EFFORTS TO ACHIEVE HARMONIZATION IN THE LICENSING OF FISSION AND FUSION POWER PLANTS

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Abstract

When it comes to the licensing of novel designs within the current licensing framework, there is a broad agreement on the fact that the differences in definitions, requirements and interpretations of legislations in different countries are not helpful, and a harmonized approach for the licensing of innovative fission and fusion power plants is needed. The EC funded project entitled ″Towards harmonisation in licensing of future nuclear power technologies in Europe″ (HARMONISE) has been working on this issue by employing the expertise of seventeen partners from eleven European States representing public and private sectors, research and industrial domains, as well as regulators and Technical Support Organizations. This paper presents the work performed in the framework of the project, the main directions followed, the challenges encountered and the results obtained. Moreover, the interactions with the stakeholders and their expectations are highlighted.

Keywords: *Licensing, Innovative reactors, Harmonisation, Standardization, Stakeholders*

Introduction

One of the main factors affecting the deployment of innovative fission and fusion power plants is the way these installations may demonstrate their safety within the current licensing framework. When it comes to the licensing of innovative designs, there is a broad agreement on the need to review and update the existing regulatory framework in order to endow it with the capabilities needed to confirm, without doubt, the safety of the design and enable a proper regulatory oversight throughout their entire life cycle. Despite the broad consensus on this need, the legislation in different countries maintains diverse definitions, requirements and interpretations.

Nowadays, the European Commission (EC) has taken the leadership in nuclear safety and radiation protection research, fostering also the cooperation among national regulatory authorities. Fully aware of the benefits that the harmonization might bring to deployment of innovative technologies, many international initiatives to reach a common understanding and approach in licensing, operation and decommissioning of NPPs have been initiated with examples like IAEA SMR Forum and Nuclear Harmonization and Standardization Initiative (NHSI), ETSON - European Technical Safety Organisations Network, WENRA - Western European Nuclear Regulators' Association, WANO - World Association of Nuclear Operators, NEA, etc. The harmonization idea has been sustained by the EU-based nuclear industry that has been promoting standardization and harmonization as a mean for improving the:

- Installation safety by sharing information on safety analysis, operation and best practices;
- General perception on consistent risk management across countries;
- Supply chain and knowledge base needed for long-term plant operation;
- Higher predictability of licensing and deployment time.

The project entitled ″Towards harmonisation in licensing of future nuclear power technologies in Europe″ (HARMONISE) (https://harmonise-project.eu/) has been working on this issue by employing the expertise of seventeen partners from eleven European States (several partners are ETSON members) representing the public and private sectors, research and industrial domains, as well as regulators and technical support organizations. Coordinated by the Lithuanian Energy Institute, having as a goal to pave the road for a more homogenous regulatory framework in the European panorama, the project has started on June 1, 2022 and its activities are planned to last 36 months [1].

The HARMONISE project activities are pursuing the following objectives [1, 2]:

- To analyze preliminary safety assessments of innovative fission and fusion installations;
- To identify the licensing needs for innovative nuclear installations;

• To investigate the use of risk-informed, performance-based (RIPB) approaches in licensing reviews and regulatory decision-making;
• To delimit harmonization and standardization on component assessments, methodologies, codes and standards;
• To accumulate and learn from earlier experience in harmonization efforts.

The project activities are organized in 6 work packages (WPs) and its main directions are presented below.

Interaction with stakeholders

An early step in the project was setting-up the widest possible network of relevant stakeholders involved in the safe operation of nuclear facilities. The efforts towards interaction with stakeholders were structured in three activities, each of them facing specific challenges [3]:
• Creating the stakeholder list (identification of relevant stakeholders)
Challenge: elaborate a comprehensive list
• Developing the stakeholder network (contacting, engaging, informing)
Challenge: find the right person to contact
• Maintaining the stakeholder network (communicating, receiving feedback)
Challenges: find the most suitable way to communicate; convince people to provide feedback.

A deliverable [4] dedicated to the network of stakeholders was elaborated at the beginning of the project, providing a comprehensive list of stakeholders relevant to the project and, at the same time, establishing the appropriate strategy for interacting with them, giving them the opportunity to express and communicate their positions and points of view regarding the opportunities and challenges envisaged to be met as a result of the harmonization process for the licensing procedures.

The deliverable includes the following information [4]:
• The list of stakeholders (for each of the stakeholders a brief description, activity and motivation for inclusion in the group, as well as information about the contact person is given). The stakeholders were divided into the following categories: International organizations; National Safety Authority; Relevant Euratom projects; Industry; Research, Education and Training communities; Relevant non-nuclear communities.
• The strategy for creating the stakeholder network took into account both the activities for maintaining contact with the stakeholders as well as for informing them.

The list of stakeholders is updated following the evolution of the project.

The main objective for communicating with the stakeholders is to inform them about the objectives and progress of the HARMONISE project in order to receive feedback regarding their views on the project results [5]. An active communication with stakeholders will help not only to communicate the position of the project towards regulators, but will also help getting clear and direct feedback from different stakeholder groups (regulators, operators, industry, policy makers, etc.) regarding the project outcomes [1].

Besides the traditional channels of communication, the stakeholders will be informed about the HARMONISE progress during the project workshops (WSs) planned every six months [5]. During the 3rd project workshop, the steps and challenges for the creation and maintenance of the stakeholder network were discussed and the results of the questionnaire sent to the stakeholders were also presented. The opinions and recommendations (regarding the challenges, discussion format and topics) received from the project stakeholders were presented and discussed [3]. The feedback received during the first three workshops (two were organized online and one with physical presence) was documented in a deliverable [6] while another deliverable will be elaborated at the end of the project, taking into account the outcomes of the remaining 3 WSs.

Assessing the applicability of IAEA safety objectives to advanced fission reactors and large fusion facilities

The project participants have performed an assessment of the IAEA series of Safety Standards applicability to advanced reactor designs, as well as SMRs. The evaluation of IAEA documents was focused to the level of General Safety Requirements (GSR) and Specific Safety Requirements (SSR), while a number of Specific Safety Guides (SSGs) were evaluated, as well. The work has also considered the findings of similar studies performed by IAEA, WENRA, GIF and the SMR Regulators' Forum. The scope of the conducted evaluation was limited to safety without considering the nuclear security.

A review and a gap analysis for each considered IAEA document was performed, identifying the need for updating a number of the surveyed documents and providing suggestions for modifications [5]. In particular for GSRs and SSRs, the publications examined are not completely technology neutral, which motivates the recommendations that are formulated in order to make them applicable to all nuclear facilities and activities. The review considered crucial technical aspects such as multi module SMR concepts, factory-built and potentially factory-fuelled designs that ought to be transported, as well as cogeneration. The technical topics of interest include the employment of passive systems, consideration of inherent safety in the implementation of the defence-in-depth concept, deliberation on the term 'core melt', recognition of the consequences of low operating experience, along with facility commissioning, operation and decommissioning [7]. It was noticed that low or missing operating experiences on novel techniques may lead to difficulties in reformulating requirements in a more technology neutral manner.

A concise depiction of the evaluation performed on a set of twenty IAEA documents (Safety Fundamentals (SFs), GSRs, SSRs and SSGs) on the basis of their applicability to advanced reactor technologies that are currently under development has been presented in a publicly available deliverable [7].

In a parallel implementation, the top-level safety objectives of fusion facilities, such as ITER and DEMO, have been reviewed and the work outcome was summarized in a review document [8] that is publicly available. Selected findings of a review performed on the existing safety case documentation of fusion facilities being at different lifetime phases were examined. The work was based on a framework established by the IAEA and the outcome was a set of observations and recommendations [2, 5].

Recommendations were formulated with respect to the harmonized regulatory framework, harmonized licensing path, harmonized safety case documentation and generic design approval process, definition of the fundamental safety functions and plant states, consideration of basic design principles as well as classification and qualification of provisions, codes and standards, availability of operating experiences and improvements of tools and data for performing safety analysis [8].

Review of innovative nuclear power plants licensing issues with a focus on ALFRED and DEMO

The licensing process of novel reactor installations using the current regulatory framework (see Fig. 1) is expected to pose new challenges on their deployment process. Notwithstanding the peculiarities of each design, since the objective of the licensing process is the same (i.e., to ensure safety of the people and the environment in all life stages of a nuclear installation), a common ground for harmonization can be foreseen. The objectives of the review work were established to [1]:

- retrieve the specific safety-related needs associated with the innovative reactor technologies;
- identify common safety principles and bases as collected from different national regulatory frameworks;
- evaluate the challenges for the harmonization of the different frameworks and the gaps for their translation to future technologies;
- propose recommendations for an evolution of current licensing processes towards a harmonized one.

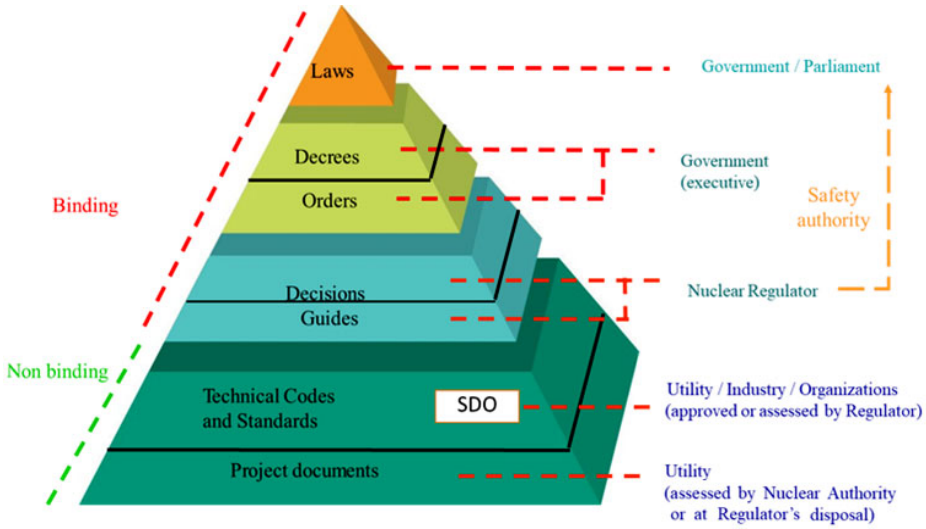


Fig. 1. Pyramidal image of the national regulatory framework [9]

In this harmonization effort to build a more comprehensive and thus technologically inclusive framework, one of the first steps is a wide review of all design and technological aspects characterizing novel nuclear installations and their impact on the licensability of innovative power plants.

A bidimensional harmonization is pursued, considering two major directions [1, 10]:

- a *harmonization towards technology neutrality*, since different technologies might lead to different regulations. The outcome would permit aligning regulations on common bases and uniform principles, enhancing safety and streamlining licensing;
- a *harmonization towards country neutrality*, since different countries might aim at different standards. The outcome would permit aligning regulations on common targets and uniform metrics, enhancing safety and streamlining the licensing process.

Two actions will be performed: retrieval of the technology-specific needs dictated by the advanced reactors, along with reviewing the existing regulations to identify the common bases and underlying principles that will be transposed to technological neutrality. Matching the technology-specific safety needs with the common regulatory bases and principles will allow the elaboration of recommendations for the harmonious evolution of the regulatory framework.

A first review has been performed, in two actions [10, 11]:

- a broad survey encompassing as many technologies as possible from the wide spectrum of innovative technologies involving designers and technology developers to shed a light on the safety-related aspects to be reflected in future regulations;
- a detailed study going from general principles and objectives towards detailed requirements for the concerned systems, structures and components, as deep as practicable in the requirement hierarchy.

″Licensing exercises″ [1, 10] will be performed for the Gen-IV LFR ALFRED and fusion power plant DEMO to identify the bottlenecks and suggest ways to improve the licensing process.

Risk-informed, performance-based approach in licensing

The extensive R&D programmes outcomes have encouraged the expectations that innovative nuclear fission or fusion power technologies will demonstrate both enhanced safety and higher robustness against security threats. The risks reduction and improved performance are expected from the extended use of inherent safety design features, passive control and protection systems as well as by decreasing the operator interventions to ensure safety. It seems appropriate to link somehow the requirements to the level of risk, this supporting a RIPB regulatory framework implementation.

The work will focus on the definition of a RIPB regulatory concept and will explore the possibilities to implement a RIPB approach in licensing advanced NPPs [12].

Harmonization and standardization of codes and standards

Identifying the licensing needs for innovative technologies requires an exhaustive analysis to determine whether or not the current codes and standards address these needs. The objectives of this activity could be briefly summarized as follows [1, 9]:

- Identification of gaps and areas of improvement of licensing procedures and qualification with special emphasis on codes and standards for mechanical components and materials;
- Learning from other industrial sectors how the new digital technologies are used;
- Investigations of the possibilities to transfer in the nuclear field the licensing procedures developed to integrate digital technologies;
- Assessment of different options and identification of the promising ones to accelerate and improve the reliability of licensing procedures and qualifications of innovative nuclear reactors through codes and standards.

Considering the innovative reactors' specifics, in particular: innovative coolants; higher temperature; modular design; reduced construction cost; enhancing safety; improving efficiency; reducing waste; minimizing proliferation risks; enabling advanced fuel types; enhancing flexibility; enhancing resilience - are expected to have new requirements in terms of codes and standards. HARMONISE will suggest approaches on how the codes and standards applied in the field of fission and fusion power could be harmonized and how the licensing processes could be simplified and made clearer. The outcome will be a roadmap for the optimization and harmonization of codes and standards [2].

In order to ensure that this analysis is performed in a robust manner, HARMONISE partners have requested the opinions of Standards Development Organisations (SDOs) responsible for code development. A questionnaire drafted for the SDOs intended to [9]:

- find out whether the needs are already taken into account in the existing codes;
- find out how to deal with needs that are partially covered or not covered;
- examine the possibility of adapting solutions found in other industrial sectors to the nuclear field.

The possibilities to adopt ″digital twins″ in nuclear licensing was investigated and information was collected regarding [1]:

- the manner they are taken into account, i.e. at which level: design, manufacture and operation and in which technical fields (mechanical, electrical, software and hardware, etc.);
- the requirements attached, whether in terms of proof of concept, qualification, skills, traceability;
- the authorization / validation procedures for these new digital technologies.

The link with the developments taking place in the aeronautical and space domains which, in terms of the level of requirements, are quite close to the nuclear field will be considered. In case of the codes and standards, a mapping of existing elements and effective gaps will be formulated. Recommendations on how to adopt, into the nuclear field, the licensing processes followed in other industrial sectors using digital twins will be also elaborated.

Take-away messages

✓ HARMONISE project collects the necessary knowledge and expertise in fission and fusion power technologies available in Europe to pave the path towards harmonization of approaches to effective licensing and safe and reliable operation of innovative NPPs and fusion power plants. All activities carried out within HARMONISE as well as actions to be taken following the project completion will have either direct, or indirect, impact to issues related to licensing of innovative NPP designs, as well as fusion power plants.

✓ A review of the current international activities for licensing fission and fusion reactors was performed and a number of recommendations were made.

✓ Overall, the challenges identified for the harmonization process are the following:

- balancing harmonization and sovereignty;
- leveraging lessons learned from other high-reliability sectors with nuclear regulators;
- setting requirements that are risk-informed and allow for innovation and technical advancement.

✓ An active communication with stakeholders was established, with a two-fold role: to communicate the position of the project towards regulators and to collect clear and direct feedback from different stakeholder groups (regulators, operators, industry, policy makers, etc.), regarding the project outcomes.

✓ Besides the traditional channels of communication, the stakeholders will be informed about the progress of HARMONISE during the project workshops planned every six months.

✓ Identifying the licensing needs for innovative technologies requires an exhaustive analysis to determine whether, or not, the current codes and standards are addressing these needs.

✓ ″Licensing exercises″ will be performed for the Gen-IV LFR ALFRED and fusion power plant DEMO to identify the bottlenecks and suggest ways to improve the licensing process.

✓ The new technologies need to be detailed and grouped into different categories depending on the qualification and licensing processes. In order to ensure that this analysis is performed in a robust manner, HARMONISE has solicited the opinion of SDOs responsible for code development.

✓ Options to implement ″numerical twins″ in nuclear licensing are under investigation.

✓ HARMONISE proposals are to be viewed as suggestions made for further consideration and analysis.

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