically work on the PRA Standards. The organization of SC is shown in Fig. 1(Ref.1). Currently five subcommittees and two working groups (WG) are organized under RTC. Each subcommittee is responsible for development, maintenance, revision and education of the some standards under its jurisdiction. Also the missions of Steering Task are planning the future development of PRA standards, improving quality of existing PRA standards based on insight thorough applying them to safety activities in NPPs.

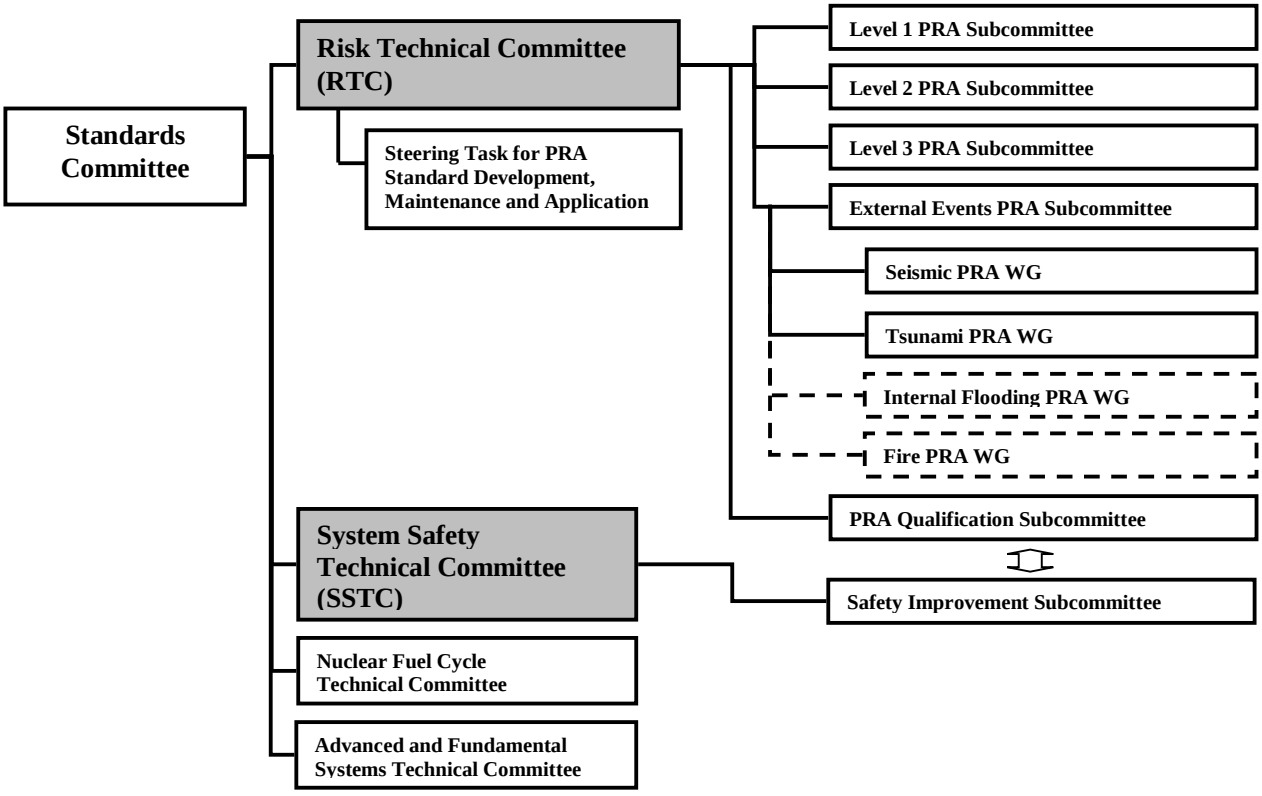



Fig. 1. Standards Committee organization chart for PRA standards development (2016)

The PRA was a distinctive method to show comprehensive safety by means of quantitative indexes with uncertainty. Each PRA standard has some specific steps of methodology, e.g. seismic fragility analysis in Seismic PRA. These were causes of developing separated subcommittees. Thus, the effects of separated subcommittee were to incorporate more expertise and to speed-up the process, and to perfect the discussion. On the other hand, because the initial events used in the PRA procedure include not only internal hazards, such as facility malfunction and human error, but also external hazards, such as earthquake, tsunami, and fire, the technical experts related to these events were also requested to participate to the subcommittee. Such kind of a variety of special knowledge is necessary for the discussions in the meeting, architecture and fuel cycle facility specialists were also called.

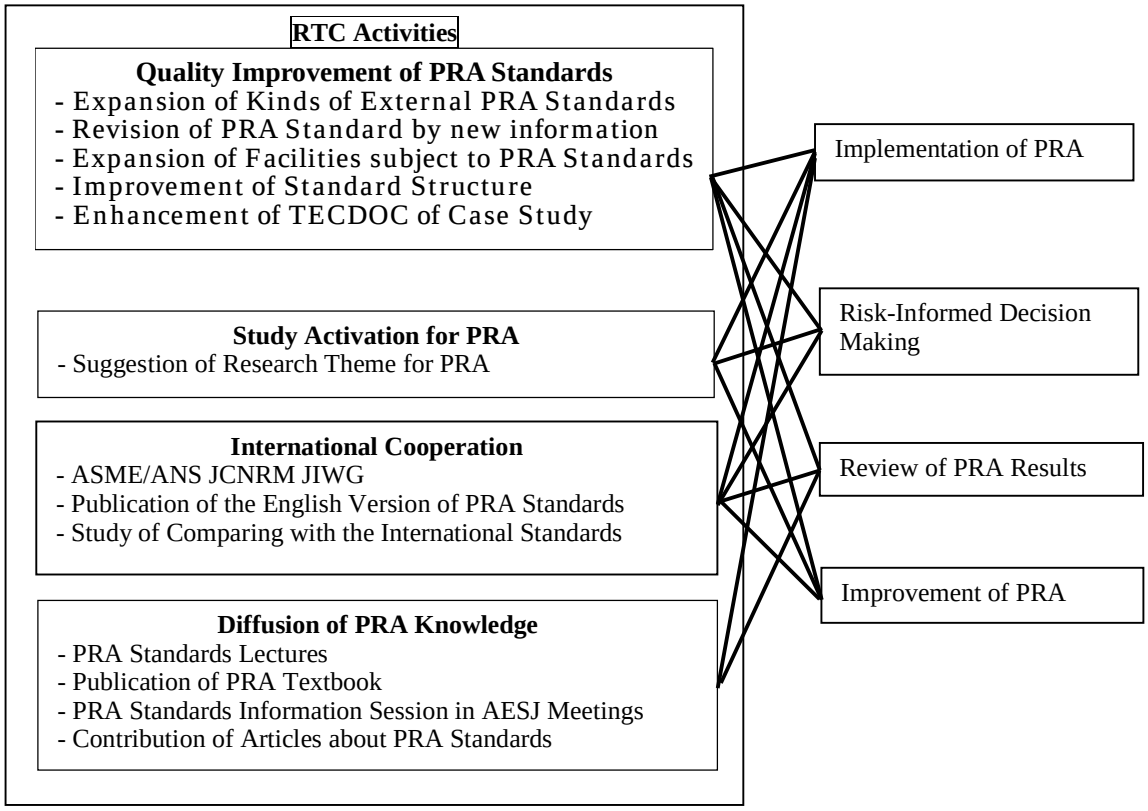
Currently, each subcommittee does not have one PRA standard. The scope of the Level 1 PRA subcommittee is expanded to formulate the Level 1 PRA standard, the PRA parameter estimation standard, and the shutdown PRA standard. The external events PRA subcommittee treats development/maintenance of the seismic PRA standard, the tsunami PRA standard, the internal fire PRA standard, the internal flooding PRA standard and the external events selection standard. And the external events PRA subcommittee is expected to develop the standards about complex events PRA, e.g. earthquake induced fire PRA through discussion with fire experts and seismic experts.

On June 2016, SC moved the risk application guideline subcommittee from RTC to System Safety Technical Committee (SSTC) and changed its name to Safety Improvement subcommittee. The purpose of the new subcommittee is an implementation standard for RIDM. RTC's role is PRA qualification for RIDM.

### II.B. Purpose and Position of PRA Standards

The first Standard undertaken by the Power Reactor Technical Committee (of the day) was the shutdown PSA procedure (the title of the day). At that time, the implementation of the shutdown risk assessment was being introduced in the Periodic Safety Review (PSR), so that the standard was formulated to ensure its quality. Later, along with the NSC's examination on safety goals and then performance objectives (Ref.2, 3), the formulation of Level 1 PRA Standard, Level 2 PRA Standard was undertaken, and then Level 3 PRA Standard followed to those. In this way, the standards have been developed

preferentially from the required fields. When the standards were extended to L3 PRA Standard, the PRA methods for the internal events ranged from core damage to emission of radioactive substances causing environmental influence in all operation status (during power generating operation, shutdown) were developed.




Fig, 2. RTC Activities

On the other hand, NISA and Japan Nuclear Energy Safety Organization (hereafter, JNES) published the quality guideline (Ref.4) which defines technical validity of PRA to prepare for the utilization of risk information. This guideline describes the requirements regarding the quality provided in PRA, so that the AESJ's PRA Standards become the specification code which materializes the performance codes described in this guideline. There are several ways to utilize PRA. If the utilities desire to assess the safety or to know the weak points of NPPs, the objective validity of the assessment can be ensured by conducting PRA according to the AESJ PRA Standard procedure. Regulating authority can also examine the conformity to PRA standards and demonstrate the achievement of technical evaluation/endorsement in PRA reviews. In the revision of NSC's "Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revised on September 2006)", necessity of quantitative risk assessment on earthquake was discussed, and as the result of this, Seismic PSA subcommittee was developed to extend PRA Standards to the external events.

The purpose consistent to these PRA Standards is "to demonstrate the matters examined and consented under the principles of fairness, impartiality, and transparency for the purpose of utilizing PRA procedures and risk information obtained from them". By using the PRA Standards developed according to this purpose, the following advantages can be obtained. The main activities of RTC are showed in Fig. 2.

- The latest PRA technique having the suitable quality will be available.
- The validity of conducted PRA can be demonstrated objectively by demonstrating its conformity to the academic society's standard.
- When reviewing the PRA validity, the part conformed to the Standard can be simplified in the review.
- If newly developed or revised methods or data are available, standardization can be achieved by submitting to the subcommittees.

After the severe accidents at Fukushima Daiichi nuclear power plants caused by the 2011 off the Pacific coast of Tohoku Earthquake and huge tsunami, the Nuclear Regulation Authority (NRA), new regulatory organization, made new regulatory requirements especially focused severe accidents and external events. There has been growing demands for assessing the effects of external hazards, such as earthquake and tsunami, and taking counter measures to address those external hazards. RTC started to develop the tsunami PRA standard for risk assessment against tsunami of utilities on April 2011 and published it on December 2011. This standard was utilized for utilities' applications for conformity inspection. The newly developed NRA requirements claim design considerations associated with external hazards. The primary objective of the risk assessment for external hazards is to develop countermeasures against such hazards rather than grasping the risk profile. Therefore, applying detailed risk assessment methods, such as PRA, to all the external hazards is not always required. Risk assessment methods can vary in types including qualitative evaluation, hazard analysis (analyzing hazard frequencies or their influence), margin assessment, and deterministic core damage frequency (CDF) evaluation. RTC comprehensively identified the external hazards which had potential risks, and has developed "the implementation standard for the identification of assessment methods for risks associated with external hazards."

Currently, RTC published 13 standards showed in the Table I that provides the relation with subcommittee and standards. SC has the standard update rule that AESJ standards have to be checked every year and to be revised every five years. Therefore several PRA standards are revising every year continuously. In 2015, four standards were revising and one standard and one technical document were developing, and in 2016, L2PRA standard and L3PRA standard were revising as periodic revision. It was clear that revision time of both standards were passed, however it was necessary to discuss about update by lessons learned of Fukushima Daiichi accidents. The developing plan is shown in Fig. 3 and main of three years before consisted of several PRA standards, as follows:

- External events L2PRA
- Earthquake induced events PRA
- Seismic Shutdown PRA

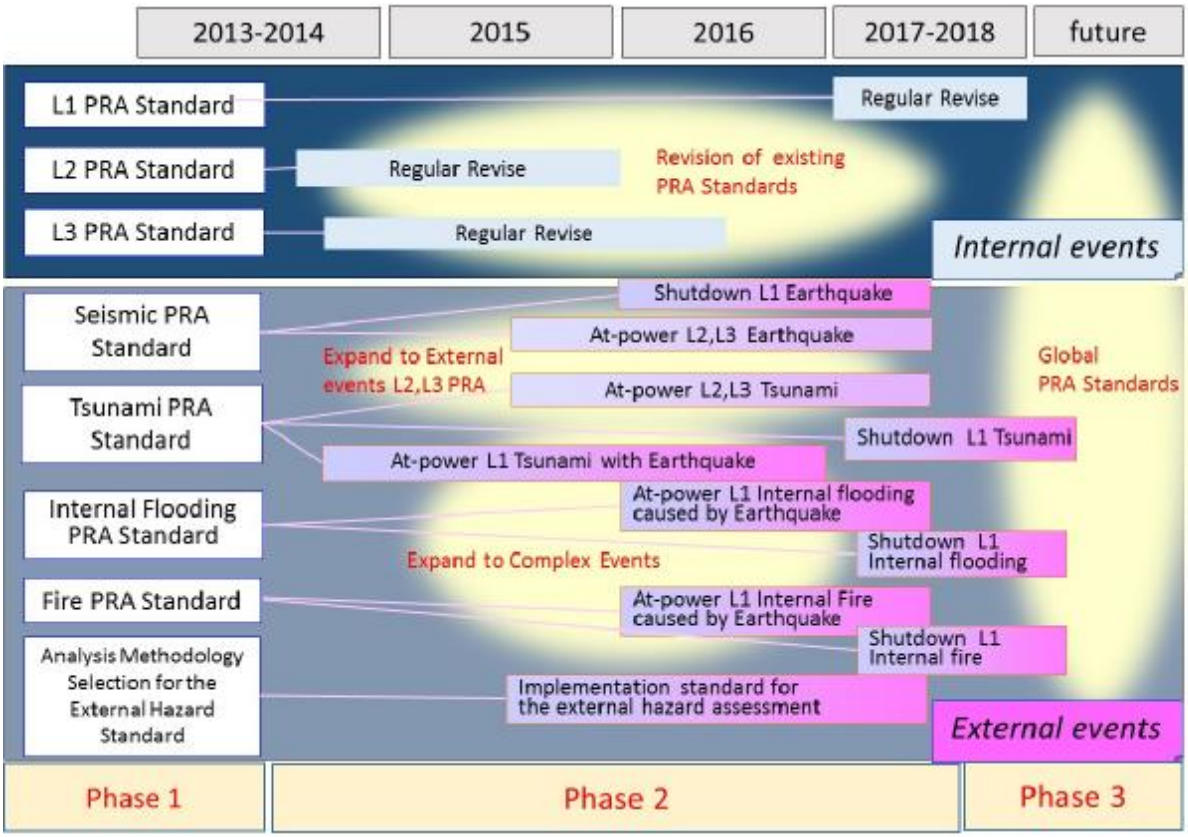



Fig. 3. The Results and Plan of PRA Standards Development (from 2013 to future)

Revising of existing PRA standards is continuous work. Now, the second edition of almost all standards have been published as indicated in TABLE I. It is significant to collect and research new technical information in revising PRA standards. Especially, one important factor to consider is classification of all problems to solve by importance before complex or combined events PRA standard is begun to develop, because these kind of PRA hardly has any prior document. For example, the steering task cleared future topics of discussion to develop a multi-unit PRA, as follows:

- Objectives and scope
- Facilities and equipment (multi-unit, multi-site, SFP, etc.)
- Model (Integrated model, Unit model)
- Operational state (combination of at-power unit and shutdown unit)
- Time dependent event sequence analysis (deferent event-progressing in each unit)
- Dependent factor (IE, Sharing system, Structure of same equipment, Distance, HF, Organization)
- Outside support
- Screening criteria
- Integration of deferent hazard
- Safety goal and performance objective

TABLE I. PRA Standards

| Subcommittee | No. | Standard | The Date of Issue |
|---|---|---|---|
| Level 1 PRA Subcommittee | 1 | Level 1 PRA Standard | 1st : 2008<br>2nd: 2013 |
| | 2 | PRA Parameters Estimation Standard | 1st:2010<br>2nd:2016 |
| | 3 | Shutdown PRA Standard | 1st:2002<br>2nd:2010<br>3rd:2017(Under revision) |
| Level 2 PSA Subcommittee | 4 | Level 2 PRA Standard | 1st:2008<br>2nd:2016 |
| Level 3 PSA Subcommittee | 5 | Level 3 PRA Standard | 1st:2008<br>2nd:2017(Under revision) |
| External Events PRA Subcommittee | 6 | Seismic PRA Standard | 1st:2007<br>2nd:2015 |
| | 7 | Tsunami PRA Standard | 1st:2012<br>2nd:2017(Under revision) |
| | 8 | Case Studies for Tsunami PRA Standard* | 1st:2012 |
| | 9 | Internal Flooding PRA Standard | 1st:2012 |
| | 10 | Internal Fire PRA Standard | 1st:2014 |
| | 11 | Risk Analysis Methodology Selection Standard for External Hazards | 1st:2014 |
| PRA Qualification Subcommittee | 12 | PRA Terms and Definitions Standard | 1st:2011<br>2nd:2014 |
| | 13 | PRA Quality Ensuring Standard | 1st:2014 |

*:This is not a standard, but a technical document

**II.C. Structure of PRA Standards**

AESJ Standards are comprised of the “Main body” and “Annex (normative)”. In addition to this, “Annex (informative)”, which describes evaluation examples as a reference, and “Description.” “Main body” and “Annex (normative)” are mandatory. “Main body” consists of several sections, “Scope”, “Normative references”, “Terms, definitions, and abbreviated terms”, “technical sections”, and “Documentation.” The technical sections are nearly style of manuals, because the manual-styled PRA standard makes it easy to explain the adequacy of PRA reports of utilities.

However, Japanese utilities will step up the second stage, risk-informed decision making (RIDM), and it is necessary to improve structure of PRA standards. Because exiting PRA standards show only one methodology to calculate PRA for

comparing performance objectives and cannot be applied for any risk-informed activity. RTC is discussing about adequate structure and contents for RIDM, and shows several provisions. One of them is "Objective" section. It is new section in the revised Level 2 PRA standard and provides clearly the objective of conducting level 2 PRA corresponding to the user's various purposes. Another idea is a hierarchical structure. RTC considers that technical sections are divided three, and fundamental parts, requirements parts and specification parts. Current idea of new structure is as follows:

- Performance requirements: which shall make its contents clearly and briefly, and be complied in any application case.
- Technical requirements: which shall be used necessary for actual PRA implementation.
- Specification requirements: which are mandatory optionally depending on purpose of RIDM.

More another idea is a publication of case studies of partial or full PRA reports as a separate volume. Now these case studies are described in annex (informative) except Tsunami PRA standard. However, a style of a technical document (TECDOC) is easier and quicker to update them by reflecting new insights.

## III. IMPROVEMENT PROGRAM OF NEW PRA IMPLEMENTATION STANDARDS

Currently, RTC is making an idea for improving new PRA standards feasible for RIDM, which consists some topics as follows:

1) Hierarchical structure
2) Separated TECDOC
3) Expansion of PRA scope

### II.A. Hierarchical Structure

The steering task considers new structure of AESJ PRA standard showed in the idea in TABLE II. Technical elements are devided to three parts, (part I) performance requirement, (part II) technical requirement and (part III) specification requirement. The part I is basic and fundamental requirement to show general conditions. This part corresponds to HLR (High Level Requirement) in ASME PRA standard. The part II includes more concrete requirements such as detail actual procedures, or important topics not to omit. The part III shows actual methods which are adequate to be provided in option, because PRA method must not be limited in only one method.

TABLE II. Comparing of Structure Design

| | Present | | Future |
|---|---|---|---|
| STANDARD | | | |
| Main body | Scope | → | Scope |
| | | → | Objectives (depending on PRA standard) |
| | Normative references | → | Normative references |
| | Terms, definitions, and abbreviated terms | → | Terms, definitions, and abbreviated terms |
| | Technical element | → | Technical element: performance requirement >>>part I |
| | | → | Technical element: technical requirement>>>>>>part II |
| Annex (normative) | | → | Annex (normative): specification requirement>>>part III |
| Annex (informative) | | → | Annex (informative): |
| | | | |
| TECDOC | | → | TECDOC |

### II.B. Separated TECDOC

The existing PRA standards include a lot of case studies for users to trace easily prior good examples, e.g. case studies are about 600 pages in Seismic PRA standard. However a period for revision of a PRA standard is at least two years. TECDOC is better style for easy and rapid revision of case studies. All contents of informative annex must not be moved to TECDOC, because some of them are needed for explanation of reason or background about technical elements. These TECDOC are expected that not only RTC but also several organization, e.g. NRRC (Nuclear Risk Research Center) of CRIEPI (Central Research Institute of Electric Power Industry), Venders, Utilities etc., publish TECDOC.

### II.C. Expansion of PRA scope

Several complex PRA standards must be developed, but have not been started yet, because no study of these PRA has not been implemented. And the steering task has the research plan of documents about earthquake induced events PRA or shutdown seismic PRA.

Fundamental method of these complex PRA will be completed by adding a seismic fragility to internal fire or flooding FT. However, several topics to consider are as follows:

- Multiple and simultaneous fire or flooding occurrence sources in B/C class equipment of seismic importance classification.
- Fire or flooding propagation routes complexly generated by earthquake.
- Complex fire-flooding interaction, e.g. fire extinguishing water became source of internal flooding, spread of fire by floating inflammable substance on water caused by earthquake.
- Screening process of tremendous many sequences and its criteria

## IV. CONCLUSIONS

RTC has the mission to develop PRA standards and has been developing full sets of PRA standards, operation modes including at-power & shutdown, initiating events including internal events and external events, and PRA level 1, 2, 3. However, Japanese utilities are in progression to the second risk application phase, RIDM. Therefore RTC decided the plan to improve PRA standards feasible for RIDM and to continue the research of complex PRA methods.

The plan of RTC are as follows:

A) Improving structure of PRA standards: objective section, hierarchical structure and separated TECDOC.

B) Continuous research of external complex events PRA methodology.

C) Implementation standard for RIDM collaborated with the System Safety Technical Committee.

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