Safety challenges for long-term operation of nuclear power plants

To ensure that plants can operate safely beyond their originally established time frames, both physical and nonphysical aging issues must be addressed.

By Greg Rzentkowski

As we look toward the future, the degree to which nuclear power will contribute to the global energy solution remains unclear. Its role will depend greatly on a commitment to invest and innovate to further improve safety. Consequently, evolutionary and innovative nuclear power technologies and the bridge between these systems and the current fleet must prioritize safety.

More than 60 percent of the approximately 450 operational reactors worldwide have been in operation for over 30 years, and taking measures to optimize their life cycles will become a growing issue in the coming years. Currently, many operators are taking steps to extend the operating lifetimes of their reactors from 40 years to 60 or even 80 years. Safe and economical continued operation must address both physical and nonphysical aging issues and reasonably practicable safety upgrades.

The International Atomic Energy Agency supports member states in the implementation of the safe long-term operation program for nuclear power plants through technical publications, coordinated research programs, peer review missions, the International Generic Ageing Lessons Learned program, and major conferences and technical meetings.

Long-term operation

Long-term operation of nuclear power plants is defined as operation beyond an established time frame determined by the license term, the original plant design, relevant standards, or national regulations. As stated in IAEA documents, to maintain a plant's fitness for service, consideration should be given to life-limiting processes and features of systems, structures, and components (SSC), as well as to reasonably practicable safety upgrades to enhance the safety of the plant to a level approaching that of modern plants.

The decision concerning long-term operation is usually made by the plant's operator based on business needs, strategy, cost, plant condition, and other considerations. Safety reviews supporting the decision-making process should cover all aspects that are important to the safety of a nuclear power plant throughout its extended operating lifetime. The reviews should address the consequences of the cumulative effects of plant aging and plant modifications, equipment requalification, operating experience, current standards, technical developments, and organizational and management issues, as well as siting, and, depending on the nature of the project, environmental aspects. An environmental assessment is required to determine that the project is not likely to cause significant adverse environmental effects.

As a part of the decision-making process, the operator should engage the regulator early on to obtain regulatory approvals on the scope of work, including proposed modifications and safety upgrades. Repairs and replacements are typically decided based on the condition assessment of major components and aging management strategies implemented by the operator. The regulatory expectations for safety upgrades are decided based on operating experience or an assessment against up-to-date safety standards and practices. These improvements, to be carried out in the plant prior to entering into long-term operation, are not only reflected in plant design or configuration changes, but are also procedural or analytical in nature.

Safety assessments

The IAEA document titled *Safety of Nuclear Power Plants: Commissioning and Operation* (Specific Safety Requirements SSR 2/2 [Rev. 1] Vienna, 2016) requires the performance of several steps to demonstrate preparedness for safe long-term operation, including the systematic selection of SSC based on safety significance, revalidation of time-limited aging analyses of SSC, review of aging management and aging-management programs, and implantation and verification of safety upgrades.

Safety assessments for long-term operation are typically performed as part of a license renewal process. The scope and depth of the review may vary, depending on national requirements. In many instances, the process used is the periodic safety review, which represents a forward-looking instrument for maintaining the safety of nuclear power plant operation. A periodic safety review is carried out at regular intervals, typically every 10 years, and relies on a systematic and comprehensive process whereby modern standards and technological developments are considered to provide assurance of the continued viability of the plant's licensing basis, given the cumulative aspects of emerging national and international standards, evolving regulatory requirements, plant aging, operating experience, and technological development.

The periodic safety review provides an effective way to obtain an overall view of actual plant safety and the quality of the safety documentation and to determine reasonable and practical modifications to ensure or improve safety. The application of deterministic and probabilistic safety goals, such as defense-in-

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depth, safety margins, physical barriers, redundancy and independence, core damage, and large release frequency, should be considered to determine a baseline against which to review the current safety provisions and past operating performance.

Specifically, the assessment for long-term operation should document the following:

- The extent to which the plant conforms to modern standards and practices.
- The extent to which the (updated) licensing basis will remain valid to the end of the plant's proposed extended operating life.
- The adequacy of the arrangements that are in place to maintain plant safety for long-term operation.
- The improvements to be implemented to resolve the safety issues that have been identified.

The review of the current and proposed safety provisions will indicate whether modifications to the facility or operational procedures are meeting existing standards and whether the optimization of protection and the limitation of risk are adequate for long-term operation.

Safety challenges

Member states use different strategies and methods to demonstrate safe and long-term operation of nuclear power plants, but their regulatory rules regarding the conduct of safety reviews are not always clearly defined. Safety reviews focus primarily on physical aging management of SSC and do not systematically consider all important safety elements, such as those in a periodic safety review, to conclusively demonstrate that the arrangements to maintain plant safety through the intended long-term operation period remain adequate.

One of the main challenges facing operators is demonstrating conclusively that the strategies for managing physical aging of SSC remain effective for long-term operation. This can be because of gaps in knowledge of the plant's condition, limited demonstration that safety and safety-related SSC will perform their functions during the intended period of long-term operation, incomplete aging management programs and time-limited aging analyses for SSC, and incomplete or missing equipment qualification programs.

Effective strategies to manage the physical aging of SSC, particularly the revalidation of time-limited aging analyses, rely strongly on the availability of up-to-date design basis documentation for nuclear power plants prior to entering the long-term operation period. This information is often incomplete or inaccessible, and its reconstitution requires significant time and effort. The unavailability of the design basis documentation prevents timely implementation of modifications and safety upgrades.

Another challenge is associated with systematic identification of reasonably practicable safety upgrades. Regulators do not have exact rules to determine what improvements might be required. Reasonable and practical modifications, however, should be considered based on an understanding of the extent to which a plant conforms to up-to-date standards. Since this information is rarely available due to the limited consideration given to modern standards in the safety reviews supporting the preparation for long-term operation, including in the periodic safety review, safety upgrades are selected mainly based on operating experience, taking into consideration the safety significance and cost-benefit evaluation.

Well-established workforce planning for the long-term operation period of a nuclear power plant is key to addressing these challenges and to ensuring that competence and knowledge are available and up to date. Knowledge transfer to the authorities, equipment manufacturers, suppliers, and contractors is also crucial. NN