American Nuclear Society

SPECIAL REPORT

Setting the Right Bar: How Consensus Standards Help Advanced Reactor Development

Report of the ANS Special Committee on Advanced Reactor Policy
chartered by ANS 2018-2019 President John Kelly

EXECUTIVE SUMMARY

United States leadership and involvement in carbon-free advanced reactor development is crucial in being able to achieve key U.S. policy objectives. The United States has led the development of nuclear energy from the earliest days of the power source, but the country is now in clear danger of losing this leadership position unless policy initiatives are developed and sustained in several different areas, including the governmental-promotional, industrial, and regulatory sectors. The United States must take action to remain influential in ensuring the safe and secure use of nuclear energy as well as nonproliferation. This report is focused on consensus codes and standards within the arena of advanced reactor development.

INTRODUCTION

Consensus standards are a vital, albeit sometimes underappreciated, aspect of nuclear energy system design, operation, and regulation. They allow commercial suppliers and regulators to leverage the collective wisdom of the entire scientific and engineering community to ensure the appropriate margin of safety in the design and construction of nuclear systems, and they provide a technically robust basis for decision makers. Bringing new nuclear energy systems to market requires serious commitment on the part of industry, government, and standards development organizations (SDOs). Additionally, harmonizing design margins as part of developing advanced reactor standards could allow for reductions of excess margin as well as have significant impacts on cost and operations.

Numerous countries are showing interest in the development of advanced nuclear energy designs. This interest is primarily driven by a growing global energy demand in combination with a desire—and government mandates—to achieve significant reductions in emissions. As the discussion about impacts of climate and environmental stewardship grows there is an escalating sense of urgency to utilize more carbon-free generation sources. Changes are also under way to reduce carbon and other emissions from other sources. For example, air quality issues in large metropolitan areas motivate the electrification of the transportation sector (i.e., increased use of electric vehicles) to curb automobile emissions. There is also an increased awareness that additional human health impacts stem from certain emissions, such as respiratory health issues associated with the emission of sulfur dioxide from the use of coal for electricity generation. As the impacts continue to grow so will the social cost of carbon. It is not unreasonable to expect that the social cost of carbon will increase over time as society gains a better understanding of the factors impacting global warming and public health and the actions necessary to slow the impacts. The increased attention to climate change has placed greater focus on increasing the percentage of energy that is generated from carbon-free generation sources including advanced nuclear. (The Intergovernmental Panel on Climate Change found in 2014 that nuclear energy's life-cycle carbon emission was lower than that from solar, geothermal, or hydropower and comparable to that from wind-generated power.).[1]

There is a consensus in the United States that its leadership and involvement in carbon-free advanced reactor development is crucial to achieve key U.S. policy objectives related to nuclear safety, national security, and nonproliferation. (Nuclear energy provides more than 55 percent of the carbon-free electricity in the United States.[2] Electricity generated by nuclear energy avoids the emission of more than 528 million metric tons of carbon dioxide each year[3]—more than the emissions from 113 million passenger vehicles.[4]) The United States has led the development of nuclear energy from its earliest days in the 1950s, but unless near-term actions are taken, U.S. leadership will be lost. These near-term actions include developing and implementing policy initiatives in several different areas, including the governmental-promotional, industrial, and regulatory sectors. Actions must also be taken for the United States to remain influential in international standards and protocols for ensuring the safe and secure use of nuclear energy as well as nonproliferation.

[1] Intergovernmental Panel on Climate Change, *Climate Change 2014,* Chapter 7, "Energy Systems."
[2] U.S. Energy Information Administration, "Electric Power Monthly – March 2019."
[3] Emissions avoided are calculated using regional and national fossil fuel emissions rates from the U.S. Environmental Protection Agency's Continuous Emission Monitoring System and latest plant generation data from the U.S. Energy Information Administration's "Electric Power Monthly – March 2019."
[4] U.S. Federal Highway Administration, "Highway Statistics 2017" publication.

Regulators are required by law to use consensus standards as a means to carry out agency policy objectives or activities unless such use is inconsistent with applicable law or is impractical. The White House Office of Management and Budget Circular A-119, "Federal Participation in the Development and Use of Voluntary Consensus Standards and Conformity Assessment Activities," sets forth the conditions in which executive branch agencies including the U.S. Nuclear Regulatory Commission (NRC) do this. Circular A-119 currently affects open government, developments in regulatory policy and international trade, and changes in technology.

Likewise, the NRC's internal guidance (Management Directive 6.5) states that, "it is the policy of the U.S. Nuclear Regulatory Commission (NRC) to (i) involve all interested stakeholders in the NRC's regulatory development processes, (ii) participate in the development of consensus standards that support the NRC's mission, and (iii) use consensus standards developed by voluntary consensus standards bodies consistent with the provisions of the National Technology Transfer and Advancement Act of 1995 (Public Law 104-113)."

It is essential that the federal government, and particularly the U.S. Department of Energy (DOE), actively supports the acceleration of SDOs' development of advanced reactor standards and that the NRC incorporates these standards into its regulatory policies, guidelines, and activities in a manner that does not delay or complicate the timely licensing of advanced reactor "early movers."

THE VALUE STATEMENT OF CODES AND STANDARDS

Codes and standards have historically played a crucial role in designing, licensing, and operating light water reactors. They should have an equally important role in the development and deployment of advanced reactors. When an industry-wide consensus (that also involves the regulators) is reached on a technical topic, and is then embedded in a formal consensus standard, the requirements embedded therein attain a stature that could not be attained if the exact same document were written by a private company or the regulatory agency working by itself. Therefore, many of the NRC's safety regulations and guides refer directly to various consensus codes and standards. In turn, compliance with codes and standards brings greater certainty to the designer and regulatory reviews, which enhances both project schedule and cost certainty. Having established consensus through a prescribed process, the codes and standards provide certainty as to what is needed to achieve reasonable assurance of safety and how to go about completing the design. Through this process the regulatory challenges can be significantly reduced.

Codes and standards reduce economic burden by avoiding unnecessary changes to designs and facilitate the establishment of technically appropriate safety margins. Perhaps the best example is the use by the nuclear power industry worldwide of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) to assure safety in that technical area. The ASME BPVC has prestige and stature, justified by experience, which could never be attained by any individual group (a company, or an agency) working by itself, and the use of that code made power reactors both economical and safe for public utilities in prior decades.

Codes and standards also provide credibility for marketing advanced reactors internationally. By showing adherence to codes and standards, advanced reactor suppliers can demonstrate and market significantly reduced risks associated with the regulatory burden and first-of-a-kind implementation challenges. United States leadership in nuclear energy codes and standards has been recognized for more than a half-century and should continue into the future. Without decisive action and government support, that U.S. advantage is in danger of being lost because of inattention and lack of financial and personnel support. This key advantage of U.S. commercial suppliers cannot be permitted to be squandered.

CHALLENGES

Where relevant, advanced reactor developers may be concerned that the time required to develop the necessary codes and standards may impact project schedules. Additionally, not all codes and standards are a prerequisite for the deployment of first-of-a-kind and early units. Time is of critical importance to developers who are making multiyear capital investments with expectations of returns. The impact of "waiting for standards" is being mitigated by the creation and use of performance-based standards. As an example, the American Nuclear Society (ANS) standards committees are proactively developing performance-based standards (which use performance objectives rather than specific criteria to demonstrate acceptability) to address both timeliness concerns and issues of over-conservatism. This approach has also been adopted by the NRC and both increases flexibility and reduces the time frame in which new designs can be licensed. ANS advanced reactor standards, many of which are performance-based, permit first movers in the advanced reactor commercial supplier community to quickly move from an ad hoc approach to a more standards-oriented operational basis.

In some cases, SDOs and advanced reactor developers may not have resources to commit to fully develop the desired codes and standards on the timelines needed by some reactor developers and regulators for relevant codes and standards of interest. Advanced reactor designers are moving expeditiously to the market. Adding the need to develop new standards or to revise existing standards creates additional cost. Additionally, in the past, the development of standards has progressed at a pace that does not support the plans that some organizations are currently pursuing. When information is not available or specific standards have not been completed, this gap is addressed by a combination of additional conservatism in design and specific testing and analysis performed or leveraged by the developers. This is often an acceptable approach for first-of-a-kind and early units, but to ensure standards are developed in an appropriate manner and time frame, appropriate resources will need to be available. Otherwise, this lack of resources to support the development of standards or the information needed to support standards can lead to delays and atrophy of the SDOs. To reap the advantages, a proactive and strong standards base for advanced reactor SDOs must be supported.

Nevertheless, it is important to recognize the need for a symbiotic and adaptive balance between advanced reactor development and standards development activities. Codes and standards are an integral part of supporting the deployment and broad commercialization of advanced technologies, but they must quickly incorporate the lessons learned from initial first-of-a-kind or early unit development and demonstration. Likewise, SDOs and regulators alike must ensure that, as new or improved standards are developed for advanced systems, they do not cause delays in the licensing process due to non-safety-significant issues for first movers already in the queue.

The NRC and commercial suppliers rely on consensus codes and standards [developed by SDOs, such as ASME, the American Concrete Institute (ACI), the Institute for Electrical and Electronic Engineers, and ANS] for the design, development, and licensing of advanced reactors. While the use of consensus codes and standards has resulted in the safe design and operation of nuclear power plants, there is a need to reexamine the cumulative impact of these codes and standards. In the past, consensus codes for specific types or classes of structures, systems, and components were developed independently by different SDOs. As a result, the interactions between different codes (e.g., ACI's civil design codes for a building and ASME's mechanical design codes for a building component) have typically not been explicitly examined. Conservative interface conditions are normally assumed, but these assumptions are made at the discretion of the code committee. This may be exacerbated for advanced reactors, as first-of-a-kind and early units are by nature not standard and involve significant customization. It is through this process of deploying early units that valuable lessons are learned, which can help create informed codes and standards. The overall effects of these code interactions should be reviewed, because inconsistent requirements with respect to design margin under different codes and standards can result in the relative under-design or over-design of components.[5]

[5] R. J. Budnitz and M. W. Mieler, "Toward a More Risk-Informed and Performance-Based Framework for the Regulation of the Seismic Safety of Nuclear Power Plants," Report NUREG/CR-7214, Lawrence Berkeley National Laboratory, report for the U.S. Nuclear Regulatory Commission (2016).

Individual consensus committees determine acceptable levels of safety based on the design philosophy related to their discipline. While the process results in codes that reflect an individual profession's definition of safety, the overall safety of the plant depends on interactions between these codes. Reviewing and aligning definitions of safety and design margin between different consensus codes and standards would have important benefits, including reductions of excess margin in components where the safety benefits of the extra margin are never realized because other components would fail first in the event of concern. Lower but still adequate design margins could produce cost savings in the manufacture of some components or provide design flexibility. Reviewing design margins in consensus codes would help address the phenomenon of gradual but continuous increases in safety requirements, commonly described as a "ratcheting" of safety requirements. Explicitly quantifying the sources and rationale for design margin in codes and standards can be used to quantify the current safety of components and identify gaps or overlaps in design codes that could be resolved. Elimination of unneeded design requirements or margin could have significant impacts on cost and operations.

OPPORTUNITIES

The NRC's commitment to move toward a risk-informed performance-based regulatory paradigm will necessarily involve an expanded and renewed foundation of consensus codes and standards. Developing new and updated codes and standards for advanced reactor designs can support the NRC's multiyear effort to develop regulations and regulatory guides directed toward evaluating the safety of advanced reactor designs and ultimately licensing them for commercial use. A recently completed Massachusetts Institute of Technology study[6] concluded that significant project cost savings could be achieved if specific codes and standards were updated and developed to reflect current technologies. An ANS/NRC workshop in the spring of 2018 was held to develop a strategic vision for advanced reactor standards.

This workshop, which included representatives from all of the major SDOs as well as the NRC and advanced reactor technology working groups, identified the need for future advanced reactor standards to be both performance-based and risk-informed. The workshop also identified some of the key standards that must be developed or updated to support development of advanced reactors, including the following[7]:

- ASME/ANS RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants"
- ANS-30.1, "Integrating Risk and Performance Objectives into New Reactor Nuclear Safety Designs"
- ANS-30.2, "Categorization and Classification of Structures, Systems, and Components for New Nuclear Power Plants"
- ANS-53.1, "Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants"
- ACI 349, "Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-13) and Commentary"

Westinghouse's redesign of the AP1000 shield building provides an example of how time and resources could have been saved if an applicable standard had been available before the design was finalized. Had the updated ACI design code been available and endorsed by the NRC, Westinghouse could have used the updated code, avoiding additional work by the vendor and review delays by the NRC.

[6] J. Buongiorno, J. Parsons, M. Corradini, and D. Petti, "The Future of Nuclear Energy in a Carbon-Constrained World—An Interdisciplinary MIT Study," MIT Energy Initiative, Massachusetts Institute of Technology, Cambridge, MA, USA (2018).
[7] ANS/NRC Workshop to Develop a Strategic Vision for Advanced Reactor Standards (May 2, 2018).

COMMITTEE RECOMMENDATIONS

In developing this report, the ANS Special Committee on Advanced Reactor Policy has worked with the ANS Standards Board and advanced reactor experts and reached out to a wide range of stakeholders from the commercial suppliers and utility community to validate our concerns and inform our understanding about the need for action. As such, in our opinion, we recommend the following:

(1) Congress should authorize and appropriate funding for a DOE program to assist SDOs and advanced reactor developers in conducting accelerated development of and/or updates to key standards needed to implement a technology-neutral licensing framework before 2027, as mandated by the Nuclear Energy Innovation and Modernization Act (NEIMA).

(2) The DOE, in coordination with SDOs, should solicit input from the advanced reactor developers, nongovernmental organizations, and other stakeholders to identify and prioritize key codes and standards for creation/improvement and an overall time frame for their development and regulatory acceptance.

(3) The DOE should provide incentives to national laboratories to ensure proactive participation in developing the new data and methods needed to support a comprehensive overhaul of priority advanced reactor codes and standards.

(4) The NRC should implement process improvements and/or provide the resources needed to ensure timely adoption of advanced reactor standards. The NRC should reevaluate the need for imposing margins in excess of the margins in endorsed standards and determine whether they are justified from a perspective of reasonable assurance of adequate protection of public health and safety.

(5) The DOE and/or the NRC should establish a formal process with the SDOs for achieving harmonization of safety margins among new and/or updated consensus standards.

REFERENCES

1) Intergovernmental Panel on Climate Change, *Climate Change 2014*, Chapter 7, "Energy Systems."

2) U.S. Energy Information Administration, "Electric Power Monthly – March 2019."

3) Emissions avoided are calculated using regional and national fossil fuel emissions rates from the U.S. Environmental Protection Agency's Continuous Emission Monitoring System and latest plant generation data from the U.S. Energy Information Administration's "Electric Power Monthly – March 2019."

4) U.S. Federal Highway Administration, "Highway Statistics 2017" publication.

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7) ANS/NRC Workshop to Develop a Strategic Vision for Advanced Reactor Standards (May 2, 2018).

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Nov 2019