

Improved Regulatory Approaches for Digital I&C Upgrade of Operating Nuclear Power Plants

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1. Introduction

Due to the difficulties in procuring replacement parts and increased maintenance costs, the number of cases of improving and replacing existing systems with upgraded systems which have applied digital technology is increasing. Generally, digital technologies have the advantages in improving performance, reliability and availability. However, they have some unique characteristics, such as using software, and can cause software common cause failures (CCFs).

In order to change the digital I&C systems of operating nuclear power plants, it is necessary to obtain licenses from regulatory body. In this study, we analyzed domestic and foreign regulatory requirements and technical standards to help upgrade for the digital I&C systems of nuclear power plants and developed the improved regulatory positions for them.

2. Regulatory Framework related to Digital I&C Upgrades

2.1 Domestic Regulatory Framework

A person, who wishes to change any licensed matters, shall obtain license from the Commission under the conditions as prescribed by the Presidential Decree as provided in Article 20(1) of the Nuclear Safety Act [1]. Provided, that when the minor matters prescribed by the Prime Minister's Ordinance are to be changed, they shall be reported. Any person who wish to obtain a change permit of permitted matters shall submit to the Commissions an application for change permit pursuant to Article 34 of the Enforcement Decree of the Act [2].

This is applicable to all reactors and related facilities for power generation, not limited to digital I&C upgrades. The term "Application for Change Permit" means a change other than minor matters prescribed in Article 6 or Article 18 of the Enforcement Regulation of the Act.

A Report of Change in Minor Matters shall be reported in accordance with Article 20 of the Nuclear Safety Act and Article 18 or the Enforcement Regulation of the Act. Fig 1 shows the regulatory framework for the digital I&C upgrades in Korea.

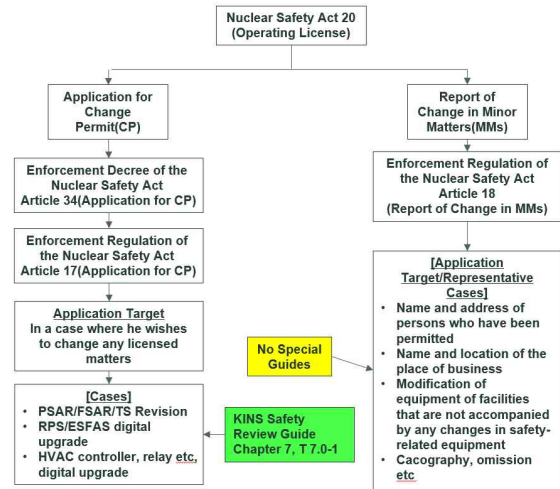


Fig 1 Regulatory Framework for Digital I&C Upgrade in Korea

Digital I&C upgrades for domestic nuclear power plants, which are accompanied by some changes in safety-related equipment, shall be obtained license from the Nuclear Safety Commission regardless of considering the safety significance and the complexity of the changes. The digital I&C upgrades shall be met the various regulations, regulatory guidelines, endorsed technical standards which are contained in Safety Review Guide Chapter 7, Table 7.0-1.

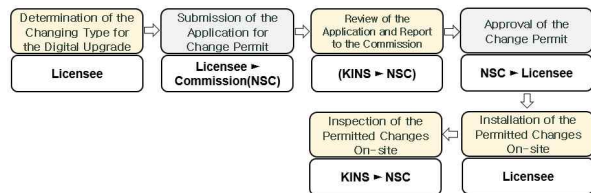


Fig 2 Process for the Approval of the Change Permit

2.2 US NRC Regulatory Framework

The regulatory framework of the digital I&C upgrades in the US can be divided into large system-level upgrades based on 10 CFR 50.55a(h), "Protection and Safety Systems" and small device-level upgrades based on 10 CFR 50.59, "Change, tests and experiments", as shown in Fig 3.

2.2.1 Digital I&C upgrades according to 10 CFR

50.55a(h)

The PSAR and FSAR reviews of new nuclear power plants or digital I&C modifications of nuclear RPS or ESFAS are the examples of the large-scale facility upgrades based on 10 CFR 50.55a(h) [3]. These large-scale facility upgrades shall be met the various regulations, regulatory guidelines and endorsed technical standards which are contained in SRP Chapter 7, Table 7-1 to meet the IEEE Std. 279 and 603's criteria referred to in the 10 CFR 50.55a(h).

In particular, regulatory guidelines and industry standards such as NRC SRP BTP 7-14, 7-19 and EPRI TR-106439 should be applied to satisfy the quality and diversity design principles of digital I&C systems.

2.2.2 Digital I&C upgrades according to 10 CFR 50.59

10 CFR 50.59 established the conditions under which licensees may make changes to the facility or procedures and conduct tests or experiments without prior NRC approval. 10 CFR 50.59(c)(2) presents eight questions. The conditions mean that the answers to eight questions are satisfied [4].

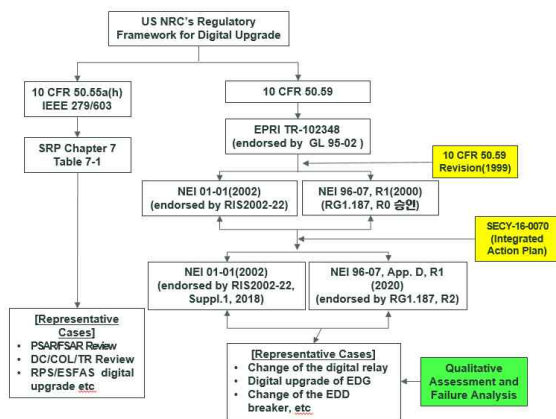


Fig 3 Regulatory Framework for Digital I&C Upgrade in Korea

In 2002, RIS 2002-22 endorsed NEI 01-01, "Guideline on Licensing Digital Upgrades: EPRI TR-102348, Revision 1". NEI 01-01 provides guidance on implementing and licensing digital upgrades and provides guidance on performing qualitative assessments for the dependability of digital I&C systems [5].

NEI 96-07 published in 2000, acknowledges that qualitative assessments can be used to address some criteria in 10 CFR 50.59. RIS 2002-22, Supplement 1 issued in 2018, provides supplemental clarifying guidance on one acceptable approach for performing qualitative assessments of digital I&C modifications [6].

Examples of upgrade in accordance with 10 CFR

50.59 include analog/digital relay replacement, HVAC digital control unit replacement, emergency diesel generator (EDG) digital control unit replacement, digital recorder and indicator replacement, and non-safety related digital facility upgrade.

These digital I&C upgrades can utilize qualitative assessment and fault analysis to allow licensee to perform digital I&C modification without prior NRC approval if the likelihood of CCF is confirmed to be "sufficiently low" as well as a single failure.

3. Improved Regulatory Approaches for Digital I&C Upgrades in Domestic Operating Nuclear Power Plants

3.1 Graded Approach according to the Scale and Safety Significance

All the digital I&C upgrades of domestic operating nuclear power plants are required to get a change permission and should meet the same regulatory requirements without differentiation depending on safety significance or the scale of the modification.

In this research, differentiated regulatory requirements are proposed, divided into system-level digital upgrades and device-level digital upgrades depending on the scale of upgrade and the safety significance.

The existing regulatory requirements are maintained for system-level digital upgrades with high safety significance, such as RPS and ESFAS. In addition, valid technical standards are applied at the time of the current system upgrade. However, if the necessity is recognized, it may be required to apply the latest technical standards.

For device-level digital upgrades, qualitative assessments and failure analysis can be utilized. If qualitative assessment and failure analysis can confirm that the probability of CCFs as well as a random single failure is sufficiently low, it can mitigate the licensing requirements related to quality criteria. However, it should be determined, whether device-level digital changes damage the redundancy, diversity, separation, or independence of design functions described in the FSAR by using networks connecting different systems, integrating design functions, or sharing resources between channels, systems and divisions. Such damages would have an adverse effect on its design function, so it should be met regulatory requirements for the system-level, not the device-level. This is because such digital upgrade can affect various design layers, e.g., RPS, ESFAS, plant control systems, and monitoring and indication systems.

If device-level digital I&C upgrades are made, the application of valid technical standards at the time of getting licensing at the system level is possible.

However, if necessary, it may be required to apply valid or up-to-date technical standards at this point.

3.2 Application of Qualitative Assessments and Failure Analysis

It has been confirmed that there are many difficulties in applying system-level digital I&C software quality standards of high safety significance for device-level digital I&C upgrades. Qualitative assessments and failure analysis can be utilized by using NRC RIS 2002-22, supplement 1 for the device-level digital changes.

This digital modification does not require the requirements of the Software Quality (BTP 7-14) and the D3 (Defense in Depth and Diversity) analysis (BTP 7-19). However, when digital devices, which are not comply with nuclear quality standards, are used, the guidance in EPRI TR-106439 on quality verification of general standards should apply.

Qualitative assessment should consider three factors: (1) the design attributes, (2) the quality of design procedures, and (3) any applicable operating experience. The design attributes and the quality of the design process are interrelated, so these two factors are essential in qualitative assessment. In most cases, operating experience can be used to compensate for the vulnerabilities of these two factors.

4. Conclusion

Regulatory requirements and related technical standards for domestic and NRC related to digital design changes were reviewed and analyzed. In addition, the improved regulatory approaches were proposed that could be applied to digital I&C upgrades for domestic operating power plants. The graded approach for the regulatory requirements according to the scale and safety significance of digital I&C upgrades was proposed, and also suggested that qualitative assessments and failure analysis could be utilized for device-level design changes which have low safety significance. However, the existing regulatory requirements should be maintained for system-level digital I&C upgrades, such as RPS and ESFAS.

The future studies plan to develop the regulatory guidelines for device-level digital I&C upgrades with low safety significance.

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- [6] NRC RIS 2002-22, Supplement 1, "Clarification on endorsement of nuclear energy institute guidance in designing digital upgrades in instrumentation and control systems"