KRŠKO PERIODIC SAFETY REVIEW PROJECT PRIORITIZATION PROCESS

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ABSTRACT

Definition of a Krško Periodic Safety Review (PSR) project is a comprehensive safety review of a plant after last ten years of operation. The objective is a verification by means of a comprehensive review using current methods that Krško NPP remains safety when judged against current safety objectives and practices and that adequate arrangements are in place to maintain plant safety. This objective encompasses the three main criteria or goals:

- confirmation that the plant is as safe as originally intended,
- determination if there are any structures, systems or components that could limit the life of the plant in the foreseeable future, and
- comparison the plant against modern safety standards and to identify where improvements would be beneficial at justifiable cost.

Krško PSR project is structured in the three phases:

1. Preparation of Detailed 10-years PSR Program (documented in [1]),
2. Performing of 10-years PSR Program and preparing of associated documents (2001-2003), and
3. Implementation of the prioritized compensatory measures and modifications (development of associated EEAR, DMP, etc.) after agreement with the SNSA on the design, procedures and time-scales (2004-2008).

This paper presents the NEK PSR results of work performed under Phase 2 focused on the ranking of safety issues and prioritization of corrective measures needed for establishing an efficient action plan. Krsko PSR Summary Report [2] has been delivered to Slovenian Nuclear Safety Authority (SNSA) for review in December 2003.

1 INTRODUCTION AND BACKGOUND

The ranking of safety issues and prioritization of corrective measures are the main tasks needed for establishing an efficient action plan. Safety issues were identified at NEK during the following review processes and already summarized in [3] and [4], respectively:

- Periodic Safety Review (PSR) task
- Krško NPP Regulatory Compliance Program (RCP) review
- Westinghouse Owner Group (WOG) catalog items screening/review
- SNSA recommendations (including IAEA RAMP mission suggestions/recommendations)

Pre-screening eliminates from consideration in the ranking process all safety issues identified in the Krško Periodic Safety Review as desirable and requiring minimum effort to implement. As an example of the type of issues considered here, minor corrections to plant procedures that can be implemented as a part of

corrective processes and programs that normally take place in the plant are screened from further consideration in the ranking process.

Some identified safety issues may necessitate conditions that require immediate or very near term resolution. For example, they may require that the plant promptly go into an outage or extend an outage in progress, a power reduction, or equipment damage or degradation which, as required by TSs, results in a near term power reduction or outage. All such safety issues do not require ranking as they must be accomplished in the near term to mitigate potential substantial economic consequences to NEK.

A significant number of issues did survive the pre-screening process. These issues are identified in [5] as required short term, required and desirable medium term, and required and desirable long term. RCP compliance review, WOG catalog items screening, RAMP mission, and SNSA issues were reviewed to identify issues, which are similar to those categorized as requiring ranking in [6].

2 RANKING OF SAFETY ISSUES

This section provides the methodology for ranking safety issues identified in [3] which survived the pre-screening step. All safety issues are assessed based on a set of attributes utilizing a telescopic filtering method as described in Haimes' Risk Modeling, Assessment, and Management [7]. In the first phase, all attributes are ranked with respect to each other based on guidance from 10 CFR Part 50, Safety Goals for the Operations of Nuclear Power Plants, Policy Statement 51 FR 30028 [8] and 10 CFR Part 830, Nuclear Safety Management [9]. Issues are initially divided into those where a direct link to plant safety can be established and those which are a re-evaluation of the safety basis only. The process is presented on Figure 1.

2.1 Ranking of Safety Issues in Which a Direct Link to Plant Safety Has Been Established

The following generic attribute categories have been derived based on the guidance provided in Reference [10] and Keeny's Decisions with Multiple Objectives: Preferences and Value Tradeoffs [11] to allow for an efficient safety issue ranking method for NEK issues where a direct link to plant safety can be established:

- Extreme event risk (public and environmental risk)
- Moderate event risk (worker risk)
- Fault tolerance (degradation of defense-in-depth)
- Prior risk information (historical information, precursor data)
- Qualitative cost evaluation
- Additional attributes (regulatory performance, operational excellence, and external confidence)

In the first phase of the ranking process for issues where a direct link to risk or degradation of defense-in-depth is determined, a distinguishment is made as to the relative significance of the attributes. Reference [12] focuses on risk to the public from NPP operation. The qualitative safety goals presented in Reference [13] are as follows:

- Individual members of the public should be provided protection from the consequences of NPP operation such that individuals bare no significant additional risk to life and health
- Societal risk to life and health from NPP operation should be comparable to or less than risk of generating electricity of viable competing technologies and should not be a significant addition to other societal risk.

Reference 3.8 provides a ranking system for structures, systems, and components (SSCs) for United States Department of Energy (USDOE) nuclear reactor and non-reactor nuclear facilities based upon the potential accident impact to the public, workers, and environment. SSCs are defined as safety class if they provide a preventative or mitigative function for public safety such that for any credible accident (> 1.0E-6/yr) a dose received by a maximally exposed member of the public is less than 25 rem. SSCs are defined as safety significant if they provide a preventive or mitigative function for worker safety. Finally, the lowest safety significance categorization is for SSCs considered as defense-in-depth.

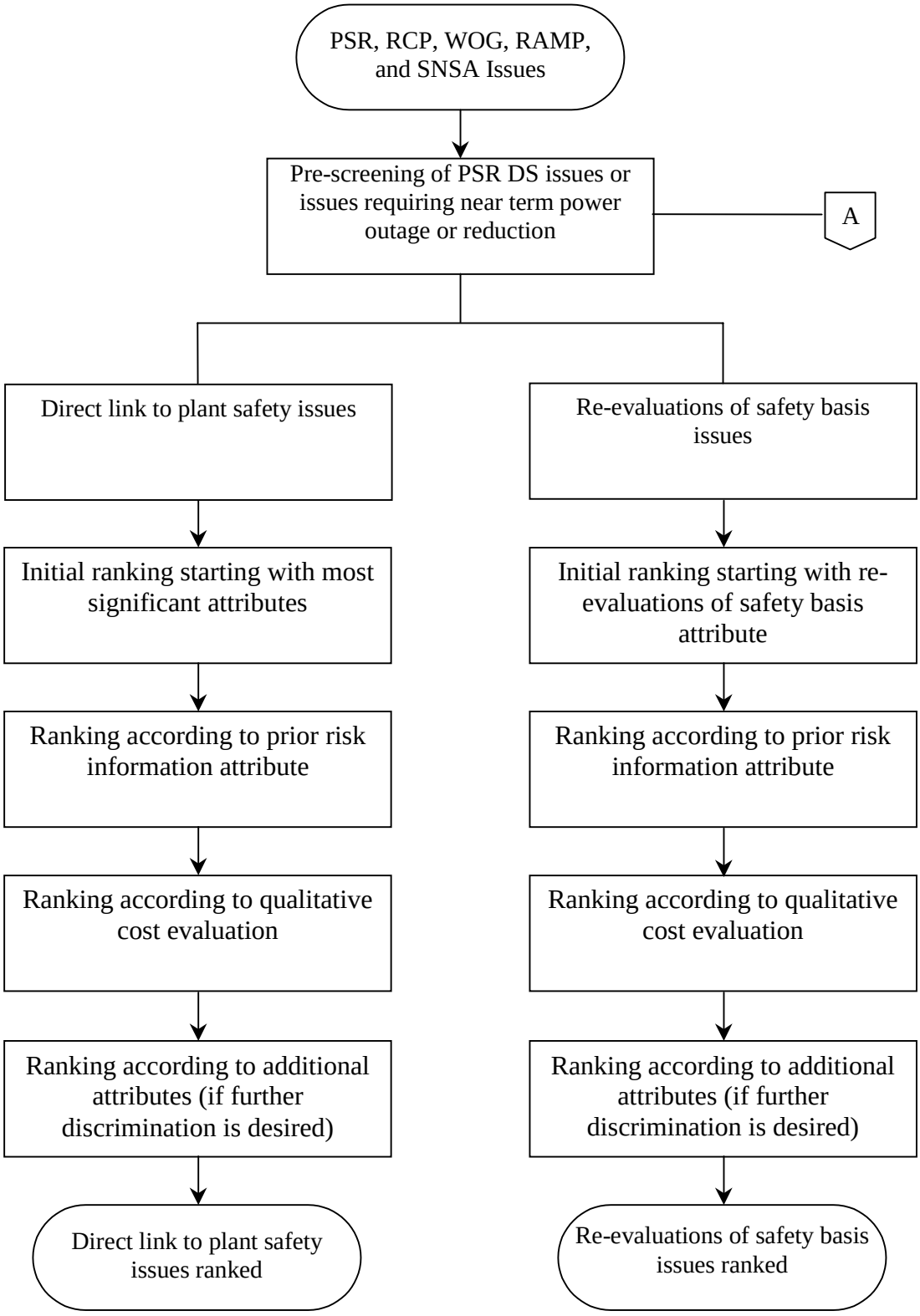

Figure 1: Flow Diagram of Pre-screening and Ranking of Issues

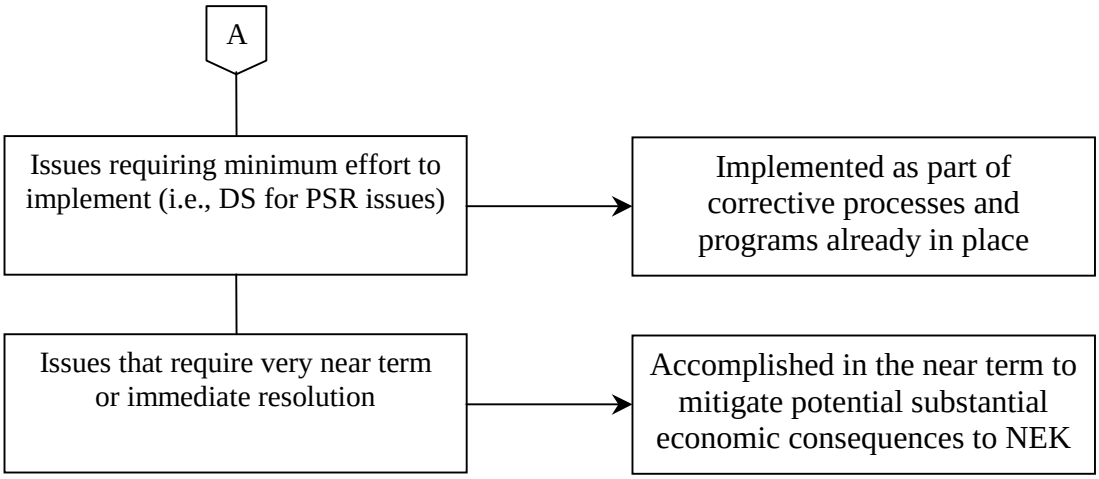

Figure 1: Flow Diagram of Pre-screening and Ranking of Issues (Continued)

Therefore, credible accidents with a CDF of greater than 1.0E-6/ry or large early release frequency (LERF) of greater than 1.0E-7/ry that impact the public safety and environment are considered more significant than those which impact at most, plant workers, or result in a degradation of defense-in-depth.

A detailed evaluation of each safety issue identified as having a direct link to plant safety is performed to map each issue into one of the three most significant attribute categories related to risk and defense-in-depth. Prior risk information and costs of resolution are not considered as significant as the three attributes directly related to plant safety. Likewise, prior risk information is considered more significant than the costs of resolution since this attribute is related to the potential for precursor events which may result in risk or degradation of defense-in-depth.

A three-tier ranking method is utilized for determining the relative significance of the attributes where first, risk and degradation of defense-in-depth are evaluated; second, prior risk information is determined; and finally, qualitative cost categories are assigned. The risk and degradation of defense-in-depth evaluation provide the dominant discriminator between safety issues. In other words, if a safety issue is ranked above another based on the evaluation of risk and defense-in-depth alone, it retains its dominance independent of prior risk information and qualitative cost evaluation. For example, if a safety issue is identified as resulting in containment failure with a CDF greater than 1.0E-6/ry, it is always ranked above another safety issue which results in degradation of defense-in-depth. The prior risk attribute is evaluated next and dominates the qualitative cost evaluation attribute. Finally, the qualitative cost evaluation provides the third discriminator for safety issues ranked identically based upon risk, degradation of defense-in-depth, and prior risk information.

In the second phase, each safety issue is ranked for risk and degradation of defense-in-depth. Also, the severity ranking within a given attribute category is evaluated. The extreme event risk attribute is evaluated first. If a safety issue is found to map to this attribute, no evaluation need be performed for its applicability to the moderate event risk or fault tolerance attributes. If it is not found to map into the extreme event risk attribute, it is progressively evaluated for the moderate event risk attribute and fault tolerance attribute. Once the attribute category and severity ranking within the attribute category are identified, no further evaluation need be performed in this phase.

Table 1 provides the severity ranking scale for the extreme event risk, moderate event risk, and fault tolerance attributes. It is assumed that if a safety issue maps into the extreme event risk attribute, that worker risk (potential fatality) and substantial degradation of defense-in-depth have occurred. Likewise, if a safety

issue maps into moderate event risk, it is assumed that substantial degradation of defense-in-depth has occurred. It is not necessary to sum severity numbers from multiple attributes to rank safety issues. Therefore, the severity ranking for a given safety issues where a direct link to plant safety is established can be directly taken from Table 1.

Table 1: Safety Issue Ranking Scale for Those Issues with a Direct Link to Plant Safety

Attribute	Description	Severity Number
Extreme Event Risk (public and environmental risk)	Core damage with early containment failure	10
	Core damage with late containment failure	9
Moderate Event Risk (worker risk)	Core damage (no containment failure) or major spent fuel pool accident	8
	Partial core damage only (no containment failure) or minor spent fuel pool accident	7
Fault Tolerance (degradation of defense-in-depth)	Substantial degradation of multiple safety systems	6
	Moderate degradation of multiple safety systems	5
	Substantial degradation of single safety system	4
	Moderate degradation of single safety system	3
	Impacts confined to non-safety systems	2
No Impact Identified	No quantifiable plant risk and degradation of safety or non-safety system	1

The third phase of safety issue ranking involves the evaluation of the prior risk information attribute. Prior risk information primarily relates to historical information concerning a safety issue. This historical information is utilized to provide another metric of plant specific relevance for NEK. Issues specific to NEK are ranked above those, which are identified in similar Westinghouse plants, and those only identified as generic.

In the fourth phase, a qualitative cost evaluation for each attribute is performed. Issues, which are identified as having a lower cost for resolution, will be ranked above those, which require a higher cost for resolution.

Finally, additional attributes such as regulatory performance, operational excellence, and external confidence are evaluated (if desired) only in the event that sufficient discrimination has not resulted from the three-tier ranking of issues based on public, environmental, and worker risk, degradation of defense-in-depth, prior risk information, and qualitative costs.

2.2 Ranking of Safety Issues which are a Re-evaluation of the Safety Basis Only

Issues involving re-evaluations of the safety basis and potential identification of new risk and degradation of defense-in-depth are ranked independently of issues where a direct link can be established to the reduction of residual plant risk or defense-in-depth.

The following generic attribute categories have been derived based on the guidance provided in References [14], [15], [16] and [17] to allow for an efficient safety issue ranking method for NEK issues where a re-evaluation of the safety basis is recommended:

- Re-evaluations of safety basis (potential identification of new risk and degradation of defence-in-depth issues)
- Prior risk information (historical information, precursor data)
- Qualitative cost evaluation
- Additional attributes (regulatory performance, operational excellence, and external confidence)

In the first phase of the ranking process for issues involving a re-evaluation of the safety basis only, a distinguishment is made as to the relative significance of potential changes to the plant risk profile. Table 2 provides a severity ranking scale for the re-evaluation of the safety basis attribute.

Table 2: Safety Issue Ranking Scale for Re-evaluations of Safety Basis

Attribute	Description	Severity Number
Re-evaluations of safety basis (potential identification of new risk and degradation of defense-in-depth issues)	A significant change in plant risk profile potentially resulting in the identification of new safety issue(s)	3
	A quantifiable change in plant risk profile potentially resulting in the identification of new safety issue(s)	2
	No quantifiable change in plant risk profile	1

A three-tier ranking method is utilized for determining the relative significance of the attributes where first, a qualitative evaluation of the potential change in the plant risk profile is performed; second, prior risk information is determined; and finally, qualitative cost categories are assigned. The potential change in the plant risk profile evaluation provides the dominant discriminator between safety issues where a direct link to plant risk or degradation of defense-in-depth cannot be established. In other words, if a safety issue is ranked above another based on the evaluation of potential change to the plant risk profile alone, it retains its dominance independent of prior risk information and qualitative cost evaluation. For example, if a safety issue is identified as resulting in a significant change in the plant risk profile, it is always ranked above another safety issue, which results in a quantifiable change to the plant risk profile. The prior risk attribute is evaluated next and dominates the qualitative cost evaluation attribute. Finally, the qualitative cost evaluation provides the third discriminator for safety issues.

In the second and third phases, the evaluation of prior risk information and qualitative cost is performed as described in Section 2.4. Also, as was the case for the evaluation of issues identified with a direct link to plant safety, additional attributes are evaluated (if desired) only in the event that sufficient discrimination has not resulted from the ranking of issues based on the re-evaluations of the safety basis, prior risk information, and qualitative cost evaluation attributes.

PSR Prioritization report [18] provides more detailed descriptions of each attribute described in this section. Additionally, mentioned report describes the methodology to allow for distinguishment of relative significance within a given attribute category.

2.3 Prior Risk Information

For all safety issues, the evaluation of the prior risk information attribute considers problems encountered with respect to a particular safety issue identified in NEK experience, similar Westinghouse designed plants (not NEK specific), or generic industry-wide sources exclusively.

In the evaluation of plant risk, plant specific and generic data are utilized to develop initiating event frequencies and component specific failure probabilities, “Procedures for the External Event Core Damage Frequency Analyses for NUREG-1150” [19]. If plant specific precursor events such as loss of electrical power have occurred, the plant specific initiating event frequency has been found to be higher than the

generic industry-wide frequency, "Analysis of the LaSalle Unit 2, Internal Fire Analysis" [20]. Likewise, plant specific component failure probabilities are higher than the generic values if component failures have occurred at a given plant. Consequently, it may be inferred that plant specific problems for a given safety issue are of greater significance than problems incurred at similar plants or generic problems. Table 3 provides the severity scale for the prior risk information attribute.

Table 3: Severity Scale for Prior Risk Information

Attribute	Description	Severity Number
Prior Risk Information	Issue identified as plant specific problem	3
	Issue identified as Westinghouse generic problem (no plant specific identification)	2
	Issued identified as generic industry-wide problem exclusively	1

The following are examples of NEK, Westinghouse, and generic industry-wide information sources:

NEK and Westinghouse Sources	Generic Industry-Wide Sources
Reports to Regulatory Body (daily, monthly, yearly)	IAEA Reports
Inspection Reports from Regulatory Body	OECD-NEA Reports
Outage Assessment Reports from Technical Support Organizations	European Commission Reports
NEK Event Reports	
Licensee Event Reports – Westinghouse Plants	

These sources are examples only and should not be considered as required references or all-inclusive. Expert judgment and consultation with plant SMEs are utilized to determine the plant specific, Westinghouse, and generic industry-wide information sources for a given safety issue and whether or not it is directly applicable to NEK.

2.4 Qualitative Cost Evaluation

For all safety issues, the qualitative cost evaluation attribute considers preliminary order of magnitude costs associated with issue resolution. By necessity, due to the large number of potential corrective measures to be considered, plant SMEs provide the primary input to this order of magnitude cost evaluations. Table 4 provides the severity scale for the qualitative cost evaluation attribute.

Table 4: Severity Scale for Qualitative Cost Evaluation

Attribute	Description	Severity Number
Qualitative Cost Evaluation	Less than $10,000 USD	4
	Between $10,000 and $100,000 USD	3
	Between $100,000 and $1,000,000 USD	2
	Greater than $1,000,000 USD	1

2.5 Additional Attributes

Additional attributes, which may be evaluated if desired, include regulatory performance, operational excellence, and external confidence. Regulatory performance can be defined by commitments that have been made to the SNSA to further ensure the safety of the plant. Operational excellence is evaluated by identified violations of procedures, deviations from defined programs, failure to meet goals, and other NEK performance indicators. External confidence relates to addressing comments from international missions such as those conducted by the IAEA and the World Association of Nuclear Operators (WANO).

As discussed previously, additional attributes are only considered in the ranking process if desired when insufficient discrimination between two or more safety issues has occurred when considering the significant, prior risk information, and qualitative cost evaluation attributes. It may be necessary to define other additional attributes on a case by case basis to discriminate between safety issues. However, regulatory performance, operational excellence, and external confidence should always be considered.

The definition of the safety issue itself as well as a review of plant documentation determines the applicability of any additional attributes for a given safety issue. Expert judgment and consultation with plant SMEs is utilized. If an additional attribute is found to be applicable for a given safety issue, it will be ranked as one. A zero ranking is given for non-applicability.

3 RESULTS OF RANKING EVALUATION

Table 5 provides a numerical breakdown by severity ranking of all issues with a direct link to plant safety.

Table 5: Summary of All Issues with Direct Link to Plant Safety

Severity Description	Severity Number	Number of Issues
Core damage with early containment failure	10	0
Core damage with late containment failure	9	0
Core damage (no containment failure) or major spent fuel pool accident	8	0
Partial core damage only (no containment failure) or minor spent fuel pool accident	7	0
Substantial degradation of multiple safety systems	6	5
Moderate degradation of multiple safety systems	5	83
Substantial degradation of single safety system	4	17
Moderate degradation of single safety system	3	30
Impacts confined to non-safety systems	2	4
No quantifiable plant risk and degradation of safety or non-safety system	1	207
	Total	346

Table 6 provides a numerical breakdown by severity ranking of all issues requiring a re-evaluation of the safety basis.

Table 6: Summary of All Issues Requiring Re-evaluation of the Safety Basis

Description	Severity Number	Number of Issues
A significant change in plant risk profile potentially resulting in the identification of new safety issue(s)	3	9
A quantifiable change in plant risk profile potentially resulting in the identification of new safety issue(s)	2	28
No quantifiable change in plant risk profile	1	85
	Total	122

A total of 468 PSR, RCP compliance review, WOG catalog items screening, RAMP mission, and SNSA issues survived the pre-screening process. Of the 468 issues remaining, 346 issues were found to have a direct link to plant safety while the other 122 issues were identified as a re-evaluation of the safety basis.

The 346 issues with a direct link to plant safety were evaluated for reduction of residual plant risk and degradation of defense-in-depth. No issues were identified with the potential for reduction of residual plant risk. Table 5 summarizes the results of this evaluation.

The 122 issues requiring a re-evaluation of the safety basis were evaluated to determine what change, if any, there might be in the plant risk profile, potentially resulting in the identification of new safety issue(s). Table 6 summarizes the results of this evaluation.

3.1 Future Actions

The future actions that NEK will take on the basis of its PSR will be influenced by considerations and perspectives of plant risk profile brought in by issues raised by PSR. The issues have been ranked according to their importance together with all other issues raised by PSR and they will be addressed by means of corrective measures proposed, as described in Issues Ranking Report [21]. The proposed measures will be prioritized according to their strength and the relevance of issues they address, which is also described in Ranking Report [22].

In developing the detailed plan and course of actions the insights from quantitative assessments of risk and its profile will be taken into account. The PSR issues that relate to the current estimate of plant risk and its profile will be subjected to a detailed analysis in a manner that corresponds to their ranking. Depending on the results of analyses, appropriate corrective measures will be proposed and implemented.

Taking into account Krško risk profile discussed above, perspectives brought in by the PSR and the quantitative objectives associated with risk measures, the Krško action plan will reflect the following guidelines.

Krško is determined to seek the most appropriate ways in a timely and cost-effective manner to further reduce the quantitative measures of permanent risk.

Based on the cumulative impact of PSR issuses, the perception of plant risk can change in a manner that it is different than its current estimate discussed above. Krško will take such a course of actions that after the implementation of corrective actions the permanent risk measures will be at the level of current values or lower.

The types of available corrective measures differ depending on the type of safety issue. Some typical deficiencies, which may be identified, are as follows:

- Deficiencies of information
- Deficiencies of design
- Deficiencies of operation
- Deficiencies of safety culture

Due to the diversity in potential deficiencies, many possible corrective measures may be identified. In some cases, multiple corrective measures may be postulated to provide resolution for a given safety issue. Identification of the optimal corrective measure for a particular deficiency will allow for a time optimal reduction of residual plant risk and enhancement of defense-in-depth. Allocation of resources between the issues where a direct link to plant safety can be established and those, which are a re-evaluation of the safety basis only, will be determined based upon severity, costs, and ease of remediation. All direct link issues ranked below Severity Category 5 and re-evaluation of the safety basis issues ranked below Severity Category 2 are recommended for exemption from further consideration since the costs are not commensurate with the minimal benefit of resolution.

4 CONCLUSION

In the frame of NPP Krško Periodic Safety Review, Phase 2, a comprehensive and documented review has been performed of the plant operational and design status. Review confirmed that the plant is as safe as originally intended and determined that there are any structures, systems, components, human activities or administrative processes that could limit the life of the plant in the foreseeable future. This review has not revealed any major safety issue. As a result, Krško NPP can safely operate, as a minimum up to completion of the next Periodic Safety Review. The review has nevertheless identified a small number of recommendations to further enhance the plant safety and its documentation, which are mentioned above.

REFERENCES

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