

An Initiative towards Risk-Informing Nuclear Safety Regulation in Hungary

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Abstract: In response to a request by the Hungarian Atomic Energy Authority (HAEA), PSA analysts of NUBIKI Nuclear Safety Research Institute developed a proposal for making advancement in using PSA information within a risk-informed regulatory decision-making framework and outlined a work plan to perform the tasks envisioned in the proposal. Key PSA application areas were identified with an overview of the associated analysis methods. Improvement was proposed in thirteen PSA application areas in total. Risk-informed safety management and risk-informed regulation were included in the proposal as an overall framework for all the other applications. It was suggested that HAEA ensure the implementation of all the PSA applications, characterized in the study, in nuclear safety regulation between 2013 and 2020. Further, it was found necessary to investigate in detail and evaluate what modifications would be necessary in safety regulation in order to underpin risk-informed safety management and risk-informed regulation. PSA applications were prioritized in support of scheduling the developmental tasks. Also, the role of risk-informed decision-making in different life cycle stages of a nuclear power plant was characterized. Finally, it was proposed to make some distinction between PSA applications to operating and newly built nuclear power plants, respectively.

Keywords: PSA Applications, Risk-Informed Regulation, Safety Management.

1. INTRODUCTION

The Hungarian Atomic Energy Authority (HAEA) makes efforts to extend and strengthen the role of risk-informed decision-making in regulating nuclear safety. Appropriate regulatory environment and infrastructure that enable effective uses of probabilistic safety assessment (PSA) are indispensable to the success of these efforts. In response to a request by the former Nuclear Safety Directorate of HAEA (HAEA NSD[†]), PSA analysts of NUBIKI Nuclear Safety Research Institute Ltd. have

- developed a proposal for making advancement in using PSA information within a risk-informed regulatory decision-making framework and
- outlined a work plan to perform the tasks envisioned in the proposal.

This paper discusses the key technical issues addressed in the proposal and it presents the most important proposal elements based on [1].

2. STATUS OF PSA APPLICATIONS IN HUNGARY

In order to underpin the proposal development the initial phase of the study included a review and analysis of PSA applications in Hungary as well as the role of these applications in regulatory and licensee activities. In total, thirteen application areas were covered in the review:

1. Support to safety management and regulation
2. Evaluation of plant safety
3. Support to design
4. Support to plant modifications

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[†] The Hungarian Atomic Energy Authority has been restructured since the completion of the study presented in this paper. Reference is made to the former organizational units of HAEA to be in conformity with the original study.

5. Safety classification of systems, structures and components
6. Support to maintenance
7. Configuration control
8. In-service inspection and testing
9. Support to establishing and reviewing Technical Specifications requirements
10. Monitoring maintenance effectiveness
11. Support to developing plant procedures
12. Support to training
13. Analysis of operational events.

For each application area the specific objectives, the expected results and benefits, and the applicable methodologies and support tools were described based on the current state-of-the art both in Hungary and worldwide. It is not the purpose of this paper to cite these details from the study, rather the discussion below focuses on the findings concerned with requirements for PSA applications in current Hungarian safety regulations and with recent regulatory and licensee practices.

Although not considered as a single dedicated application, *risk-informed safety management and safety regulation* were characterized in the study as an overall framework that needs to be established and maintained to set up preconditions necessary for successful risk-informed decision-making by both the nuclear safety authority and the licensee. According to the Nuclear Safety Codes (referred to as the Codes hereafter) as high level safety regulations in Hungary, the licensee is obliged to use probabilistic safety assessment and PSA information in support of safety management. More specifically, some application areas are explicitly cited in the Codes as discussed in connection with dedicated PSA applications in the following. Furthermore, the policy statement and the basic operating principles of the HAEA NSD witness commitment to combined uses of deterministic principles and risk information during decision-making on nuclear safety matters. At the time performing the study there was an action plan in place to make a transition to risk-informed safety regulation at the HAEA NSD [2], [3]. Additionally, the HAEA and the Paks Nuclear Power plant had signed an agreement on coordinating actions aimed at better uses of risk information in decision-making including specific application and developmental areas: safety classification, maintenance planning, risk monitoring, and advanced regulatory and licensee infrastructure [4]. Despite these initiatives, the study emphasized the need for further substantial improvements so that HAEA NSD can fully take advantage of risk-informed regulation:

- improvement of nuclear safety regulations
- systematic introduction in risk-informed approaches in
 - internal regulatory procedures
 - all relevant regulatory activities
- improvement and development of associated regulatory tools
- development of human infrastructure and personnel training
- increased involvement of technical support organizations.

Concerning the use of PSA information in the *evaluation of plant safety* it is to be mentioned in the first place that in Hungary level 1 as well as level 2 probabilistic safety assessments are mandatory by safety regulations. Acceptance criteria are defined in the Codes for both the core damage frequency and the frequency of large releases. These criteria are less stringent (i.e. an order of magnitude higher) for operating nuclear power plants in comparison to newly built plants. Probabilistic safety assessment has to be applied to evaluate and justify that the plant design is balanced and the analysis results must be used to show that the defenses against beyond design basis accidents are appropriate. A regulatory guide on PSA [5] defines acceptable methods to perform level 1 and level 2 PSA. The guide covers internal events and internal hazards, analysis of full power as well as low power and shutdown states. A review of the regulatory PSA guide has been initiated to extend its scope and to incorporate the results of recent methodological developments and PSA standardization efforts. The HAEA NSD performs a systematic review of probabilistic safety assessment available for the four units of the Paks Nuclear Power Plant as the single nuclear power plant operating in Hungary. The review evaluates the adequacy of PSA models, data and results and it assesses suitability of the PSA for uses in risk-

informed applications. To meet regulatory requirements the licensee makes use of PSA to evaluate the safety level of the Paks NPP. Reactor and spent fuel pool accidents, full power, low power and shutdown states are within the scope of the Paks PSA. Detailed modelling has been performed for internal events, internal fires and flooding (including high energy line breaks), seismic events, and extreme weather phenomena. The analysis scope has been gradually broadened and it is still being increased. A living PSA approach has been adopted to update PSA models, results and documentation on an annual basis. An extended summary of the plant PSA is included in the Final Safety Analysis Report of the plant which is also a living document.

With respect to *support from PSA to plant design*, the Codes prescribe the use of PSA to justify the design and to review the design. Besides this high level requirement, no additional requirements or guidance are available in current safety regulations on what could be considered as acceptable methods to meet the requirement. As discussed in the preceding chapter, PSA has to be applied to check that the design of the plant is well balanced. It assumes the use of PSA as a design support tool in a follow-on mode. However, PSA is not an integrated element of the design process according to current safety regulations in Hungary. PSA must be representative for the actual plant design but this requirement is related to the quality of PSA rather than its use for design support. A regulatory guide on specific design aspects of nuclear power plant equipment [6] emphasizes that safety functions need to be ensured with high reliability, but there is no guidance on how risk information can be used for this purpose, only the actual design options are specified in this guide. The licensee applies PSA to support design of plant modifications (see below). A structured risk-informed approach in its contemporary understanding was not applied in the overall plant design process due to the vintage of the plant (four Russian designed VVER-440/213 plant units commissioned in the 1980's).

Safety regulations assume the *use of PSA in support of plant modifications*. High level requirements in the Codes call for the application of PSA to evaluate the necessity of plant modification and to identify modifications, if seen necessary from risk point of view. Safety analysis has to be performed and a safety analysis report has to be submitted to the regulatory body for each plant modification. PSA is to be used to verify the adequacy of a plant modification (risk follow-on). The safety level must not decrease due to a modification according to the current regulatory requirements. Although it can be argued whether the safety level of a nuclear power plant can be described merely using PSA terms, taking this requirement literally, no increase in the core damage frequency or in the large release frequency is allowed by Hungarian safety regulations. There is a regulatory guide available for the safety analysis of plant modifications [7]. It describes that safety analysis includes both deterministic and probabilistic analyses. However, the guide does not integrate the two kinds of approaches into a common framework and analysis process. Within a large safety modernization program between 1996 and 2002 PSA was used to a great extent to identify necessary plant modifications, substantiate modifications from risk point of view, support the design of modifications and evaluate risk following the implementation of modifications. Several additional plant changes have been made since the completion of this modernization program, and these modifications have also been subject to PSA. A recent example is the implementation of severe accident management measures that has largely been supported by PSA.

The HAEA NSD has been investigating the use of risk information for the purposes of *safety classification of systems, structures and components* since the late 1990's. Early studies included comparative analyses of risk ranking, based on PSA importance measures, with existing (deterministically driven) safety classifications used in the Paks NPP [8], [9]. Later on more attention was paid to this PSA application area due to (1) regulatory initiatives to move forward towards risk-informed regulation and (2) the agreement between the HAEA and the Paks NPP on risk-informed decision-making [4]. As a result, a detailed methodology document was developed for risk-informed safety classification of active plant equipment. Results from the earlier HAEA studies and good practices internationally were considered to draw up the proposed methodology. Trial applications of the methodology were made using the emergency feedwater system of unit 2 at the Paks NPP. The methodology was refined and a draft regulatory guide was outlined based on the lessons learnt from the trial applications [10]. Also, concrete proposals were made to modify safety requirements in the

Codes so that design, quality assurance and treatment of active plant components can make use of risk-informed safety classification [11]. Furthermore, NUBIKI PSA analysts set up a proposal to extend the approach to passive components in order to fully implement risk-informed safety classification in safety regulations.

As far as the *use of PSA in support of maintenance* is concerned, regulatory requirements clearly describe that the acceptance criteria for PSA (including quantitative probabilistic safety criteria) must be met by modelling maintenance of plant systems and equipment “as planned” in a design stage PSA and “as practiced” in a PSA valid during plant operation. According to the Codes, the maintenance program is supposed to be set up by seeking balance between improvement in equipment reliability due to maintenance and risk increase caused by maintenance related equipment unavailability. If the maintenance program is modified, then expected changes in plant risk have to be assessed. PSA can be a useful tool to help satisfy these requirements, although there is no explicit reference to PSA in the wording of the requirements. Additionally, changes in the maintenance program are considered as a plant modification. As such, PSA needs to be included in the safety analysis of the modification.

The HAEA issued a regulatory guide on the maintenance program of nuclear power plants and on the monitoring of maintenance effectiveness [12]. As an option, the guide points out the use of regulatory approved plant specific probabilistic safety assessment to determine the scope of maintenance. Also, the guide refers to the possibility to review the maintenance program and specify maintenance frequencies (intervals) by applying PSA. The actual ways and acceptable methodologies of PSA usage are not discussed in the guide. The guide specifies that the licensee performs risk assessment for all safety related activities of the plant personnel and makes use of risk assessment to determine the requirements for personnel training, procedures, supervisory and risk management actions. These conditions in the guidance are seen very important from the point of view of enabling PSA driven support to maintenance, even if the associated methods and acceptance limits are not referred to in the guide.

The agreement between the HAEA and the Paks NPP [4] explicitly refers to the use of PSA in maintenance planning. Accordingly, the plant examines the risk impact of changes in maintenance scheduling and the applicability of PSA as part of the safety analysis for such changes. Maintenance of standby safety systems is performed only during shutdown states of regular refueling outages. Currently, the analysis focuses on re-scheduling the maintenance of some safety systems to full power operation of the plant (e.g. the introduction of on-line maintenance). A risk monitor based on the RiskSpectrum RiskWatcher software is available for the plant that uses the unit specific PSA models. The risk impact of introducing on-line maintenance is evaluated quantitatively by the use of this plant risk monitor. The results of these calculations are to be used as input to an integrated safety analysis for the planned modifications of maintenance scheduling.

At present there are only a limited number of requirements in safety regulations that can be loosely related to *risk-informed configuration control* of plant systems and equipment. The PSA of an NPP is supposed to be performed by giving appropriate considerations to all kinds of plant operational states and system configurations. This requirement calls for an adequate coverage of all plant and system operating modes in the PSA but it does not in itself establish a basis for configuration control. Some additional requirements in the Codes include the need to use probabilistic safety assessment in safety management activities of the licensee. Risk-informed configuration control can be an outstanding element of risk-informed safety management. However, it is not spelt out in the safety regulations explicitly. In addition, the findings about safety regulation for maintenance planning discussed in the preceding paragraph are applicable to configuration control, too.

One of the concrete tasks laid down in the regulatory-licensee agreement on improving risk-informed decision-making [4] is making advancement in the use of a risk monitor for the Paks NPP. The plant specific risk monitor is considered as the primary tool that can directly support risk-informed configuration control. Following a review and evaluation of potential application areas and expected benefits, implementation of the risk monitor in different licensee activities is on-going, which, among others, can lead to the use of the risk monitor in configuration control. (As discussed above, short-term actions are concerned with the introduction of on-line maintenance using support from risk monitor analyses.)

According to safety regulations, the intervals for *in-service inspection and testing* (RI ISI and RI IST) have to be based on dedicated analysis. Also, the Codes refer to the need to consider risk aspects. However, this requirement is related to the surveillance test intervals of active plant systems rather than inspection frequencies passive systems. Similarly to maintenance modelling, the acceptance criteria for PSA must be met by considering the actual inspection programs in the PSA model. This is a requirement for PSA quality and not for the application of PSA in support of in-service inspection. The Codes require that the inspection program include high risk components, although no guidance is available to help the fulfilment of this requirement. The regulatory guide that is available for in-service inspection of plant components [13] does not refer to the use of PSA to any extent. However, “continuous risk assessment” can be a means to define inspection intervals according to the guide. The technical details of such a risk assessment and the associated acceptable methodologies are not described in the guide.

In 2006 and 2007 PSA analysts of NUBIKI (as a technical support organization to HAEA NSD) participated in the RISMET Project on risk-informed in-service inspection jointly organized by the Joint Research Centre of the European Commission (JRC) and the Nuclear Energy Agency of the OECD (NEA). The project included a benchmark exercise on risk-informed in-service inspection applying various methodologies to the same case [14]. Hungarian project participants prepared a summary of methodological insights and experience gained from the benchmark exercise for use by both the HAEA NSD and the Paks NPP. In practice no real application of risk-informed inspection has been made to the piping systems of the Paks plant yet.

As to the *PSA support to establishing and reviewing Technical Specifications requirements*, two kinds of technical requirements have to be addressed: allowed outage times (AOTs) and surveillance test intervals (STIs). The Codes prescribe that safety analysis is required to determine the allowed outage times and the surveillance test intervals of safety related plant systems and components. There is no requirement or regulatory guidance in place concerning the methods to be used in this safety analysis. However, reference is made in the safety regulations to the use of probabilistic safety assessment to verify the adequacy of limiting conditions of operation. Additionally, STIs have to be determined by ensuring balance between increase in equipment availability due to testing and test caused unavailability. Again, the acceptable analysis methods to help fulfil this requirement are not specified in the safety regulations, although PSA appears to be a natural choice. There is an additional requirement in the Codes to make use of probabilistic safety assessment to define the intervals for those tests of programmable plant systems and components of safety class 2 that are applied to reveal failures remained undetected in programmed self-tests. If the licensee intends to change existing Technical Specifications requirements, then the general regulatory requirements for plant modifications apply – see the previous discussion in this subject.

Attempts have been made to perform a PSA-based review of Technical Specifications requirements since the mid-1990’s [15], [16]. Initial studies included a trial application of a method to determine AOTs by giving considerations to risk at full power, at shutdown and at the transition low power states with equipment out of service and with equipment available following repair. Also, a software tool was developed and used to help optimize STIs for all plant systems from risk point of view using an optimization algorithm that took into account the risk benefits from as well as the adverse effects of testing. Despite substantial efforts, the analysis results from these early studies had limited uses due to the novelty of the methods, the incompleteness of the PSA models and the lack of necessary data (e.g. data on the adverse effects of testing). Recently, the earlier studies have been revisited; the methods have been customized to licensee needs and to the current Paks PSA models and data. Then new analyses have been performed to underpin AOT and STI definitions by PSA [17]. The plant intends to prepare a submittal to the regulatory body to change Technical Specifications requirements by incorporating the results of supporting PSA studies.

Monitoring of maintenance effectiveness is required by safety regulations to ensure that safety functions are fulfilled with high reliability, and corrective measures are determined and implemented to avoid deteriorating safety performance of active plant equipment. This requirement emerged when licensee initiatives showed up to extend the service life of the Paks NPP. The regulatory guide on maintenance program and monitoring maintenance effectiveness [12] allows the use of probabilistic

safety assessment to set performance criteria to be applied during monitoring the effectiveness of maintenance on active plant equipment. A separate guide defines the roles and tasks of the nuclear safety authority in inspecting monitoring activities of the licensee [18]. Regulatory inspection includes a review of PSA-driven performance criteria.

A detailed methodology and criteria document had been developed as the technical basis for monitoring maintenance effectiveness at the Paks NPP [19]. Use was made of this document to determine safety performance indicators and set up performance criteria for 23 plant systems and the associated system components. Quantitative criteria were derived by performing dedicated fault tree analyses using component reliability data taken from the PSA model of the plant. Random equipment failures were considered in supporting fault tree analyses. Some of the 23 systems analyzed are not included in the plant PSA model because they are not important from the point of view of core damage risk; however they have lower level safety related functions (e.g. limiting the consequences of design basis accidents).

Requirements for *support from PSA to developing plant procedures* are only implicitly present in the Hungarian nuclear safety regulations. As an explicit regulatory requirement, PSA is supposed to take into consideration emergency operating procedures (EOPs) and severe accident management guidelines (SAMGs) “as planned” in a design stage PSA and “as implemented” in a PSA valid during plant operation. Failures to take proceduralized actions must be considered in the analysis. Like in many other instances, these requirements are concerned with the quality and credibility of PSA and do not in themselves contribute to establishing a basis for PSA applications. A separate requirement necessitates plant (design) specific safety analysis in support of EOP development. However, the role of probabilistic considerations and risk information in this analysis is not spelt out in the safety regulations. Similarly, dedicated severe accident analyses are required to work out guidelines on severe accident management, but there is no reference to the use of level 2 PSA, risk ranking, whatsoever in the Codes. Changes in the EOPs have to be considered as plant modifications, therefore the regulatory requirements for safety analysis of plant modifications apply if the licensee intends to modify the EOPs.

In the Paks NPP some use was made of the plant specific level 1 PSA in modifying the emergency operating procedures. When symptom oriented EOPs were introduced to replace the earlier, fully event based procedures the core damage sequences found important by probabilistic safety assessment were taken into consideration to define the scope of the new procedures in terms of the accident sequences that had to be covered. In addition, as part of the support from PSA to plant modifications, PSA results were used to modify and improve plant procedures especially to reduce core damage risk from low power and shutdown states. The development of severe accident management guidelines was based to a large extent on the findings of the plant specific level 2 PSA just as the whole area of severe accident management and the associated severe accident management measures recently implemented at the plant.

Support to training from PSA is required by explicit requirements in the safety regulations. It is laid down that use has to be made of the PSA results to underpin the development of the training program of the plant personnel and also to validate the program. This requirement establishes the foundation to make the training program risk-informed. However, there is no guidance available on the methods that can be considered acceptable to meet this requirement.

In the mid-1990s a PSA-based review was made of the accident scenarios included in the continuing training program of the Paks control room crews at the full scale replica training simulator [20]. Recently, explicit considerations to risk aspects and to the available plant specific probabilistic safety assessment have been incorporated into the training programs of plant personnel whose tasks and responsibilities can be associated with the fulfilment of safety functions. In addition, regular PSA related training is provided for the plant personnel by the in-house PSA group and by technical support organizations. This training is customized to job positions and duties. Representative examples are training to facilitate the application of PSA in monitoring maintenance effectiveness and training on the use of the plant specific risk monitor.

PSA-based *analysis of operational events* is present in Hungarian safety regulations to some degree. Within the requirements for licensee reports on safety related events the need for safety evaluation and for the assessment of degradation in safety margins appears. However, probabilistic safety assessment does not have to be included in the licensee event reports. Also, an additional requirement calls for the analysis of real and potential consequences of the operational events and for the assessment of consequence severity. Probabilistic assessment can support this kind of analysis. Finally, it is also required by safety regulations to judge event importance by means of probabilistic safety assessment. PSA-based analysis is performed at the Paks NPP for each operational event that results in a PSA initiating event. The conditional core damage probability is assessed for such events. Events involving equipment unavailability without the occurrence of a plant transient are not subject to PSA-based analysis. For regulatory use the approach applied by the US NRC in the Accident Sequence Precursor program was adapted in 1997 followed by the development of software aid to PSA-based event analysis [21], [22]. Using this approach and the supporting analysis tool all the operational events reported by the licensee to the HAEA have been subject to PSA-based analysis and evaluation since 1999.

3. PSA APPLICATIONS PROPOSED FOR IMPLEMENTATION AND IMPROVEMENT

In addition to reviewing the status of PSA applications in Hungary, a high level survey of risk-informed decision-making was made for a number of OECD member countries operating nuclear power plants. The aim was to appropriately substantiate the proposal to be developed for the HAEA NSD. The survey was based on

- a Nuclear Energy Agency (NEA) report of the OECD on PSA in member countries [23]
- open technical literature
- information exchange from bi- and multilateral cooperation efforts.

The following countries were included in the survey:

- Belgium
- Canada
- Czech Republic
- Finland
- France
- Germany
- Japan
- Mexico
- Slovakia
- Slovenia
- South Korea
- Spain
- Sweden
- Switzerland
- Taiwan
- The Netherlands
- United Kingdom
- USA

Particular attention was paid to the United States and Finland within the survey because the US has had a pioneering role in probabilistic risk assessment (PRA) and risk-informed decision-making, while in Europe Finland can be considered as one of the leading countries applying PRA, risk-informed regulation and risk-informed safety management for nuclear power plants. Moreover, the Finnish experience with the use of PRA in licensing new nuclear power plants was seen useful for the

purposes of the study. The information from licensees was limited, so the survey could mostly rely on input provided by the nuclear safety authorities and their technical support organizations.

In brief, the results of the survey witness great diversity in the scope and level of detail of PSA applications as well as in the integration of explicit risk considerations into the decision-making process. Instances of good practices in different countries were highlighted[‡] in the study to justify the subsequently developed proposal to the HAEA NSD.

On the whole, the proposal for improving and extending PSA applications was developed by giving considerations to the following factors:

- the role of probabilistic safety assessment applications in current safety regulations in Hungary as outlined Section 2
- experience with PSA applications in Hungary and ongoing regulatory and licensee developmental efforts as depicted in Section 2
- regulatory intention to move towards risk-informed regulation including incorporation of PSA information into the decision-making process
- main directions of research and development indicated in the regulatory policy of the HAEA NSD on technical support activities for 2013-2016 [24]
- results of the survey on PSA applications internationally as referred to above
- experience and expertise of NUBIKI personnel in PSA, PSA applications and application developments
- initiatives to build new nuclear power plants in Hungary.

In order to take the best advantage of integrated decision-making that blends deterministic and probabilistic principles

- it was suggested that HAEA NSD ensure the implementation of all the PSA applications, surveyed and characterized in the study (see Section 2), in nuclear safety regulations in Hungary between 2013 and 2020,
- it was further suggested that HAEA NSD
 - intensify and extend its activities aimed at introducing risk-informed regulation
 - investigate in detail and evaluate what modifications were needed in safety regulations in Hungary in order to underpin risk-informed safety management and risk-informed regulation as the overall framework for PSA applications
 - identify further developmental needs in technical support for each PSA application area
 - identify what modifications were necessary in the Nuclear Safety Codes and in the regulatory guides for each PSA application
 - initiate changes in safety regulation and ensure technical support activities.

Not surprisingly, the study concluded that risk-informed safety management by the licensee and risk-informed regulation by the nuclear safety authority could ensure an appropriate framework for expanding and improving PSA applications and for making the best uses of PSA information. Therefore it was considered of prime importance to fully implement risk-informed regulation parallel to improving PSA applications in the proposed developmental period, i.e. by 2020.

Appropriate nuclear safety regulations that enable risk-informed decision-making are a precondition for both risk-informed safety management and risk-informed regulation. Thus the study proposed a review of the Nuclear Safety Codes and the associated regulatory guides. (In addition, introduction of new regulatory documents over and above the Codes and the regulatory guides was raised as an option.) More specifically, development of a regulatory guide was proposed to clearly define the scope of expected PSA applications, and the role and uses of these applications in risk-informed safety management by the licensee. This document would represent high level guiding on risk-informed

[‡] A discussion of details of these examples is beyond the scope of this paper.

safety management without describing methodological details specific to the various individual PSA application areas. Since the requirement to apply probabilistic safety assessment is already laid down in the Codes, such a guide would fit very well into the current system of Hungarian safety regulations.

Besides the high level guidance on the role of PSA applications in safety management it was also proposed to develop more detailed guides on the methodologies that could be followed to implement the various PSA applications. However, it is important to note that integration of the PSA and the associated risk considerations was recommended to the HAEA NDS as opposed to developing separate guides on the individual PSA applications. This approach was thought to serve best the goal to make integrated, risk-informed decision-making. For instance, it was suggested that the existing regulatory guide on maintenance should be reviewed and modified to include explicitly the role and expected uses of PSA in maintenance planning, realization and verification. Risk-informed safety classification was cited as good example on the actual developmental tasks since proposals for modifying high level requirements in the Codes were available and also a draft regulatory guide had already been developed on how to make safety classification risk-informed in an integrated decision-making framework.

As indicated above, it was found necessary to examine in detail and identify (1) further developmental needs in technical support for each PSA application area and (2) the modifications to be made to nuclear safety regulations. Although the study did not endeavor to perform such detailed analyses, a top level review was made to identify the key areas of further developments in both technical support and safety regulations for each PSA application area proposed for implementation. Also, the study prioritized those applications that had had no or limited uses in Hungary in the past. Since evaluation of plant safety, support to plant modifications and monitoring maintenance effectiveness were found relatively well developed, prioritization was made to the other ten application areas to support scheduling of activities. The achievements of PSA developments in Hungary and the intention to make the best potential uses of PSA applications in licensing new nuclear power plants were the key factors considered during prioritization. Based on these aspects PSA applications were proposed to be fully implemented in the following order by 2020:

1. Support to safety management and regulation (to establish a general framework for risk-informed decision-making and for all the envisaged PSA applications)
2. Safety classification of systems, structures and components
3. Support to maintenance
4. Support to establishing and reviewing Technical Specifications requirements
5. Configuration control
6. In-service inspection and testing
7. Analysis of operational events
8. Support to design
9. Support to developing plant procedures
10. Support to training.

4. ROLE OF PSA APPLICATIONS IN DIFFERENT LIFE CYCLE STAGES OF AN NPP

Since some PSA applications may have distinguishing features in the different lifecycle phases of a nuclear power plant from the point of view of scope, expected results and underlying methods, risk-informed safety regulation must be exercised with giving considerations to such differences. For this reason the role of the proposed PSA applications during plant design, construction, commissioning and operation was examined and characterized in the study. Naturally, use of a risk-informed approach to site selection and plant decommissioning is also justifiable. However, these life cycle stages and activities were not in the scope of the work. Table 1 presents a concise description of the conclusions from the analysis with respect to the role of PSA applications in the life cycle stages addressed in the study.

Table 1: Role of PSA Applications in Different Life Cycle Stages of an NPP

PSA Application	Life Cycle Stage		
	Design	Construction, Commissioning	Operation
Evaluation of plant safety	Yes, evaluation according to design	Yes, update during construction, feedback from commissioning experience	Yes, in living PSA
Support to design	Yes, this application is focused on this stage	Yes, update of design stage PSA to reflect actual state, feedback from commissioning experience	No (only during design of plant modifications)
Support to plant modifications	No	Yes, to analyse modifications due to commissioning experience	Yes, this application is focused on this stage
Safety classification of SSCs	Yes, classification is to be risk-informed during plant design	Yes, update of classification to actual plant state by making use of construction phase PSA	Yes, classification is to be kept living to reflect operating experience and updated PSA
Support to maintenance	Yes, to the extent maintenance considered in design	Yes, to establish risk-informed maintenance program	Yes, risk-informed verification and modification of maintenance program
Configuration control	Limited to verification of fulfilling safety goals with account taken to configurations planned in design	Yes, evaluation of changes compared to design stage, development of risk-informed configuration control program	Yes, continuous risk-informed configuration control
In-service inspection and testing	Yes, to the extent in-service inspection activities are considered in design, development of RI ISI, RI IST methodology	Yes, evaluation of changes compared to design stage, development of risk-informed RI ISI and RI IST programs, RI ISI during commissioning, feedback from commissioning experience	Yes, risk-informed verification and modification of ISI and IST programs
Support to Tech. Specs. requirements	Limited to verification of fulfilling safety goals with account taken to Tech. Specs requirements planned in design	Yes, development of risk-informed Tech. Specs. requirements	Yes, risk-informed verification and modification of Tech. Specs. requirements
Monitoring maintenance effectiveness	No	Yes, development of monitoring program	Yes, continuous monitoring and evaluation of maintenance effectiveness
Support to developing plant procedures	Limited to verification of fulfilling safety goals with account taken to plant procedures considered in design	Yes, development of risk-informed plant procedures	Yes, risk-informed verification and modification of procedures
Support to training	Limited to verification of fulfilling safety goals with account taken to training level of plant personnel assumed in design	Yes, development of risk-informed training program	Yes, risk-informed verification and modification of training program
Analysis of operational events	No	Yes, development of event investigation program, feedback from commissioning experience	Yes, continuous event analysis
Support to safety management and regulation	Yes. risk-informed evaluation and licensing	Yes, development of risk-informed safety management program, feedback from commissioning experience, risk-informed regulatory supervision	Yes, continuous risk-informed safety management and regulation

5. DISTINCTION BETWEEN OLD NPPS AND NEW BUILDS

Due to the differences in the design features (and partly in the operational characteristics) of old nuclear power plants and new reactors some of the design requirements in the Nuclear Safety Codes differentiate between old reactors and new builds. Accordingly, some distinction was seen reasonable concerning the requirements for PSA applications to old and new reactor designs. Moreover, a few applications cannot be effectively implemented backward for those life cycle stages of old reactors that have already been passed. The proposed PSA application areas were examined one by one and differences in use for operating plants and for new builds were identified and described. The end result was that notable differences could be pointed out in the application areas of: support to design; safety classification of systems, structure and components; in-service inspection; support to developing plant procedures; and support to training. For example it was proposed to explicitly require risk-informed (integrated) safety classification for new reactors, while it could be used as an option for plants already operating. Less significant distinction was seen justifiable for the rest of the application areas. For example, the way of applying PSA to evaluate plant safety is essentially the same for old plants and for new builds even if there are differences in probabilistic safety criteria in the Codes.

6. CONCLUSION

A study was conducted to outline a work plan for making advancement in risk-informed decision-making in the Hungarian Atomic Energy Authority. A proposal was developed to extend and improve the use probabilistic safety assessment and risk information in thirteen key application areas. Further developmental needs in technical support and safety regulation – seen necessary for introducing practically useful PSA applications – were determined for each application area. PSA applications were prioritized in support of scheduling the developmental tasks. Also, the role of risk-informed decision-making in different life cycle stages of a nuclear power plant was characterized. Finally, it was proposed to make some distinction between PSA applications to operating and newly built nuclear power plants, respectively.

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