



## Regulatory Strategy for Operational Safety and Aging Management of NPPs in Korea

H. J. Kim<sup>1)</sup>, H. K. Kim<sup>1)</sup>, T. E. Jin<sup>2)</sup>

<sup>1)</sup> Korea Institute of Nuclear Safety, Korea

<sup>2)</sup> Korea Power Engineering Company, Korea

### ABSTRACT

Since Kori Unit 1 started its commercial operation in 1978, design life is rapidly approaching and is scheduled for 2008. In addition, 9 other nuclear power plants have been operating more than 10 years in Korea. As the number of aging plants rise, public concern over the safety of existing operating nuclear power plants (NPPs) has increased. Comprehensive and systematic safety assessments in addition to existing safety reviews are proposed as an effective way to verify that operating NPPs maintain the high level of safety. In this regard, the Ministry of Science and Technology (MOST), Korea's nuclear regulatory body, recently established an institutional process through revision to the atomic energy act to introduce the periodic safety review (PSR). The PSR considers, among other factors, improvements in safety standards and practices, the cumulative effects of plant aging, operating experience, and the evolution of science and technology. In particular, the assessment and management of plant aging is one of the major areas. It includes identification of SSCs for aging management, assessment of aging effects and implementation of aging management program. In addition, the PSR results could be one of the procedural requirements that are utilized to approve life extension or renew an operating license of a nuclear power plant. This paper describes current regulatory requirements for operational safety and aging management, technical requirements for aging assessment and management, regulatory strategy, objectives and approach of the PSR process recently established in Korea. This paper also includes the strategy and method for the application of PSR results to the aging management of nuclear power plants and further plant life extension.

### INTRODUCTION

Since the first NPP started commercial operation in 1978, Korea has built and currently operated 18 NPPs with 6 additional NPPs under construction. Among them, 9 NPPs have been operating more than 10 years while Kori Unit 1 approaching its design life of 2008. The first CANDU NPP, Wolsung Unit 1, is also approaching its design life in 2013 according to its 30-year design life.

As the number of aging plants rise, public concern over the safety of existing operating nuclear power plants (NPPs) has increased. Systematic and comprehensive operational safety assessment and plant life management are necessary to maintain a high level of safety, taking into account improvements in safety standards and practices, the cumulative effects of plant aging, operating experience, and the evolution of science and technology.

Operating license is issued without a fixed term in Korea. Design life is established in FSAR for the basis of design and safety assessment. Institutional process for the plant life extension should be established in the very near future, considering the remaining life of Kori Unit 1 and the time required for the safety assessment.

Periodic safety review (PSR) system was introduced and well established with sound legal basis for the comprehensive and systematic safety evaluation of operating plants. The results of PSR with focusing on aging assessment can be utilized in the safety assessment for plant life extension. Nuclear Safety Commission determined that the results of PSR would be used for the life extension of NPPs.

This paper describes the current regulation for operational safety and aging management, the regulatory strategy, objectives and approach of the PSR system established in Korea, and the technical requirements for aging assessment and management in PSR. The strategy and method for the application of PSR results to the aging management of nuclear power plants and further plant life extension are also included.

### CURRENT REGULATION ON LIFE MANAGEMENT

#### Legal Basis for Regulation

The legal basis for regulation of Korean NPPs is composed of the following attributes:

- Atomic Energy Act
- Enforcement Decree of Atomic Energy Act (Presidential Decree)
- Enforcement Regulation of Atomic Energy Act (Ministerial Ordinance)
- Regulation on Technical Standards of Nuclear Installations (Ministerial Ordinance)
- Regulation on Technical Standards of Radiation Protection (Ministerial Ordinance)
- Notice of the Minister of Science and Technology

**Table 1. Status of Nuclear Power Plants in Korea**

Plant	Reactor Type	Thermal Power (MWt)	TBN Power (MWe)	Operation Permission	Commercial Operation
Kori-1	PWR	1724	587	1972. 5.31	1978. 4. 29
Kori-2	PWR	1876	650	1983. 8.10	1983. 7.25
Wolsong-1	PHWR	2064	688	1978. 2.15	1983. 4.22
Kori-3	PWR	2775	950	1984. 9.29	1985. 9.30
Kori-4	PWR	2775	950	1985. 8. 7	1986. 4.29
Yonggwang-1	PWR	2775	950	1985.12.23	1986. 8.25
Yonggwang-2	PWR	2775	950	1986. 9.12	1987. 6.10
Uljin-1	PWR	2775	950	1987.12.23	1988. 9.10
Uljin-2	PWR	2775	950	1988.12.29	1989. 9.30
Yonggwang-3	PWR	2815	1000	1994. 9. 9	1995. 3.31
Yonggwang-4	PWR	2815	1000	1995. 6. 2	1996. 1. 1
Wolsong-2	PHWR	2061	700	1996.11. 2	1997. 7. 1
Uljin-3	PWR	2815	1000	1997.11. 8	1998. 8.11
Wolsong-3	PHWR	2061	700	1997.12.30	1998. 7. 1
Wolsong-4	PHWR	2061	700	1999. 2. 8	1999.10. 1
Uljin-4	PWR	2815	1000	1998.10.29	1999.12.30
Yonggwang-5	PWR	2815	1000	2001.10.24	2002. 5.21
Yonggwang-6	PWR	2815	1000	2002. 6	2002.12
Uljin-5	PWR	2815	1000	2003 (Schedule)	2004 (Schedule)
Uljin-6	PWR	2815	1000	2004 (Schedule)	2005 (Schedule)
Shin Kori-1	PWR	2815	1000	2002.3(1)	2008.9
Shin Kori-2	PWR	2815	1000	2002.8(1)	2009.9
Shin Wolsong-1	PWR	2815	1000	2002.12(1)	2009.9
Shin Wolsong-2	PWR	2815	1000	2002.12(1)	2010.9

(1) Issue date of CP

#### Procedural Requirements

Construction permit is issued based on radiological environmental report, preliminary safety analysis report, quality assurance program for design and construction and early site approval for limited construction work on a proposed site before the construction permit is issued. Operating license is issued based on the operational TS, FSAR, quality assurance program for operation, radiological environmental report and radiological emergency plan. It should be noted that prescriptive limit on license term is not given, however the FSAR clearly identified the design life.

#### Design Requirements

- Quality standards : Design, testing, and inspection of SSCs conducted to quality standards commensurate with the importance of the safety functions.
- Environmental and dynamic effects design bases: SSCs designed to accommodate the effects of, and be compatible with the environmental conditions including the effects of aging.
- Qualification requirements of equipment: The equipment installed after qualification of its functional capabilities by experience, analysis, test, or their combination.
- Testability, monitorability, inspectability, maintainability: SSCs designed to be tested, monitored, inspected, and maintained to ensure that their structural integrity, leak tightness, functional capability, and operability are maintained during the life of the nuclear power plant.

#### Inspection Requirements

- Pre-operational inspection: conducted regarding the installation and performance of the facilities by means of a document inspection and a field inspection by construction stages
- Periodic inspection: conducted regarding the performance of the 11 facilities including reactor with a 20-

- month interval during refueling outage
- Quality assurance inspection: to check quality assurance activities according to the quality assurance program

#### Requirements on Safety Measures for Operation

- Conformance to technical specifications (TS): to monitor that the limiting conditions for operation in TS are met, and to take proper actions. TS is to be reviewed throughout the operating lifetime of the plant. Any modifications of the TS to affect and enhance safety need approval.
- Feedback of operating experience: to reflect the operating experience in plant facilities, safety related criteria, procedures, and training programs.
- Testing, monitoring, inspection, and maintenance of SSCs
  - ISI : Aging related degradation in material and performance of safety related SSCs shall be monitored and evaluated, and appropriate actions taken.
  - IST : For major pumps and valves necessary for safe shutdown and reduction of accident consequences, the performance and the aging related degradation shall be monitored and evaluated, and appropriate actions taken.
  - Reactor pressure vessel surveillance: The degradation in material properties of reactor pressure vessel due to neutron irradiation shall be monitored and evaluated, and appropriate actions taken.
    - Instruments calibration: Instruments and radiation detectors directly related to monitoring of states of nuclear facilities shall be calibrated periodically.

#### Corrective Actions and Enforcement

Nuclear facilities shall be used when the installation and performance of nuclear facilities are confirmed to be satisfactory through pre-operational inspections for each construction process. The reactor is allowed to be at a critical state if the performance of nuclear facilities is confirmed to be satisfactory through periodic inspections. Regulatory body could order to take corrective or complementary measures, such as suspension of use, repair, or modification of guidelines for operation, against inadequate performance of facilities and safety measures for the operation. Also they could order to submit report or documents on their business, and order to take corrective or complementary measures as a result of the inspections.

### **IMPLEMENTATION OF PERIODIC SAFETY REVIEW**

#### Up-to-date Progress

Nuclear Safety Commission decided basic framework for the implementation of the PSR on December 21, 1999. Public hearing was held on Dec. 9, 1999. In addition, MOST issued 'Implementing Guidelines for PSR' on May 30, 2000 after deliberation of Nuclear Safety Commission on May 25, 2000. KHNP submitted the PSR Plan on May 30, 2000 which includes the plan for Kori Unit 1 to be completed by Nov, 2002 and Wolsung Unit 1 by June 2003. Atomic Energy Act was revised to adopt PSR system on Jan. 2001, including basic direction and framework for the implementation of PSR. Detailed provisions including review scope, method, procedure, & technical standards are included in the Enforcement Decree(Presidential Decree) and the Enforcement Regulation(Ministerial Ordinance) of the Atomic Energy Act.

#### PSR Implementing Method

PSR is specified to be carried out every 10 years after issuance of an operating license. The operator of NPPs (KHNP) has the responsibility of performing the PSR. MOST specifies PSR requirements and reviews the PSR results. Review scope is based on 11 safety factors suggested by IAEA in Safety Series No. 50-SG-O12, and detailed scope may vary depending on plant age. PSR for twin plants having a single FSAR assembled together into a single report but separately consider the aging of SSCs and the physical status of each plant.

#### PSR Process

KHNP performs PSR with safety improvements of the plant through hardware or procedural modifications based on the results, and prepares PSR Report. MOST/KINS reviews PSR results and prepares Safety Evaluation Report with identification of safety issues. MOST with deliberation by Nuclear Safety Commission makes a decision on whether continued operation is appropriate or not. Corrective actions are to be issued including PSA, if necessary. KHNP implements corrective actions, if there are, and prepares 'Implementing Report' for the review of MOST/KINS.

#### Technical Requirements

- PSR Review Standards
  - PSR is performed based on technical requirements of reactor facilities and the safety measures for the operation of facilities prescribed under the nuclear legislative and regulatory framework. Detailed technical requirements are referenced to those applied to the operating license of a NPP issued near the beginning of

the PSR. Exemptions may be possible, if the technical requirements are deemed inappropriate to be applied as they are; due to differences in the design principles of a nuclear reactor, or due to the operational characteristics of a nuclear reactor. Justification for the exemptions should be provided taking into account physical possibility, safety significance and cost-benefit. PSA could provide useful insights for the justification.

- Technical Requirements on Aging Assessment
  - Review whether plant aging is being effectively managed so that required safety margins are maintained and whether an adequate aging management program is in place for future safe operation of the plant.
  - Classification and selection of SSCs required for the review
  - Evaluation of aging mechanism of SSCs
  - Effect of aging on functional capability and safety margin of SSCs
  - Prediction of future state and time-exceeding acceptance criteria of SSCs
  - Program for aging management and mitigation of aging effects

The safety functions of nuclear facilities shall not be impaired by aging and sufficient safety margin shall be ensured against aging. Aging management program for nuclear facilities shall be established so that safety functions and required safety margins are ensured.

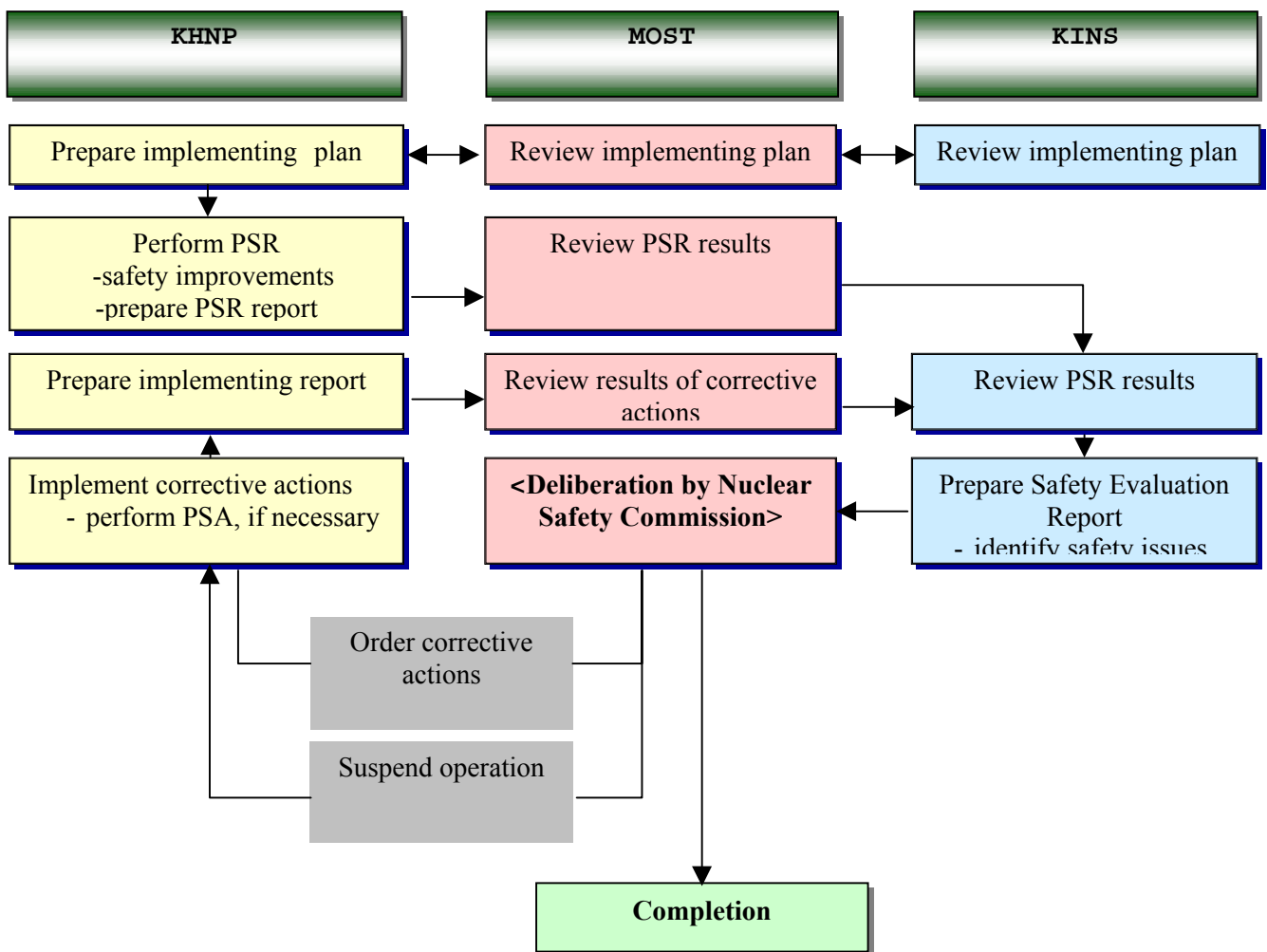


Fig. 1 PSR Implementing Process

## PLANT LIFE MANAGEMENT WITH PSR

Factors to be Considered for Plant Life Management

Principles on the Plant Life Management from IAEA INSAG-14, "Safe Management of the Operating Lifetimes of NPP" requires the following major factors:

- Consideration of degradation mechanism from the design stage
  - Surveillance, test, inspection, repair and replacement
- Comparison with the design basis
  - Maintaining the design safety level of the plant
  - Monitoring the effects of aging and reviewing the life limiting equipment
  - Assessment of the surveillance results and anticipation of possible repair or replacement work
- Review of the reference safety levels : Improvement of reference safety levels as far as reasonably practicable and the preferable achievement by step
- Safety review : Effective aging management and possible evolution of reference safety level
- Infrastructure support for safe management
  - Maintaining sufficient staff with adequate competence
  - Handling major organization changes to avoid any significant impact on safety
  - Maintaining excellence in operation by use of self-assessment and peer reviews

As a result, the following basic factors, as a tentative, were identified for life management(life extension) considering IAEA principles for operating lifetime management, license renewal process in USA, and practices of plant life extension using PSR in Europe.

- Consideration of Aging Mechanism in Design
- Maintenance of Design Safety Level
- Upgrade of Safety Level with Current Safety Standards
- Utilization of New Technologies and Operational Experiences
- Evaluation and Monitoring of Aging
- Plan for Repair and Replacement
- Probabilistic Safety Assessment (PSA)
- Evaluation of Environmental Effects
- Infrastructure Support for Safe Management
- Complement of Safety-Related Documents

#### Relation between PSR and Life Management

The basic factors for life management are considered in PSR except PSA, evaluation of environmental effects and complement of FSAR (TS) in safety-related documents. The basic factors for life management were partially considered in license renewal process in USA, except following items that are considered in the other regulations in 10CFR.

- Reflection of Current Safety Regulation : Backfitting Rule (10CFR50.54(f))
- Utilization of New Technologies/Operational Experiences : Backfitting Rule
- Plan for Repair and Replacement : Maintenance Rule (10CFR50.65)
- Probabilistic Safety Assessment : PRA Regulation (10CFR50.34(f)(1)(i))
- Complement of Documents : Maintenance of Record (10CFR50.71)

#### Procedural Requirements for Plant Life Extension

Possible models to be considered for life extension are license renewal, official approval for continued operation beyond design life and continued operation with PSR results without any procedural requirements. For any models, PSR results can provide useful information for the decision of continued operation.

### CONCLUSION

Periodic safety review system was introduced and well established with sound legal basis for the comprehensive and systematic safety evaluation of operating plants. Institutional processes for the plant life extension should be established in the very near future, considering the remaining life of Kori Unit 1 and the time required for the safety assessment. PSR could be utilized in determining the plant life extension by adding PSA, evaluation of environmental effects and complement of FSAR(TS) in safety-related documents.

**Table 2. Comparison of Basic Factors for Life Management with PSR & License Renewal**

Basic Factors	PSR Safety factor	License Renewal
Consideration of Aging Mechanism in Design	Actual Condition, Safety Performance, Aging, Qualification, Procedures	License Renewal (Technical Information)
Maintenance of Design Safety Level	Actual Condition, Safety Analysis, Safety Performance	License Renewal (Technical Information)
Reflection of Current Safety Regulation	Safety Analysis	Backfitting Rule
Utilization of New Technologies and Operational Experiences	Operational Experiences and R&D results	Backfitting Rule
Evaluation and Monitoring of Aging	Aging, Actual Condition	License Renewal (Technical Information)
Plan for Repair and Replacement	Qualification, Aging, Procedure, Safety Performance	10 CFR Regulations
Integrated Safety Review	PSA (Optional)	PRA Regulation
Evaluation of Environmental Effects	Environmental Effects (Monitoring only)	License Renewal (Environmental Report)
Infrastructure support for safe management	Organization, Human Factor	10CFR Regulations
Complement of Safety-Related Documents	Procedure, No Requirement on Complement of FSAR(TS)	License Renewal Reporting Rule