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Why a consistent approach to nuclear codes and standards is crucial for the serial deployment of standardized SMRs

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Widespread SMR deployment is important for energy sustainability

Small modular reactors (SMRs) represent a reliable, low carbon energy source that is expected to easily integrate with existing grid infrastructure and in new locations, including remote communities. Their deployment is essential to achieving energy security and net zero objectives while meeting the increasing electrification and heat demands of diverse economies worldwide. To enable their rapid and cost-effective international deployment, SMR designs should be standardized as much as possible, with minimal ad hoc design changes to meet jurisdictional requirements. This standardization will enable serial manufacturing of reactor modules to be shipped throughout the world, unlocking the benefits of scaling and a fleet approach to deployment.

Engineering C&S provide a design basis

The use of appropriate engineering Codes & Standards (C&S) for the design of nuclear power plant structures, systems and components (SSC) that are important to safety is mandated by the IAEA's SSR-2/1 (Rev. 1) Safety Standard, under Requirement 18.[2] However, C&S are also vital for SSCs that are not nuclear safety-related, as all manufactured and constructed SSCs need them as their basis.

The C&S also provide the criteria to which SSC must be designed: the detailed quality criteria, allowable materials, manufacturing requirements, safety factors, reliability, inspectability etc. C&S exist across all engineering disciplines: mechanical, electrical, instrumentation & control (I&C), civil, structural and other areas such as environmental management, radioactive waste, etc. They are developed and maintained by industrial standards development organizations (SDO) committees that work to incorporate current best practices into requirements in the standards.

C&S differ between jurisdictions

Across the engineering disciplines, a wide range of C&S have been developed to provide quality requirements. They are continuously updated to incorporate state-of-the-art technologies and operational experience. Their development is typically done on a national or regional basis.

Additionally, national regulatory frameworks determine the selection of C&S to be used for nuclear power plant (NPP) design, typically as a function of their regulatory philosophy. This approach can either be prescriptive, in which the legislation or the regulatory bodies defines the C&S to which NPPs must be designed, or goal-based, in which the law sets safety goals, and a licensee is required to justify their selection of C&S and demonstrate achievement of safety and compliance with other code requirements, e.g., the civil code.

The combination of these two elements presents multiple challenges. Firstly, licensees need to make changes to meet differing requirements across jurisdictions, preventing a single standardized design from being deployed globally due to different regulatory interpretations of high-level global standards[3]. Secondly, goal-based regulators must develop competencies across multiple C&S to enable their reviews of designs. Finally, nuclear suppliers/nuclear vendors must not only comply with multiple C&S but also establish different qualification processes to serve multiple markets. In practice, this means that fewer suppliers are available for SMR projects due to cost barriers to entry in markets with different requirements. All three elements combined present not only a significant time and cost burden on the parties but also a significant obstacle to the global deployment of SMRs as licensees are less able to benefit from economies of serial production without standardized designs.

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[1] This working report is not an IAEA publication. It reflects the consensus opinion of the members of the NHSI Industry Track Topic Group 2. The views expressed do not necessarily reflect those of the IAEA or its Member States

[2] International Atomic Energy Agency, Safety of Nuclear Power Plants: Design SSR-2/1, (Rev. 1) IAEA, Vienna (2016)

[3] World Nuclear Association, Different Interpretations of Regulatory Requirements (2021)

Work has been undertaken at the SDO level to limit differences between C&S and to reconcile them where possible. Such initiatives have had varying results, but a notable success story has been the dual-logo agreement developed for electrical engineering and I&C by the Institute of Electrical and Electronics Engineers (IEEE) and the International Electrotechnical Commission (IEC), which allows the two SDOs to jointly develop new standards or revise existing standards[4]. It should be noted that this work is time consuming. Differences in scope and content also widely persist across C&S in other engineering disciplines and topics.

A full reconciliation of nuclear C&S across all SDOs is probably unrealistic and unnecessary. It is more important to understand equivalencies and differences across them to determine where the use of C&S could be possible and acceptable by different authorities. One possibility would be to compile a core selection of nuclear C&S for SMR projects that would be acceptable by most nuclear regulatory bodies and other authorities.

IAEA NHSI Industry Track TG2 comparison exercises pave the way

To help overcome some of these challenges, NHSI Industry Track Topic Group 2 has undertaken a mapping exercise for a selection of nuclear design codes and in-service inspection codes. It produced a comparison of mechanical engineering C&S following a top-down approach building on a methodology from previous work completed by the World Nuclear Association[5]. The chapters, sub-chapters and clauses of C&S have been studied and mapped against each other as a function of their scopes. Hyperlinks to SDO websites to view the C&S have also been provided.

The exercise aims to provide a description of how the mentioned engineering C&S differ from each other and where scope overlaps lie. This approach would produce an illustration of the C&S landscape, enabling multiple stakeholder groups (reactor designers and vendors, licensees, regulatory bodies, component manufacturers, etc.) to easily visualize where counterparts to existing knowledge and capabilities for a given code or standard can be found.

The outputs of the exercises are now hosted on the IAEA MSCQ[6] [7] network with tables displaying correlations between the selected nuclear mechanical C&S for pressure boundary design and in-service inspection. The code comparison exercise has shown that, at a high level, all considered C&S cover the same main topics and use safety classifications as a means of structuring the documents. Differences were found in the structure of the codes, with some opting to first categorize by safety class and then component type while others used the inverse ordering. The applicability of the C&S content varied too, often reflecting the variety in national approaches to engineering and the different histories of the countries' nuclear sectors.

Future work

The code comparison exercise provides an overview of the C&S landscape; however it does not, for now, aim to identify and address topical areas in C&S which have been challenging for the export of nuclear reactors and their equipment. Other TG2 work focuses on areas including fire codes, long-lead items and the use of commercial grade items in safety systems. Further cooperation between all parties, including regulatory bodies, both to determine the most potentially impactful topics and also to provide a perspective on the code comparison work and its potential for enabling the use of C&S for the design of nuclear power plants will be necessary.

The second phase of NHSI will see the Industry Track TG2 continue its code comparison work in the immediate future with the focus moving to civil and structural codes, as they are the most significant contribution to cost. This would follow the completion of work on mechanical design and in-service-inspection issues.

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[4] https://standards.ieee.org/wp-content/uploads/import/documents/other/iec-ieee-coop.pdf

[5] World Nuclear Association, Nuclear I&C and Electrical System Standards Tables with URLs (2024)

[6] https://nucleus.iaea.org/sites/connect-members/msn/SitePages/TG2-Participants.aspx

[7] https://nucleus.iaea.org/sites/connect/MSNpublic/SitePages/Home.aspx