Analysis of Technical Standard Conformity for European Export in the MMIS Domain

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1. INTRODUCTION

To satisfy the technical requirements for the Czech new Nuclear Power Plant (NPP) project, a comprehensive gap analysis is essential between the Czech technical standards—rooted in the European Utility Requirements (EUR) and IEC standards—and the APR1400 Man-Machine Interface System (MMIS) design, which was originally developed based on U.S. NRC regulations and Korean KEPIC standards [1].

Notably, IEC 61513 mandates that the Instrumentation and Control (I&C) architecture and system development account for the entire I&C life cycle, spanning design, manufacturing, construction, commissioning, operation, and maintenance [2].

Accordingly, this paper conducts a comparative analysis of approximately 200 technical standards and regulatory requirements between Korea and Europe across key MMIS domains, including the Main Control Room (MCR), Information Processing System (IPS), and Control and Protection Systems. Furthermore, by examining relevant design implementation cases, this study proposes practical engineering strategies to accommodate the unaddressed technical requirements.

2. Analysis of APR1400 MMIS Design Specifications and Comparison of Technical Standards

This section presents the analysis of the APR1400 MMIS design specifications and applicable codes, along with the comparative review between domestic (Korean) and European technical standards.

2.1. Review of APR1400 MMIS Design Specifications and Applicable Codes

In this subsection, based on the design specifications of the APR1400 MMIS for Shin-Hanul Units 1 and 2, the core design features and applied domestic standards and codes were analyzed. In addition, the corresponding European standards and technical requirements (such as EUR [1] and IEC) were identified and mapped.

2.2. Comparative Review and Applicability Assessment of Domestic and European Technical Standards

The comparative review of approximately 200 domestic technical standards and their European counterparts confirmed that most domestic standards either encompass or are comparable to the requirements of European standards.

Although minor differences were identified in the scope and specific technical requirements for certain standards, an engineering evaluation indicated that there are no critical technical constraints in adopting and applying European standards. Furthermore, an assessment based on the baseline APR1400 MMIS design specifications concluded that, despite these differences, the European technical standards can be successfully incorporated into export-oriented NPPs (e.g., APR1000) through complementary engineering.

3. Analysis and Applicability Assessment of Key MMIS Technical Standards

This section summarizes the comparative review and applicability assessment between IEC standards and domestic (Korean) nuclear codes (IEEE, NUREG, etc.) across seven key MMIS domains to satisfy the requirements for the Czech new build project.

3.1. Main Control Room (MCR)

While minor scope differences exist in IEC 60964 and 61508, the requirements can be seamlessly incorporated into the APR1400 design through existing NUREG-0711 based Human Factors Engineering (HFE) processes and supplementary project execution plans [3,4].

3.2. Information Processing System (IPS)

While the IPS itself is a non-Class 1E system, safety-class information systems (such as QIAS-N and QIAS-P) performing Category A functions are subject to IEC 61500. Unlike the domestic standard (NUREG/CR-6082), IEC 61500 mandates the independent segregation of processing and communication modules. This stringent requirement is natively met without design modifications, as the safety PLC (e.g., POSAFE-Q) utilized in the safety-grade architectures inherently separates these functional modules.

3.3. Control Systems

Isolation requirements under IEC 60709 are fully satisfied by equivalent domestic standards, including IEEE 384, equipment qualification (IEEE 323/344), and EMC guidelines (RG 1.180).

3.4. Protection Systems

Hardware requirements for Class 1 and 2 systems under IEC 60987 are comprehensively encompassed within IEEE 603 [5] and IEEE 7-4.3.2 [6], confirming direct applicability.

3.5. I&C Life Cycle

Although general system requirements are met, IEC 61513 [2] mandates a holistic life-cycle framework not explicitly detailed in domestic codes, requiring complementary implementation procedures.

3.6. Software Verification and Validation (V&V)

Procedural variances with IEC 60880 [7] are thoroughly addressed by the established domestic V&V and configuration management framework based on IEEE 1012 and 828.

3.7. Human Factors Engineering (HFE)

Visual Display Unit (VDU) requirements in IEC 61772 are fully covered by the detailed methodologies of NUREG-0700 and NUREG-0711 [4], ensuring compliance without engineering constraints.

4. Comparative Safety Classification Analysis of MMIS Technical Standards

This section comparatively analyzes the Czech safety classification system based on IEC 61226 (Category A, B, and C), the domestic regulatory system under KINS guidelines (IC 1, 2, and 3), and the APR1400 Software Program Manual (SPM) categorization (SC, ITS, ITA, and GP). The evaluation revealed that structural differences between these frameworks lead to nominal classification disparities for certain systems. For instance, while the alarm system is classified as IC 3 under Korean regulations, it is designated as Category C under European standards, superficially suggesting a requirement for an upgraded safety classification. However, in the Shin-Hanul Units 1 and 2 baseline design, the Information Processing System (IPS)—which incorporates the alarm functions—was categorized as Important To Availability (ITA) under the SPM and underwent rigorous verification activities equivalent to Category C requirements. Therefore, leveraging the established ITA/ITS verification records from the baseline APR1400 development provides a robust technical basis to demonstrate full compliance with European safety classification requirements without engineering impediments.

5. Conclusions

To satisfy the technical requirements for the Czech new nuclear power plant project, this study conducted a comprehensive comparative analysis of approximately 200 technical standards between European codes (EUR, IEC) and domestic Korean codes (KEPIC, IEEE, NUREG, etc.) across seven key MMIS domains: MCR, IPS, Control Systems, Protection Systems, I&C Life Cycle, Software V&V, and HFE.

The results demonstrated that while minor variances exist in phrasing and specific scopes, the overarching safety and reliability requirements are substantially comparable, with domestic standards comprehensively encompassing most European provisions.

Furthermore, an applicability assessment based on the baseline APR1400 MMIS design specifications (Shin-Hanul Units 1 and 2) confirmed that the existing hardware architecture and established software verification programs fully satisfy European technical requirements, verifying that the MMIS for export nuclear power plants (e.g., APR1000) can accommodate European standards without significant engineering constraints.

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