A Review on the Adaptability of the Most Recent Technical Standards for Continuous Operation of Nuclear Power Plants

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1. Introduction

Continuous operation means that a nuclear power plant that has reached the end of its design life is evaluated for safety in accordance with the technical standards prescribed by the Nuclear Energy Act and continues to operate even after reaching the end of its design life.

Due to the expiration of the design life of domestic nuclear power plants in December 2023, applications for continuous operation will be submitted for more than 10 nuclear power plants over the next five years. In accordance with the latest version of the Enforcement Decree of the Nuclear Safety Act, the most recent operational experience and research results should be taken into account during the evaluation process.

The technical standards approved at the time of operation licensing and those approved through operation modification licensing are being used in combination. In the case of new nuclear power plants, various technical standards are applied, reflecting the incorporation of the latest technical standards into their design. It is necessary to verify the importance of utilizing these technical standards and assess the applicability of the most recent ones during the ongoing assessment of continuous operation.

2. Status of Continuous Operation of Domestic Nuclear Power Plant by Plant Type

The domestic nuclear power plant operates four types of Pressurized Light Water Reactor and one type of Pressurized Heavy Water Reactor. [1]

- Pressurized Light Water Reactor (PLWR)
  - Westinghouse Type
  - Framatome Type
  - OPR1000
  - APR1400
- Pressurized Heavy Water Reactor (PHWR)

The status of continuous operation for the five types currently in operation is shown in the following table.

Table 1. Westinghouse Type

Name of Power Plant	Construction Permit Day	Commercial Operation Start Date	Design Life Expiration Date	Note
Kori Unit 1	1972. 05. 31	1978. 04. 29	2007. 06. 18	Permanently Shut-down
Kori Unit 2	1978. 11. 18	1983. 07. 25	2023. 04. 08	Continuous Operation Application Completed
Kori Unit 3	1979. 12. 24	1985. 09. 30	2024. 09. 28	Continuous Operation Application Completed
Kori Unit 4	1979. 12. 24	1986. 04. 29	2025. 08. 06	Continuous Operation Application Completed
Hanbit Unit 1	1981. 12. 17	1986. 08. 25	2025. 12. 22	Continuous Operation Application Completed
Hanbit Unit 2	1981. 12. 17	1987. 06. 10	2026. 09. 11	Continuous Operation Application Completed

Table 2. Framatome Type

Name of Power Plant	Construction Permit Day	Commercial Operation Start Date	Design Life Expiration Date	Note
Hanul Unit 1	1983. 01. 25	1988. 09. 10	2027. 12. 22	C
Hanul Unit 2	1983. 01. 25	1989. 09. 30	2028. 12. 28	C

C: Application for continuous operation as of November 2023 (scheduled)

Table 3. OPR1000

Name of Power Plant	Construction Permit Day	Commercial Operation Start Date	Design Life Expiration Date	Note
Hanbit Unit 3	1989. 12. 21	1995. 03. 31	2034. 09. 08	-
Hanbit Unit 4	1989. 12. 21	1996. 01. 01	2035. 06. 01	-
Hanbit Unit 5	1997. 06. 14	2002. 05. 21	2041. 10. 23	-

Hanbit Unit 6	1997. 06. 14	2002. 12. 24	2042. 07. 30	-
Hanul Unit 3	1993. 07. 16	1998. 08. 11	2037. 11. 07	-
Hanul Unit 4	1993. 07. 16	1999. 12. 31	2038. 10. 28	-
Hanul Unit 5	1999. 05. 17	2004. 07. 29	2043. 10. 19	-
Hanul Unit 6	1999. 05. 17	2005. 04. 22	2044. 11. 11	-
Shinkori Unit 1	2005. 07. 01	2011. 02. 28	2050. 05. 18	-
Shinkori Unit 2	2005. 07. 01	2012. 07. 20	2051. 12. 18	-
Shinwolsong Unit 1	2007. 06. 04	2012. 07. 31	2051. 10. 31	-
Shinwolsong Unit 1	2007. 06. 04	2015. 07. 24	2054. 11. 24	-

Table 4. APR1400

Name of Power Plant	Construction Permit Day	Commercial Operation Start Date	Design Life Expiration Date	Note
Saeul Units 1	2008. 04. 15	2016. 12. 20	2075. 07. 20	-
Saeul Units 2	2008. 04. 15	2019. 08. 29	2078. 12. 20	-
Saeul Units 3	2016. 06. 27	Under Construction	Under Construction	Under Construction
Saeul Units 4	2016. 06. 27	Under Construction	Under Construction	Under Construction
Shinhanul Units 1	2011. 12. 05	2021. 07. 09	2080. 11. 09	
Shinhanul Units 1	2011. 12. 05	Under Construction	Under Construction	Under Construction

Table 5. Pressurized Heavy Water Reactor (PHWR)

Name of Power Plant	Construction Permit Day	Commercial Operation Start Date	Design Life Expiration Date	Note
wolsong Units 1	1978. 02. 15	1983. 04. 22	2012. 11. 20	Permanently Shut-down
wolsong Units 2	1992. 08. 28	1997. 07. 01	2026. 11. 01	C
wolsong Units 3	1994. 02. 26	1998. 07. 01	2027. 12. 29	C
wolsong Units 4	1994. 02. 26	1999. 10. 01	2029. 02. 07	C

C: Application for continuous operation as of November 2023 (scheduled)

3. Importance of Technical Standards for Continuous Operation Safety Assessment

In accordance with Article 38(1) 4 of the Enforcement Decree of the Nuclear Safety Act, the Periodic Safety Review (PSR) of continuous operation utilizes the technical standards that are valid at the time of the evaluation criteria. Generally, the technical standards falling under the following categories are set as reference criteria used for the evaluation of the PSR of continuous operation.

- Category 1: Technical standards specified by statutory requirements related to PSR evaluation
  - Nuclear Safety Commission Notice No. 2022-6, Regulation on the Safety Rating and Classification of Reactor Facilities
  - Nuclear Safety Commission Notice No. 2023-2, Regulations on the Operational Inspection of Reactor Facilities
  - Nuclear Safety Commission Notice No. 2021-27, Regulations on Operation Testing of Safety-Related Pumps and Valves
  - Nuclear Safety Commission Notice No. 2018-7, Regulations on Pre-Use inspection of Reactor Facilities
  - Nuclear Safety Commission Notice No. 2017-29, Guidelines on the Application of Technical Standards for the Evaluation of Continuous Operation of Reactor Facilities
- Category 2: Technical standards set out in the PSR Safety Review Guidelines (KINS GE-N018, Rev.2) [2]
- Category 3: Inherent technical standards described in the FSAR
- Category 4: Criteria not included in categories 1, 2 and 3 but cited, referenced, or applied in the assessment.

Specific periodic safety assessments are carried out considering the evaluation contents and methods described in Chapters 1 through 14 of the PSR Safety Review Guidelines (KINS GE-N018, Rev.2) [2]. In addition, an analysis of the differences between the effective and recent technical standards related to structures, systems, and components (SSCs) is conducted, including the following four PSR factors, to derive potential safety enhancements.

- Design of Reactor Facilities
- Deterministic Safety Assessment
- Probabilistic Safety Assessment
- Risk Assessment

In terms of the importance of technical standards, it is necessary to prioritize conducting a gap analysis evaluation of reference technical standards using the PSR evaluation factors selected by the above categories. The focus of the difference analysis should be on technical standards related to SSCs, which are crucial for safety among the PSR evaluation factors. Subsequently, the identified discrepancies should be appropriately categorized into potential safety enhancements, unnecessary items, and unrealistic matters. The final safety enhancements should then be selected through a comprehensive review process.

4. Applicability of Most Recent Technical Standards to Continuous Operation

The qualitative goal of nuclear safety is that 'the construction and operation of nuclear power plants do not pose an undue risk'. Quantifying these safety goals allows limiting the added risks from the construction and operation of nuclear power plants to one-thousandth of the risks encountered in daily life. This is achieved by applying the frequency of damage to the reactor core to the design of nuclear power plants. In the past, nuclear power plants were designed to match a damage frequency of 10^{-4}/year.

The question arises: what standard should be used to adjust the core damage frequency when continuing to operate previously constructed nuclear power plants? It may be considered that it should align with those of new nuclear power plants. This implies that continuous operation must adhere to the latest technical standards. The majority of recent technical standards include numerous newly formulated provisions designed for new nuclear power plants. Nevertheless, even if the nuclear power plant has been operating based on a 10^{-4}/year criterion, it can still adhere to the one-thousandth principle.

On the other hand, most of the recent technical standards also specify that some requirements apply to new power plants and state that operating power plants must meet the approved technical standards at the time of operation permission. Therefore, some recent technical standards recognize that it may be impossible for operating power plants to fully comply with the latest technical standards or provide additional safety benefits. In such cases, they evaluate the importance of the identified gaps using a graded approach method, allowing for selective application. Hence, it appears that the most recent technical standards should be applied to the extent practically feasible.

5. Conclusion

In this paper, the importance of technical standards for continuous operation and the applicability of the most recent technical standards were reviewed. Instead of demanding that continuously operating nuclear power plants meet the same standards as new ones, it is deemed appropriate to utilize gap analysis, ensuring that the highest safety goals are not compromised, and apply the most recent technical standards to the extent feasible, taking safety benefits into consideration.

REFERENCES

[1] IAEA, Power Reactor Information System
[2] PSR Safety Review Guidelines (KINS/GE-N018, Rev.02).