RECENT APPROACHES RELATED TO SAFETY ENHANCEMENT OF OPERATING NPPS IN KOREA

T.E. JIN
KEPCO E&C
Gimcheon Gyeongsangbuk-Do, Republic of Korea
Email: renewfuture@gmail.com

Abstract

There are 25 operating nuclear power plants (NPP) in Korea and five units are under construction. The safety of NPP is the most important goal in Korea like many other countries. The paper deals with the various safety enhancement activities in Korean NPPs. First of all, to conduct a Periodic Safety Review (PSR) based on IAEA safety series is one of the most effective ways to enhance the plant safety. The current status related to PSR is reviewed and some safety enhancement remedy actions are described. Also stress test is the effective way to improve the safety of operating NPPs against extreme natural disasters. Stress test targets, procedures and upgrading activities are presented. On September 12, 2016, there was an earthquake in Gyeongju, the southeastern part of the Korean peninsula, near Wolsong site. Fortunately, there are no serious casualties or damage. After this earthquake, Korean government started seismic-resistant program. The paper describes these kinds of safety re-enhancement actions in Korea.

1. INTRODUCTION

Since the first nuclear power plants (NPP) started commercial operation in 1978, Korea has built NPPs and currently operates 25 NPPs with 5 additional NPPs under construction [1]. Among them 20 NPPs have been operating more than 10 years while Kori Unit 1 will finish almost its first life extension on 2017. The first CANDU NPP, Wolsong Unit 1, started its continued operation from 2015 after its 30 years of design life.

As the number of aging plants increases, public concern over the safety of operating NPPs has risen. Systematic and comprehensive operational safety assessment and plant lifetime 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.

Periodic Safety Review (PSR) system was introduced and well established with sound legal basis for the comprehensive and systematic safety evaluation of operating plants. Stress test which was introduced after Fukushima accident in Korea is also one of effective ways to ensure the safety of NPP. There was an earthquake in Gyeongju area near Wolsong last year. It recorded 5.8 in Richter scale magnitude which was the largest in the history of Korean earthquakes since 1978 when the government started monitoring seismic activities. Various countermeasures are considered against earthquake.

This paper describes the current status, implementation structure and safety enhancement activities for operating NPPs, especially in the area of PSR including aging management and stress test which was introduced after Fukushima accident. Description of the safety enhancement activities after Gyeongju earthquake, led by the government, is also provided in this paper.

2. CURRENT TRADITIONAL REGULATIONS

2.1. Legal Basis for Regulation

The legal basis for regulation of Korean NPPs [2] 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
2.2. 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 technical specifications (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 in the license, however, the FSAR clearly identifies the design life. After the commercial operation, all the important changes related to the safety should be reported and reviewed and then the changes of FSAR have to be made.

2.3. Design Requirements

—Quality standards: Design, testing, and inspection of Structures, Systems and Components (SSCs) conducted to quality standards commensurate with the importance of the safety functions.
—Environmental and dynamic effects design bases: SSCs are designed to accommodate the effects of, and to be compatible with the environmental conditions including the effects of aging.
—Equipment qualification: Equipment is installed after meeting 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.

2.4. Inspection Requirements

—Pre-operational inspection: Conducted regarding the installation and performance of the facilities by means of a document inspection and a field inspection.
—Periodic inspection: Conducted regarding the performance of the several facilities including reactor with a 20-month interval during refueling outage.
—Quality assurance inspection: Conducted to check quality assurance activities according to the quality assurance program.

2.5. Requirements on Safety Measures for Operation

—Conformance to technical specifications (TS): To monitor the limiting conditions for operation in TS, and to take proper actions.
—Testing, monitoring, inspection and maintenance of SSCs
  • ISI: Aging related degradation in material and performance of safety related SSCs shall be monitored, evaluated and managed based on the appropriate remedy actions.
  • 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 evaluated and managed.
  • RPV surveillance test: The degradation in material properties of reactor pressure vessel due to neutron irradiation shall be monitored, evaluated and managed.

2.6. Corrective Actions and Enforcement

Nuclear facilities shall be used when the integrity and performance 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 the corrective activities, and order to take corrective or complementary measures as a result of the inspections.
3. PERIODIC SAFETY REVIEW

3.1. Current Progress

Nuclear Safety Commission decided basic framework for the implementation of the PSR in December 1999. Ministry of Science and Technology (MOST) issued 'Implementing Guidelines for PSR' in May 2000 after deliberation of Nuclear Safety Commission. Korea Hydro and Nuclear Power Company (KHNP) submitted the PSR Plan on 30 May 2000, which includes the plan for Kori Unit 1 to be completed by November 2002 and Wolsong Unit 1 by June 2003. Atomic Energy Act was revised to adopt PSR system in January 2001, including basic direction and framework for the implementation of PSR. Detailed provisions including review scope, method, procedure, and technical standards are included in the Enforcement Decree (Presidential Decree) and the Enforcement Regulation (Ministerial Ordinance) of the Atomic Energy Act. Since then PSR have been performed continuously in Korea. The 1st round PSR for 20 NPPs that have been operating for more than 10 years has been completed. The 2nd round PSR for the following three NPPs are currently being carried out:
- Kori-2
- Hanbit-5,6

3.2. PSR Implementation Structure

PSR is specified to be carried out every 10 years after the first criticality before the commercial operation. The operator of NPPs (KHNP) has the responsibility of performing the PSR. Former Ministry of Science and Technology (MOST) specified PSR requirements and currently Nuclear Safety and Security Commission (NSSC) reviews the PSR results. Review scope is based on 14 safety factors suggested by IAEA in Safety Series [3], and detailed scope may vary depending on plant age. PSR for twin plants having a single FSAR is assembled together into a single report but separately consider the aging of SSCs and the physical status of each plant. Once the PSR report is submitted, NSSC/KINS (Korea Institute of Nuclear Safety) reviews PSR results and prepares safety evaluation report (SER) with identification of safety issues.

Aging review is focused to ensure that plant aging is being effectively managed so that required safety margins are maintained and adequate aging management program is in place for future safe operation of the plant. The aging management for the passive system is one of the most important factors in PSR and implemented as shown in Fig. 1.

![FIG. 1. Evaluation method of passive SSCs in PSR](image)

3.3. Safety Enhancement Activities in PSR

All the possible remedy actions based on each PSR per plant are clarified and performed to improve the safety of the NPPs. For example, transient evaluation results showing the fatigue integrity of the pressure boundary components is important for the next 10 years of safe operation. Transient counting monitoring system is installed for each NPP. Not only the results of the past 10 years in-service inspection but also the
effectiveness of applicable code and standard are confirmed and check again to re-ensure the integrity of the results and evaluations.

The utility (KHN) has to report the implementation status of PSR to KINS every three months and regulatory authority controlled the follow-up measures.

4. STRESS TEST

4.1. Current Progress

After Fukushima accident, there was a strong need for comprehensive and transparent risk and safety assessment of NPPs. The Korean government also decided to perform stress test of the older NPPs. Stress test for Kori-1 and Wolsong-1 were performed based on the international experience to reassess the targeted safety margin. Stress test aims to strictly re-confirm the safety of NPPs by evaluating its capability to respond to large-scale natural disasters beyond the design basis. Stress test report for Wolsong-1 was submitted to KINS on June 2013. KINS and civilian inspection team reviewed the results and finally the continued operation of Wolsong-1 was permitted on February 2015. Stress Test Report for Kori-1 was also submitted on December 2013. The Korean government decided to perform stress test for the remaining 22 NPPs by late 2018.

4.2. Stress Test Implementation Structure

Evaluation areas for the stress test are mainly the following 5 areas.
— Safety of SSCs against Earthquakes
— Safety of SSCs against Tsunami, Storm Surge, and Other Natural Disasters
— Plant Response to Loss of Electrical Power and or Loss of the Ultimate Heat Sink
— Severe Accident Management Capability
— Emergency Preparedness and Response

4.3. Safety Enhancement Activities in Stress Test

Probabilistic seismic hazard analysis was performed and the exceeding probability was much less than the criteria based on 0.2g. Safety of SSCs against tsunami, storm surge, and other natural disasters was also evaluated and the appropriate measures are prepared. All the safety equipment important to maintain the safety functions of the NPPs was evaluated to test the plant response to loss of electrical power and or loss of the ultimate heat sink. Natural cooling concept was prepared shown in Fig. 2. [4] Severe accident management guide (SAMG) was updated and passive autocatalytic recombiners (PAR) were installed additionally to mitigate the possibility of hydrogen explosion. Emergency preparedness and response procedure was also reinforced.

FIG. 2. Natural Circulating Cooling System
5. EARTHQUAKE ISSUE

5.1. Current Progress

There was an earthquake on September 12, 2016 at Gyeongju near Wolsong site. Measured at 5.8 on the moment magnitude scale, it was the strongest ever recorded in Korea since measurements begun in 1978. Even though there was no significant damage on the human and houses, it was the starting point to strengthen the anti-seismic remedy actions. Various seismic evaluations including the fault survey are performed currently.

5.2. Seismic Design Structure

The OPR 1000 which is the Korean standard nuclear power plant with a two-loop 1000MWe PWR reactor was originally designed to withstand 0.2g Peak Ground Acceleration (PGA) of the Certified Seismic Design Response Spectra (CSDRS) from RG 1.60. After the Fukushima accident, the OPR1000s have been upgraded to withstand 0.3g PGA. The APR1400, the advanced type of the OPR1000, is being designed to withstand 0.3g PGA and to perform their intended safety function at 0.5g PGA level. Emergency response buildings designed to withstand 0.5g PGA were planned to be constructed at every site for nuclear power plants in Korea after Fukushima accident and accelerated to be constructed by 2020 after Gyeongju earthquake.

5.3. Safety Enhancement Activities against Earthquake

Ministry of Trade, Industry and Energy set up the following 5 tasks and seismic measures which consist of 22 sub-tasks.

— Evaluation and countermeasures of seismic hazard near NPP areas
— Acceleration of seismic performance enhancement
— Strengthening emergency response capability
— Continuous evaluation and enhancement of earthquake-resistance
— Improvement of NPPs long-term safety

Nuclear Safety and Security Commission also prepare safety enhancement actions against seismic damages.

— Improvement of seismic responses systems
— Seismic reinforcement and detailed evaluation of seismic capability for operating NPPs
— Enhancement of the safety of Korea radioactive waste agency (KORAD) in Gyeongju
— Detailed geological survey and re-evaluation of design criteria around Gyeongju area
— Preparedness of emergency response facilities against earthquakes
— Enhancement of emergency response capability against earthquakes

6. CONCLUSIONS

Safety enhancement activities are continuously reinforced for the operating NPPs in Korea. It is mainly based on PSR structure, in addition to the routine operation activities like ISI, IST and so on. PSR system was introduced and well established with sound legal basis for the comprehensive and systematic safety evaluation of the operating plants. Aging assessment and remedy actions in PSR contribute directly to the safety enhancement of NPPs. Recently stress test and earthquake countermeasures also play an important role to increase the safety of the Korean NPPs.

REFERENCES