Occupational radiation protection principles and criteria for designing new nuclear power plants

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1 Introduction

New nuclear power plants (NPP) are designed and implemented according to broadly standardised criteria. Such standardisation can help to share experience and knowledge at the international level, and thus help to optimise the resources of the countries faced with the review of new reactor power plant designs in the near future. After building approval, the regulatory body or another relevant governmental body supervises the implementation of the plant project in detail. The various stages of the construction of an NPP are managed on the basis of the nationally and internationally adopted approaches to assure that for each stage of construction, factors affecting nuclear safety and operational availability have been given adequate attention. Occupational radiation protection (ORP) is only one among many other conditions to be met prior to the granting of licenses for site preparation, construction, operation or even decommissioning of a new NPP. However, the earlier ORP is integrated in the design and implementation process of a new build the more doses and long term costs can be saved. These are elaborated in this publication.

It introduces a policy and technical framework that may be used when formulating technical assistance and guidance for use by the executive management of NPPs, designers, manufacturers, contractors and by authorities responsible for regulating occupational radiation exposure. This material is aimed at assisting the design and license assessment of new nuclear power plants (*i.e.* 3rd generation or beyond), and is based on experience and lessons learned from the existing fleet of reactors. Although not primarily aimed at the needs of countries newly embarking with nuclear power, this material can also provide valuable input on ORP issues for the implementation of new nuclear energy programmes.

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The future reactors are based on evolution of PWRs, BWRs, CANDU and VVER reactor types. Thus the focus is to shed light on the experience of these types of technology.

2 Objects of the publication

The publication focuses on the strategic areas of ORP as practiced in the nuclear power sector in order to bring clear benefit to future generations of nuclear reactors. Particularly, it is focused on:

- description of ORP principles for use by new NPPs
- evaluation of potential implications of newly available and emerging technologies on ORP aspects of new NPP designs
- implementation of ORP experience, in particular:
  - lessons from the operation of 1st and 2nd generation reactors that can be used for new NPP designs
  - experience with the replacement of various components
  - ORP experience relevant to decommissioning

3 Motivation and background

The global need of electricity continues to increase and numerous new NPPs are being planned or erected in the member states of the OECD in the near future. Most of these new NPPs will be NPPs of the 3rd generation and designed for operating as long as 80 years.

That implies:

- the reactor design influences the required ORP for two or more generations of NPP workers,
- during the long operation time new technical developments will emerge and unforeseen maintenance and repair activities will occur.

Many international documents on ORP in NPPs are available from international institutions or national initiatives. The publication includes those provisions for ORP principles developed from experience with existing NPPs that can serve as a practicable tool for the design phase of new NPPs.

Experience from the past decades shows that ORP was very successful in reducing the radiation doses received by workers during operation and maintenance/refuelling phases in NPPs of the 1st and 2nd generations.

One of the lessons learned during these decades is that a substantial amount of exposure resulted from lack of attention for ORP concerns in NPP designs. Factors such as nuclear safety and operational availability dominated during the design and construction phases of the NPP, whereas ORP aspects were addressed to a lesser extent. Later, after significant numbers of NPPs had begun operation and undergone maintenance and refueling outages, ORP found itself faced with a *fait accompli* and was forced to deal with exposure situations that resulted from initial architectural/engineering and design shortcomings.

There is a significant potential to avoid radiation doses, as well as long-term maintenance costs, if ORP considerations are embedded at the architectural design and construction phase (*e.g.* integrated ladders/stairs instead of mobile scaffolds, easily accessible cable tunnels, in-duct laid pipelines etc). Furthermore, the productivity of an NPP can be improved if ORP, as well as other risks to workers, are considered early in the design phase (*e.g.* if correctly designed and planned, some maintenance operations could be performed during reactor operations or with a reduced shutdown time; the exchange of whole components instead of repairing defect parts *in situ* etc.). Finally, radiation doses of workers can be substantially avoided when future exposure situations in all phases of a reactor life-cycle are anticipated and proactive measures taken.

4 Guiding principles

Good management of ORP is sustainable, economic and confidence-building. Several guiding principles that should be considered as crucial for the successful integration of ORP in design of new NPPs are as follows:

- *Proactive implementation of lessons learned:* Crucial decisions affecting future radiation exposure of workers, and also long-term expenses for maintenance, outages and modifications are made in the design phase of a new NPP. Both radiation doses and costs can be reduced over the life-cycle of the new NPP when the practical experience from decades of ORP in existing NPPs is taken into account at an early stage, *i.e.* included already in the architectural design. Furthermore, it is wise to anticipate potential occupational exposure for the full NPP life cycle (*i.e.* from operation to decommissioning) and take optimisation measures in advance.

- *Balance of risks and allocation of resources:* Radiation exposure is not the only risk to be considered in designing new NPP. The allocation of resources for occupational health and safety at the design phase should be based on a rational balance aimed to optimise protection against all risks to workers.

- *Effective communication in optimising design:* Licensing requirements for safety and protection of public and environment may require technical and organisational measures that increase radiation exposure of workers. The designer and operator must understand regulatory requirements and their interpretation for surveillance, inspection, and other activities during the plant's operating phase. Having that clear understanding enables the designer to develop means and use design elements that reduce radiation exposures. This requires close co-operation between regulators, designers and operators, as well as transparent and active consultation with other stakeholders.

- *Publicly recognisable effective ORP:* The concept of ORP should be forward looking, addressing all phases of the life-cycle of the NPP and supported by the full pool of operational experience. This demonstrates effective management and creates trust in the operation of the NPP. Management must always be aware that if the handling of ORP appears negligent in the public's or regulator's view, then the trust in the nuclear safety and in the reliability of the management is put at risk. This jeopardises not only the operational availability of the NPP but also the nuclear technology as a whole.

5 The content of the publication

The publication is structured into chapters, as to clearly address the topics listed in the scope. At the beginning of each chapter, the corresponding key messages are given, as in the following presentation of these chapters:

Chapter 1: Occupational radiation protection principles at the design stage of nuclear power plants

- international guidance and compliance with standardisation
- national guidance and role of regulatory authorities
- implementation of ORP philosophy at the design stage: Requirement for a structured organisation, such as an ALARA Design Review Committee

Chapter 2: Lessons learned, knowledge management, education and training

Operating experience should be utilised to identify opportunities for dose reduction as part of design.

- lessons learned, taking into account the experience and feedback from designing, operating, maintenance and dismantling of existing NPPs
- collection and exchange of data, networking, data analysis, good practice
- knowledge management and its organisation as early as during the design stage, as to be effective during the whole life cycle of the plant
- need for well trained, skilled and knowledgeable persons in ORP during the design stage and during the full life cycle of the plant

Chapter 3: Integrating occupational radiation protection criteria during the design phase

- screening process for compliance of proposed design with existing ORP criteria
- ALARA design check-list
- Example of EPR
- Evaluation of newly available and emerging techniques in ORP aspects

Chapter 4: Evaluation and integration of occupational radiation protection cost in the design process

- most significant ORP costs to be evaluated
- decision making criteria

The list of references, including international guides and networks websites is provided at the end of the document.

6 Conclusions

The objective of the publication is to analyse existing ORP experience in currently operating nuclear power plants in order to assess how ORP should best be applied in future NPPs. The purpose of this document is to assist in the assessment of ORP aspects of design and license applications for new nuclear power plants by providing a policy and technical framework that can be used for making judgments. It is primarily, but not exclusively, directed to designers, manufacturers, contractors and authorities responsible for regulating occupational radiation exposure. It identifies the following major issues that need to be considered and incorporated into design:

- Basic ORP principles – justification, optimisation and dose limitation to be maintained through the expected full life-cycle, in order to address international and national guidance and regulations.
- Optimisation should consider not only potential health risks from ionising radiation, but also other potential risks for the workers' health in order to allocate resources in a well balanced way so that the best worker protection is achieved.
- Organisation of training and knowledge management to assure the availability of highly qualified personnel and adequate design-basis documentation over the full lifetime of the facility, from design to decommissioning.
- Active networking in support of information, experience and data exchange and assessment to maintain sustainable implementation of good practice, and ensure an effective traceability and use of lessons learned.
- Need for the integration of ORP principles and criteria into all components and future operations in order to save time, money and exposure over the lifetime of the facility.

All the above issues are further elaborated in the publication, providing guidance and technical information when needed.

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