Regulatory Aspect of Aging Management for Periodic Safety Review in Korea

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ABSTRACT

In less than 10 years, the first commercial Pressurized Water Reactor (PWR) plant in Korea will reach its official design life. As part of safety activities, developed countries have already implemented periodic safety review (PSR) or equivalent programs to check and improve the safety of operating nuclear power plants (NPP) during their plant life. At the end of 1999, it is decided by Korean Atomic Energy Safety Committee to adopt the PSR program to apply to Korean operating NPP. Recently, Kori unit 1 has started the review for the first tentative application of PSR as a model case. Management of aging is one of the major factors to be considered in periodic safety review or life extension of a nuclear plant. This paper is intended to introduce the regulatory aspect and strategy of Korean PSR and especially of aging management. The background and scope of basic PSR guidelines are described, and a summary of technical criteria for aging management, which shows a regulatory direction for PSR, are also presented.

INTRODUCTION

Since Kori Unit 1 initiated its commercial operation in 1978, about 20 units of nuclear power plant are being operated or under construction now in Korea. In addition to the existing safety assessments and examinations for operating NPP, a comprehensive safety review system called PSR has been recently adopted as complementary. Though there had been not a few debates about necessity of adoption of the new system by owners, Korean government have reached the conclusion that it would be adequate to apply the full scope of PSR system to Korean NPP as a member state of International Atomic Energy Agency (IAEA) as well as a contracting party to the Nuclear Safety Convention [1].

In this paper, a regulatory aspect in preparation of guidelines for smooth implementation of PSR is described with some details of the aging management of operating NPP in summary. One of the major issues at initial stage in the process of PSR adoption was owner's mind of reluctance about whether a large set of additional safety activities should be really necessary in our condition. One of the owner's aspects was that PSR did not seem to be directly implemented at NPPs of United States whose design concept and regulation practices had been referenced in Korea. At that time, owners apprehended that PSR would be an excessively duplicating safety measure requiring unnecessarily big resources. However, steadily a belt of consensus were widen in 3 or 4 years through several technical and policy meetings including public hearing between specialist, owner, regulator, government, and public. It was arranged and resolved in such a way as owner's accepting

implementation of PSR, and regulator's promising to allow maximum exemptions for duplicative jobs, and both parties trying for best effectiveness within safety criteria.

Another issue was about applicable criteria to judge the PSR result. One of the major objectives of PSR is to identify any differences between the original safety requirements and the current safety standards and practices of a NPP [2]. Referring to IAEA safety guides [3], the judgement in terms of current safety requirements does not require that an operating nuclear power plant meet all the current requirements, but it requires comparison between original and current requirements to pick up shortcomings for safety enhancement. As the terminology, current safety standards and practices, is not clearly defined, however, it is liable to be confused with the terminology of current licensing basis used by Nuclear Regulatory Commission (NRC) of United States [4]. Therefore, discussion is still going on in order to decide the level of applicable criteria, and to judge whether the level of safety significance for a shortcoming is acceptable or not. In next section, a summary of basic PSR guidelines including regulatory aspects is described [5,6].

PERIODIC SAFETY REVIEW (PSR) OF KOREAN NPP

Situation for PSR Implementation

1) Background

The necessity has been increasingly recognized for a means of systematic safety review and verification which can incorporate the change of safety review environment including equipment degradation of NPP due to increase of total operation age, scientific and technical development, accumulation of operating experience, and etc. And it has been also emphasized for effective execution of nuclear plant lifetime management. In the Nuclear Safety Convention leaded by IAEA, implementation of systematic and comprehensive safety review for operating nuclear power plants during the lifetime as well as before commencing construction is emphasized as a mandatory binding system for contracting parties [1]. And it is regulated in the guidelines regarding national report that safety assessment should be periodically performed. To fulfill the contract with Nuclear Safety Convention, Korea had promised to adopt the PSR as one of the action programs for safety enhancement in the national report.

2) Process of Adoption

In Nov. 1998, Ministry of Science and Technology (MOST) as a representative of government requested related organizations including Korea Electric Power Company (KEPCO) as an owner and Korea Institute of Nuclear Safety (KINS) as a regulator to submit their opinions about application of PSR to domestic NPP. Besides the opinions from related organizations, MOST steadily laid out a scheme through lots of public hearing and collecting the extensive opinions of specialist. In Dec. 1999, Korea Nuclear Safety Committee (KNSC) approved a basic PSR program to adopt and to implement the periodic safety review. The program included a basic direction, strategy of enforcement, selection of target plants and legislation, and etc. Tentative schedule was also set up in the committee such as PSR application from 2002 to all NPPs that had operated more than 10 years on the older-the former basis [6]. As the committee resolved, legislation of PSR

implementation was made in Dec. 2000, and Kori Unit 1, the oldest NPP in Korea, which had operated over 20 years, initiated its PSR as a model case in May 2000.

Summary of Basic Guidelines of PSR

1) Objectives and Scope

Presentation of review principle, scope and method, applicable criteria, skeleton of owner's safety report necessary to implement PSR of operating NPP are the objectives of the guidelines. The guidelines apply to both of plant operators and regulator, and it is recommended for related organizations to positively utilize this document for consistent and efficient execution of the program. The purpose of a PSR is to comprehensively review whether the plant is safe as judged by current safety standards and practices, and whether adequate arrangements are in place to maintain plant safety until the next PSR. The scope of a PSR includes all nuclear safety aspects of a nuclear power plant. Therefore, the object of a PSR consists of all facilities and equipment on the site covered by the operating licence (including, for example, waste management facilities) and their operation, together with the staff and its organization. The review also includes radiological protection, emergency planning and radiological impact on the environment. The safety factors to be taken into account in the PSR are as follows, and scope and method of review for each safety factor are described in the next section.

(1) Actual physical condition of the plant
(2) Safety analysis
(3) Equipment qualification
(4) Management of ageing
(5) Safety performance
(6) Use of operational experience and of research findings
(7) Procedures
(8) Organization and administration
(9) Human factors
(10) Emergency planning
(11) Impact on environment

Although the PSR demonstrates compliance with current safety standards and practices for each safety factor, the level of plant safety shall be determined by the combined effect of all safety factors. Therefore, their combined effect as well as individual acceptability shall be reviewed. Quality assurance (QA) shall not be considered as separate safety factors because they should be an integral part of every activity affecting safety, but be reviewed with respect to each safety factor. QA is assessed in its own right as an aspect of organization and administration. Similarly, radiological protection is not regarded as a separate safety factor since it is related to most of the other factors. The arrangements for radiological protection and their effectiveness should be reviewed as specific aspects of safety performance, procedures and actual physical condition of the nuclear power plant. As probabilistic safety assessment (PSA), which is not mandatory, provides useful insights into the safety of a nuclear power plant, it is recommended that a PSA be undertaken for every plant and utilized in a subsequent PSR. The results of relevant safety studies, and of routine and special safety reviews, should be utilized in the PSR to minimize duplication of effort between PSR and actions according to current licensing basis. An overall assessment of nuclear power plant safety shall be made to take into account all safety factors and any shortcomings that may remain unresolved after implementation of corrective actions.

2) Execution Principles

Owners shall voluntarily perform PSR in consideration of IAEA safety guides, practices of experienced countries, availability of necessary information for review, and etc. Regulator shall report to KNSC for final approval after judging the result of owner's PSR implementation. The period of PSR shall be 10 years considering the recommendation of IAEA guide, experience of foreign countries, significant change of scientific knowledge, current activities for assurance of plant safety, limit of validity in utilizing the experience and result of PSR, general duration of document and record keeping. The reference starting point of PSR period is taken to be the time of initial criticality after the plant obtains initial operation license. As it may be necessary to allow temporary delay of the first implementation of PSR for plants aged more than 10 years in consideration of public acceptance and for efficient utilization of resources at relevant interval. Therefore, 5-year delay is permitted for plants aged more than 10 years to implement the first PSR. For copy or pair plants which had applied construction and operation permit at the same time and which had been constructed in the same design concept with common final safety analysis report, single set of report resulting from simultaneous execution of PSR is allowed. However, separate consideration shall be made for differences between them such as equipment aging, operation condition, and etc. For duplication items whose contents are fully covered by existing regulatory requirement, the result of work done may be utilized in the report as references without further effort.

The general procedure of PSR is as shown in Fig. 1[5]; Owner shall prepare overall PSR program through discussion with MOST, implement review actions, and submit a set of PSR result report to MOST. MOST then assess the PSR result, solution status and future schedule about shortcomings with help of KINS, and can require the owner to perform total risk analysis using PSA method or to shut down the plant when a significant safety issue is found. Then, owner may apply again after completion of supplementary actions even for the plant once shut down. MOST shall report the result of assessment to KNSC where the finally approval can be made.

3) Review Scope and Method for Safety Factors

Detail description is omitted because this is quite similar to the contents of IAEA safety guides [2].

4) Application of Current Technical Criteria

All technical standards and requirements available at the time of PSR implementation shall be utilized to be compatible with the objective of PSR. Detailed items shall be referred to a licensing basis which had been applied to a plant of same type licensed most recently within the country, on the basis of current technical criteria regulated in the present Nuclear Act such as location, structure, arrangement, performance, QA, operational safety measures of NPP. In case that it is not appropriate or physically impossible to apply the current technical criteria due to a typical operational characteristics, its justification shall be provided through an evaluation of safety significance of the structures, system, and components (SSCs), cost-benefit analysis, and PSA. The evaluation of safety significance of the SSCs shall be based on the assessment of relative contributions to the total risk by PSA.

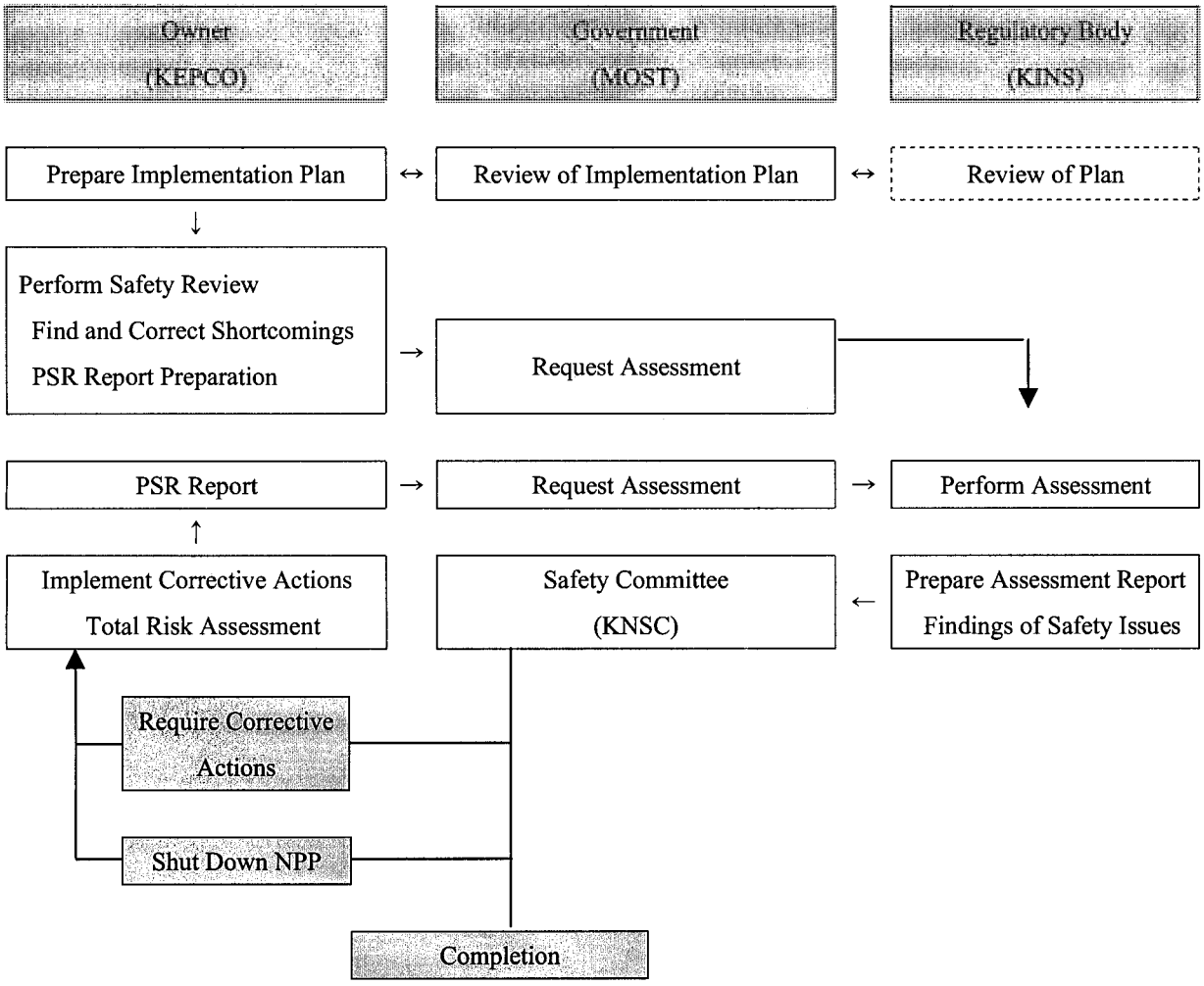

Fig.1 Schematic Diagram of PSR Procedure in Korea

5) Basic Scheme of PSR report

For the purpose of consistent review about an operational history of SSC from its design phase, main frame of PSR report shall be set up in such a form as enough to incorporate 11 safety factors to corresponding systems or areas adequately and to enable a systematic review of securing condition and maintaining capability of safety. Based on the frame of final safety analysis report (FSAR) with which all of the designer, operator, and regulator are very familiar, safety factors and review elements of PSR should be adequately incorporated into the format so that review activities interfacing with existing SSCs can be in harmony. The PSR report for plant operator is recommended to use the existing regulatory and licensing documents at maximum as references, and should be in a similar format with guidelines for regulator in order to get more efficiency in regulator's assessment and judge.

AGING MANAGEMENT IN PSR

Regulatory Aspect for Aging Management

Though it is thought to be no big differences in the basis of aging management between PSR and License Renewal, the objects concerned in PSR are actually the whole SSCs in NPP while long-lived and passive components by screening method is specially emphasized in viewpoint of lifetime. In the sense that PSR results could be utilized for future License Renewal, however, regulatory strategy for aging management in PSR is being set up to prepare a bit detailed guideline similar to the one used for life extension. On this purpose, recent experience of NRC in the review of license renewal of old nuclear power plants in United States would be studied as a reference. Aging management program in IAEA safety guides [7,8] and in Standard Review Plan for License Renewal [4] are expected to be commonly referred. Summary of guidelines and criteria of aging management proposed for the recent model implementation of PSR are shown in the next section.

Basic Guidelines for Aging Management

1) Objective and Contents

The objectives of the review are to determine whether aging of SCCs of nuclear power plants is being effectively managed so that required safety margins are well maintained, and whether an appropriate aging management program is in place for the safety of future plant operation. To achieve the objectives described above, followings shall be included in the safety review.

(1) Classification and selection of SCCs for review
(2) Evaluation of aging mechanism of SCCs for review
(3) Effect of aging on function and safety margin of SSCs
(4) Prediction of future state and time exceeding acceptance criteria of SSCs
(5) Program for aging management and for mitigation of aging effects

2) Scope and Method

In aging management of SSCs important to safety, it should be predicted and detected when required safety functions are threatened, and adequate corrective or mitigative actions should be taken. A nuclear power plant should have a systematic ageing management programme and a feedback mechanism consisting of all relevant activities, such as surveillance, maintenance, chemistry control and feedback of operating experience to ensure that required safety margins of SSCs important to safety are maintained throughout plant service life. Ageing management program should include both managerial aspects (e.g. program policy, procedures, performance indicators, staffing, resources, record keeping, etc.) and technical aspects (e.g. ageing management methodology, the extent of understanding of relevant ageing phenomena, SSC-specific acceptance criteria, ageing detection and mitigation methods, and actual physical condition of SSCs).

Technical Criteria for Aging Management

1) General Criteria

Structures, systems, and components of a nuclear power plant should be capable of maintaining their safety function with enough margins for any of time-dependent degradation mechanisms. A relevant aging management program established for the NPP should assure the safety function and margin of SCCs.

2) Classification and Selection of SCCs

SSCs ensuring the safety functions as follows should be included in the scope of review; the capability to shut down the reactor and to maintain it in a safe shutdown condition, the integrity of the reactor coolant pressure boundary, the capability to prevent and mitigate the consequences of accident that could result in potential offsite exposure. Non-safety-related SCCs whose failure could affect any of the plant safety function and SSCs relied on for meeting specific regulations required by regulator should be included in the scope of review.

3) Evaluation of Aging Mechanism of SCCs

In the review of aging of metallic, nonmetallic and concrete material for the selected SSCs, following aging mechanisms should be assessed at least as applicable effects;

(1) Fatigue
(2) Erosion
(3) Corrosion
(4) Erosion-corrosion
(5) Wear
(6) Thermal embrittlement
(7) Irradiation embrittlement

Component level evaluation should be performed in consideration that aging mechanism varies with difference of SSCs. A component specific list of data about degradation mechanisms of SSCs for review should be recorded.

4) Prediction of Future State and Time Exceeding Acceptance Criteria

Component specific quantitative evaluation should be performed on potential degradation mechanisms of SSCs for review. In case that quantitative approach is not adequate, experimental approach can be utilized. From component specific evaluation, assurance of rest of life or safety margin should be demonstrated for the next 10 year and following criteria should be satisfied;

(1) In case of fatigue, the cumulative fatigue damage factor until next PSR should not exceed unit.

(2) In case of erosion, corrosion, erosion-corrosion, and wear, minimum required thickness of each component should be maintained until next PSR.

(3) In case of thermal embrittlement and irradiation embrittlement, change of required material characteristics of each component should be maintained within acceptance criteria until next PSR.

Estimation of remaining lifetime and safety margin should be carried out incorporating the information of inspection, test, maintenance, and actual operating experience of the plant. The estimation result for remaining lifetime and safety margin

of aged SSCs should be listed in written form and classified into two groups of no further action required until next PSR and of future complementary measures or monitoring required.

5) Plans for aging management and for mitigation of aging effects

Based on the estimation result for remaining lifetime and safety margin, mitigation measures including maintenance and replacement should be executed to maintain the safety function of the aged SSCs. Aging management program should be established to assure that the aging of SSCs affecting safety be effectively managed until next PSR, which should include at least following items;

(1) List and program of SSCs for supplement in aging management

(2) List and program of SSCs for supervision in aging management

(3) Organization and administration for aging management

CONCLUSIONS

Regulatory aspect of PSR implementation process and guidelines for Korean NPPs are introduced in summary. Taking into account both the increase of plant owner's design and management cost for NPP and endless demand about safety improvement by public, regulator is to elaborate a harmonious skeleton of safety and aging management, especially for PSR. On the point open technical meetings inviting specialists have been held, and some partial co-work between regulator, owner, and professors has been progressed. Issues needed more discussions and ideas in future are as follows;

(1) Effective adaptation of PSR to existing operation and regulation practices

(2) Establishment of more definite acceptance criteria and technology for judge of safety significance

(3) Close Linkage of PSR with Life Extension

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