

Study on Regulatory Status of Artificial Intelligence Technology in Nuclear Instrumentation and Control Fields by the U.S. NRC

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1. Introduction

As artificial intelligence (AI) technology is introduced into the nuclear industry, regulatory agencies are establishing regulatory frameworks to ensure the safe and reliable use of this innovative technology. In particular, the instrumentation and control (I&C) field of nuclear power plants, which is a core system for safe operation, has seen both interest and concerns regarding the application of AI technology.

This paper studies the regulatory status on AI of the nuclear regulatory agencies in the United States. It examines how each agency defines AI in the I&C field, the criteria for allowing or restricting its application, and the regulatory approaches to the development and evaluation of AI technology.

Additionally, this study investigates concerns regarding safety, reliability, and transparency associated with AI utilization and the regulatory approaches to address these concerns. It summarizes the key contents of relevant guidelines, reports, and policy documents.

2. Regulatory Status of AI in U.S. NRC

The I&C system of a nuclear power plant is essential for monitoring and controlling the status of the reactor and is a collection of safety-grade equipment. Recently, there have been increasing attempts to implement advanced data analysis, anomaly prediction, and autonomous control assistance using AI technology (especially machine learning).

While AI can contribute to I&C in terms of aging management, anomaly detection, operational decision support, and intelligent control, it also raises new challenges, including difficulties in verification and validation, unpredictable behavior, data quality and security vulnerabilities. In this context, regulatory agencies in various countries and the IAEA are exploring ways to integrate AI into existing regulatory frameworks and identifying necessary additional safety. The following sections examine the regulatory status of AI in the U.S. NRC.

2.1 Applicability and Criteria of AI

Currently, the NRC does not prohibit the application of AI technology in nuclear power plants, but

emphasizes the need to apply strict criteria depending on safety classification.

According to a 2023 research report by the U.S. ORNL, Currently, any use of AI at nuclear power plants is focused on non-safety applications. The NRC and other regulatory bodies are evaluating providing guidance to address gaps rather than create new regulations to address the use of AI and ML[1]. This approach seems to be the best to encourage AI development without adding regulatory uncertainty. In other words, if AI is incorporated into instrumentation and control systems, it must meet existing digital I&C regulatory requirements based on the system's functions and safety classification.

2.2 Assessment and Verification Approach of AI Technology

The NRC recognizes the reliability and verifiability of AI-based systems as key concerns. It points out that traditional software V&V (Verification & Validation) methods may be insufficient to assess the reliability of complex AI algorithms, emphasizing the need for efforts to ensure transparency and explainability. For example, quality management of training data, documentation of algorithm decision logic, and independent verification of outputs may be required.

The NRC published its final report[2] in October 2024, identifying AI-related issues not addressed by existing regulations and providing considerations for regulatory review. Additionally, to enhance AI technology evaluation capabilities, the NRC established a corporate AI strategy plan (NUREG-2261)[3] in May 2023 and is promoting initiatives such as building an AI review framework within the organization, training experts, and strengthening collaboration with industry.

In summary, the NRC is not immediately introducing new regulations for AI but is preparing to integrate AI into existing safety regulatory frameworks and establishing necessary guidelines and evaluation criteria.

2.3 Concerns and Responses Regarding the Safety, Reliability, and Transparency of AI Technology

The NRC identifies key concerns related to the use of AI, including ensuring safety (especially when applied to safety systems), difficulties in verifying reliability and accuracy, and the lack of transparency in decision-

making processes. The NRC and U.S. research institution reports emphasize that "to trust AI results, reliability, transparency, and the ability to validate and verify the results must be ensured above all else." In response to these concerns, the NRC reaffirms the principles of compliance with design criteria and ensuring safety margins, and requires a thorough evaluation of the impact of AI on safety. For example, it is discussed that when AI is involved in automatic control, redundancy or independence must be maintained to prevent AI failures from impairing safety functions.

Additionally, the NRC acknowledges issues arising from data bias or insufficient training data, noting that the performance of AI systems is directly influenced by the quality of input data, thereby highlighting data quality management as a critical regulatory element. In terms of transparency, the NRC may recommend submitting model documentation and log records to enable traceability of AI decision-making, while also incorporating human review (human check) procedures to enhance reliability.

To address the "black box" problem of AI algorithms, the NRC is monitoring the latest techniques from industry and academia (e.g., explainable AI, new V&V technologies) across AI utilization and regulatory response by appointing an AI Governance Board and Chief AI Officer[4].

2.4 AI-Related Guidelines, Reports, and Policies

In the United States, various official documents related to AI are being published under the leadership of the NRC. The AI Strategy Plan (NUREG-2261) mentioned earlier contains a roadmap for strengthening regulatory capabilities from 2023 to 2027.

Additionally, the report SECY-24-0035[5] identified 61 potential use cases for applying AI within the regulatory agency and proposed measures to enhance workforce efficiency and review capabilities.

Externally, the NRC collaborated with Canada's CNSC and the UK's ONR to publish the "Considerations for the Developing AI Systems in Nuclear Applications" principles report[6] in September 2024, outlining core principles across the entire AI lifecycle. This document covers topics such as compliance with existing safety engineering principles, consideration of human and organizational factors, AI architecture design, AI lifecycle management, and safety and security documentation, and provides guidelines that all stakeholders (developers, licensees, and regulators) should keep in mind when applying AI in the nuclear field.

Additionally, the NRC collaborated with INL and others to publish the NUREG/CR-7294 report (2022)[7], which investigated the current status and future technical trends of AI/ML utilization in commercial power plants.

To date, the NRC has not established separate regulations for AI but maintains the position that it will

respond by revising and supplementing existing guidelines as necessary. The NRC plans to establish a strategy to remove barriers to AI adoption and revise the regulatory framework by 2025.

3. Conclusions

This paper studied the regulatory status of the U.S. NRC regarding AI in the field of nuclear power plant instrumentation and control. U.S. NRC acknowledges the inevitable adoption of AI technology and are pursuing their own efforts to ensure safety, reliability, and transparency.

The U.S. NRC acknowledges the potential of AI to enhance nuclear safety and efficiency while revising regulatory frameworks to maintain or complement existing stringent safety standards. Notably, they are leveraging existing digital instrumentation and control regulatory frameworks to incorporate AI and, when necessary, clarifying expectations through guidelines or policy documents.

In conclusion, regulations on the application of AI technology in the field of nuclear instrumentation and control fields are still a work in progress, and the NRC reaffirms existing safety philosophies while attempting to adapt flexibly. This balanced approach, which embraces innovation under the principle of safety first, is an essential condition for the successful utilization of AI. South Korea must also closely monitor these trends in the NRC and respond proactively in order to maintain its position as a leading country in the nuclear safety regulation in the era of the fourth Industrial Revolution.

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