ABSTRACT

Definition of a PSR (Periodic Safety Review) project is a comprehensive safety review of a plant after ten years of operation. The objective is a verification by means of a comprehensive review using current methods that the plant remains safe when judged against current safety objectives and practices and that adequate arrangements are in place to maintain plant safety. The overall goals of the NEK PSR Program are defined in compliance with the basic role of a PSR and the current practice typical for most of the countries in EU. This practice is described in the related guides and good practice documents issued by international organizations. The overall goals of the NEK PSR are formulated as follows:

- To demonstrate that the plant is as safe as originally intended;
- To evaluate the actual plant status with respect to aging and wear-out identifying any structures, systems or components that could limit the life of the plant in the foreseeable future, and to identify appropriate corrective actions, where needed;
- To compare current level of safety in the light of modern standards and knowledge, and to identify where improvements would be beneficial for minimizing deviations at justifiable costs.

The Krško PSR will address the following safety factors: Operational Experience, Safety Assessment, EQ and Aging Management, Safety Culture, Emergency Planning, Environmental Impact and Radioactive Waste.

1 INTRODUCTION

The subject of this paper is the assessment (under NPP Krško Periodic Safety Review Project) of the Safety Factor entitled Safety Assessment and Analyses. The basic reference for the mentioned project task is Krško NPP technical report ESD-TR-03/01 [6]. Paper discusses the Safety Assessment definition and the overall methodological approach (assessment of the plant safety status for this safety factor). The deterministic assessment concentrates on determining whether the current design and operation of the plant reflect the good practice, the suitable management policies and procedures are in place, and that the current safety analysis is comprehensive, suitably validated and demonstrates the required level of safety. Engineering rules and deterministic criteria based on good practice applied in this assessment depend on specific area of review.
The general approach adopted for the NEK PSR reflects that given in EUR 15555 EN [1], INSAG-8 [2] and IAEA Safety Reports Series No. 12. Other relevant sources are also used as needed.

It should be noted that the assessment criteria used at stage of Krško NPP PSR Program definition are not very precise. In most cases, the point at which a particular element of the review shows sufficient deviation from the ‘ideal’ to be classified as a ‘safety issue’ will be a question of expert judgement. For each identified safety issue detailed resolution have to be defined. If hardware change and associated installation are needed, resolution plan should include also the conceptual design. Westinghouse Electric Europe S.A has been chosen on international tender to help Krško NPP to perform the Periodic Safety Review of the mentioned Safety Factor.

2 SUBJECT OF PSR SAFETY FACTOR "SAFETY ASSESSMENT AND ANALYSES"

2.1 Safety Standards and Practices Topic List Review

The Westinghouse established a list of safety standards and practices to which the review will be made. This list was based on the latest USNRC requirements and on the Westinghouse's practical experience, and included the current US safety standards regarding regulatory rules for safety analyses of operator action, common cause events, cross-link effects, single failure criterion, redundancy, diversity and separation. This will be the subject of topical report PSR-NEK-2.1.

2.2 Design Aspects

The adequacy of the present design, as defined in the existing plant documentation, will be the subject of expert review by the Westinghouse based on the above-mentioned topical report PSR-NEK-2.1. This review involves the following:
- Review of the description of the safety systems, their functions and their interactions.
- Review of the functional capability of each structure, system and component important to safety.
- Review of the current analytical methods and computer codes of safety analysis, particularly those for structural analysis and for transient analysis.
- Examination of the descriptions and safety evaluation checklists of all the modifications performed since 1983 to ensure that cumulated impacts have been correctly addressed.
- Identification of any shortfalls against current safety standards and consideration of any design weakness revealed by the existing PSA studies.

The topics and safety elements to be covered are the following:

Mechanical Analyses Review
- Reactor Vessel
- Reactor Internals
- Reactor Coolant Loop Piping and Supports
- Reactor Coolant Loop Components (Pressurizer and Pumps)
- Steam generators
- ASME Class 2 and 3 Piping and Supports (Residual Heat Removal System, Safety Injection System, Control Volume and Chemical System, Main Steam, SG Blowdown and Feedwater Systems)
- Containment Structure.

Essential Safeguard Systems and Components Performance Verification
- Emergency Core Cooling System
- Ultimate Heat Sink
- Containment Systems
- Auxiliary Feedwater System
- Chemical and Volume Control System
- Electrical Supply Support Systems
- Shutdown Support Systems

**Instrumentation and Control Assessment**
- Reactor Protection System
- Engineered Safety Feature Actuation System
- Safety Related Display Instrumentation
- ATWS Mitigation System

**Civil Structure Review**
- Seismic Design
- Category I Structures
- Wind Loading
- Water Level - Flood Design

**Review of Hazard Analyses**
- Fire Hazard Analysis
- Seismic Analysis*
- Flooding Analysis
- Other external events considered in NEK IPEEE.

**Review of Deterministic Accident Analyses**
- Design Basis Accidents
- Severe Accidents

**Probabilistic Safety Analysis***
- PSA Level 1 and 2 Analyses

**Re-evaluation of anticipated operational occurrences**

**Up-dating information on local meteorological conditions**

**Up-dating information on off-site population distribution**

*It should be noted that seismic risk is recognized as one of the relevant safety aspects of the Krško plant design. Re-evaluation of the seismic hazard is one of the important issues, which will be evaluated separately from this Safety Factor. The results of seismic hazard re-evaluation will be considered for their potential impact on existing Seismic PSA model, as a part of the scope of work described here.

### 2.2.1 Physical Plant Conditions

Specific objectives are to determine the actual physical condition of the NPP, and its surroundings. A precise and accurate description of the plant status is an important starting point for several aspects of the PSR. It includes, in particular, identification of the structures, systems and components (SSC) important to safety (to confirm the above given list of topics and safety elements to be covered), providing sufficient information on the current state of each SSC to enable comparison with the assumptions and requirements of the safety analysis review and for use in other aspects of the PSR, as well as ensuring that the description of the NPP surroundings is up to date.

**Assessment approach**

It is anticipated that ‘expert judgement’ will be required for a significant part of the review activities associated with this part of the review. A detailed knowledge of nuclear engineering is therefore essential for the responsible PSR team member(s). Access will be required to all documentation on the design, installation, commissioning and subsequent operation, testing, inspection and maintenance of the plant. Access will also be required to up-to-date information on the immediate vicinity of the NPP site. Direct visual observation of parts of the plant will be required on occasion, and permission to discuss aspects of the review with various persons from NPP staff will
also be needed. Since a major part of the review involves judgement on the adequacy of the plant information, it is planned that a high level ‘plant status sub-report’ be prepared (sub-report PSR-NEK-2.0.1 of main report PSR-NEK-2.0). The purpose of this sub-report would be to address each part of the plant, identify the relevant plant documentation, comment on the completeness and correctness of this documentation, and then identify where any additional information is required. This report will be supported by a set of individual ‘review sheets’ that record the type of review undertaken for each document, document type or set of associated documents, and the conclusions reached. These sheets would include details of checks made against other documents of the plant. The ‘plant status’ sub-report will be considered a ‘living’ document that is updated progressively as deficiencies in the plant documentation are identified and then later rectified. Particular attention will be paid to SSC ‘design’ and ‘operational’ design bases. The review will concentrate on ensuring that the functions of all SSC are adequately specified, those SSC ‘important to safety’ are appropriately identified, the physical and functional boundaries of the SSC are clear, all interactions and inter-dependencies between SSC are identified, and the way in which the SSC perform their functions is clear. Definition of plant ‘condition’ will include all aspects that are used in different parts of a PSR:
- Layout, physical construction, capabilities (from design drawings /descriptions);
- Design criteria i.e. limits and margins (from design descriptions / design calculations);
- Physical condition (from special tests and inspections);
- Performance (from functional tests, including trend information);
- Residual life (from tests, inspections and records of operational occurrences);
- Anticipated reliability (from data sources and specific operational experience);
- Anticipated maintainability (from spares situation, staff skill base, ageing impact records).

2.2.2 Safety Analysis

Specific objectives are to determine to what extent the existing safety analysis remains valid when the actual status of the plant, its predicted end-of-life state, and current analytical methods, safety standards and knowledge are taken into account. Any need to extend the analysis to address newly identified concerns will be pointed out.

Assessment approach

Very specialized knowledge will be necessary for undertaking certain aspects of the review of the safety analysis. Those members of the PSR team responsible for this task will have a sufficient breadth and depth of knowledge to address all these aspects. The existing safety report, with any amendments arising from additional analysis and/or plant modifications, will be the starting point for the review activities. Access will also be required to the up-to-date design and operational information derived from the review of the ‘actual plant conditions’, and all analyses/calculations (including computer runs) that support the safety report. It is planned that a high level ‘safety analysis status’ sub-report (sub-report PSR-NEK-2.0.2 of main report PSR-NEK-2.0) will be used as a means of capturing and recording the point-in-time view of the PSR team on the adequacy of the safety analysis. The purpose of the subreport will be to address each major aspect of the safety analysis, identify the relevant documentation, comment on (a) the completeness of the analysis, (b) the adequacy of the methods used (including analysis tools and modelling codes), and (c) the acceptability of the results, and then identify where additional work is required. This report will be supported by a set of individual ‘review sheets’ that record the type of review undertaken for each aspect of the safety analysis, discuss the relevant issues and then record the conclusions reached. The ‘safety analysis status’ report will be considered a ‘living’ document that is updated progressively as deficiencies in the analysis are identified and then later rectified.

Specific aspects of review

The review will focus on demonstrating that the existing safety analysis is comprehensive, suitably validated, reflects good practice and demonstrates that the plant is safe. In reviewing the completeness of the list of PIEs, including external and internal hazards addressed, this will be
considered in the light of the unique features of the plant, not just in comparison with a generic list or that applicable to an equivalent plant. The review is expected to verify that the safety analysis identifies all elements of the protection required in response to each PIE (from recognition of the need through to achievement of the necessary actions). Where claims are made in the safety analysis for ‘operator safety actions’, substantiation needs to be provided that the necessary control room provisions required to accomplish these actions are available to the operator and that the times assumed are sufficient. By its very nature, safety analysis includes conservatism. The review is expected to show that this is not excessive, that the methods, assumptions and data used have similar built-in conservatism, and that mutually incompatible assumptions are avoided. Sufficient sensitivity studies should have been undertaken to confirm that the various uncertainties inherent in the analysis methods, assumptions and data do not invalidate the results. In particular, the absence of ‘cliff edge’ effects should have been confirmed. For the purposes of BDBA analysis, the plant models should have been run for a wide range of potential accidents from low probability / high consequence ones through to higher probability / lower consequence ones. From these, the behavior of the plant should have been sufficiently understood to determine the ‘symptoms’ exhibited and ‘conditions’ prevailing for each type of BDBA. In addition, the plant capability should have been sufficiently understood to identify the ‘practical measures’ that can be taken, despite the accident conditions, to maintain the critical safety functions.

2.4 Operational Aspects

Specific objective is to determine whether the existing technical specifications and safety-related procedures reflect good practice, are compliant with plant design and operating experience, and are adherent to human factor principles. The related plant practices will be evaluated considering the existing procedures, provisions for their review and maintenance as well as their understanding and acceptance by the plant staff. The safety related procedures include:
- operating procedures for normal, abnormal and accident conditions, including the associated limiting conditions of operation (Technical Specifications);
- procedures for maintenance, testing and inspection activities;
- procedures for work permits issuance;
- procedures for the control of plant modifications and data amendments.

Review Elements

The plant procedures for the normal operating regime have been well established during the operating life of the plant. They are essentially the operating rules and instructions, maintenance instructions, permit to work arrangements, test methods, inspection arrangements, modification arrangements and radiation protection. The elements for this factor review should be the following:
- Formal approval and documentation of all safety related procedures
- Arrangement for regular review and maintenance of these procedures
- Formal system for modification of a procedure
- Understanding and acceptance of these procedures by management and on-site staff
- Adequacy of these procedures with respect to the good practice
- Evidence that these procedures are followed
- Clarity of procedures taking into account human factor principles
- Adherence of these procedures to good practice and human factor principles
- Compliance of these procedures with the assumptions and findings of the safety analysis, plant design and operating experience

Krško NPP PSR should demonstrate for these procedures that they are regularly reviewed and maintained as part of the normal management arrangements taking account of feedback from the NPP staff and from other NPP operators, simulator experience, new concepts and new methods. Procedures should be formally recorded with a control system for proposed changes.
Assessment Approach

The PSR team member(s) responsible for this part of the review will between them have broad knowledge of the plant design and safety case and more specific knowledge of human factor issues as well as good practice in procedure writing. In addition to the plant procedures themselves, access will be required to design and other operational documentation. Direct visual observation of parts of the plant will also be required on occasion, and permission to discuss aspects of the review with the plant staff. The review will evaluate the existing safety-related procedures taking into account the basic attributes. The procedure system will be considered effective and adequate if:
- All plant operations are covered by procedures to ensure that the associated risks are adequately controlled;
- There is a common understanding between management and the staff affected on the role of each type of procedure e.g. guidance versus prescription.
- Procedures assume a base level of staff competency to avoid excessive detail. This base level is consistent with the staff selection and training philosophy.
- Selection of the most appropriate means (e.g. type of display) to assist an operator in undertaking a task is based on operator preference, task complexity, operator familiarity with the task and the associated risks.
- Procedures include easily understood and practical means of place recognition place marking and navigation.
- Classification/indexing scheme that reflects operator's conception of plant operations is used.
- Procedures are regularly updated as necessary to reflect changes to the plant, revised safety requirements, experience feedback and changes in best practice.

The following requirements will be considered in evaluating the existing Technical Specifications:
- Operational limits and conditions should be defined for all reactor conditions including power operation, shutdown, refueling, etc.
- The extremes of the region of operating variables and conditions should be verified by conservative analysis. Demonstration is needed that operation within this region will not result in undesirable effects or unacceptable damage to the plant.
- Additional conditions shall ensure that the safety systems are either in operation or ready for use. Minimum staffing requirements shall also be laid down, particularly for the control room.

Topical Reports Related to the Operational Aspects

The review of the operational aspects will be detailed in the following topical reports, PSR-NEK-2.2, PSR-NEK-2.3 and PSR-NEK-2.4, and will be summarized in the subreport PSR-NEK-2.0.3 of the main report PSR-NEK-2.0.

2.5 Radiological Protection Systems and Procedures

The review of the radiological protection systems and procedures, will be the subject of the topical report PSR-NEK-2.5.

2.6 Probabilistic Safety Assessment

In the overall NEK PSR process there are two different aspects of use of NEK PSA study and model:
- Review of NEK PSA, its inputs and results
- NEK PSA as a tool for ranking of safety issues and prioritizing proposed compensatory measures.

PSA study and model should reflect to the extent achievable the current plant design, operating practice, history and broader context. Also, it should be generally accorded to the state of the art of methodology. These matters will be considered as a part of NEK PSR. The considerations will be documented in the topical report PSR-NEK-2.6. With respect to methodological concerns, an
overview will be made of the developments in the PSA field in the worldwide practice following the completion of NEK IPE and IPEEE. Relevant new documents concerning methodological issues, application guidelines, standards, and good practice in general that have been issued worldwide (IAEA, US NRC, industry, etc.) will be identified. NEK PSA will be reviewed for general adequacy in this context, in order to demonstrate that it is in accordance to the general state of the art and knowledge in the field. Any issues and findings with respect to this will be reported and described in topical report PSR-NEK-2.6. It is stressed here that NEK PSA has recently been used as a tool to perform Integrated Safety Assessment (ISA) of NEK modernization program. For this purpose, a major update of IPE PSA had been performed in order to make it reflect the current plant status. Living PSA program has been established and proceduralized in order to ensure periodical according of PSA model to the actual plant status. Thus, no major issue is expected to be raised with respect to the compliance of PSA to the plant status. As a part of NEK PSR, a number of reviews and evaluations will be performed that are expected to improve the general and, in some cases, specific knowledge on various hazards that NEK plant is exposed to. (As an example, one can point out the review of hazard analyses or review of deterministic accident analyses). Some of them can have an impact on PSA or its input. In these cases, Westinghouse will have to determine the impact of evaluations’ results on PSA and to specifically define the changes to be made to the PSA model. NEK will implement the changes into the model and perform re-quantification. All the changes done to the model, re-quantification runs and results with interpretation shall be documented in topical report PSR-NEK-2.6. One specific matter of concern, which is recognized as one of the relevant safety aspects of the NEK plant design, is seismic risk. As a part of NEK PSR, a re-evaluation of the seismic hazard will be performed. It is expected that it will improve the knowledge and understanding of seismic hazard at NEK. As a result, seismic hazard curves (e.g. seismic event occurrence frequency and NEK plant probabilistic seismic response spectra) produced by NEK PSR seismic hazard study can differ from those currently used in Seismic PSA. Westinghouse will have to determine an impact of new hazard curves on NEK Seismic PSA and specifically define changes to be done to the model, as necessary. For example, Westinghouse will perform any re-calculation of parameters used in the model, such as:
- frequencies of seismically-induced initiating events,
- conditional probabilities of seismically-induced failures of equipment.

The implementation of changes into the model and subsequent re-quantification will be performed by NEK. All the changes done to the model, re-quantification runs and results with interpretation shall be documented in topical report PSR-NEK-2.6. As a part of an expert review of design aspects of NEK, the results of NEK PSA studies will be considered in order to reveal potential design weaknesses and vulnerabilities. This will be documented in topical report PSR-NEK-2.1. (Some aspects can be addressed in other sections and covered by respective topical reports.)

NEK PSA model, modified accordingly to the considerations above, will be used as a tool for ranking of safety issues and prioritizing of proposed compensatory measures.

3 CONCLUSIONS

Since May 2002 (Contract between Krsko NPP and Westinghouse, as main supplier, was signed on 24th April), when this part of Krsko NPP PSR project intensively started the following subjects were successfully evaluated by interviews between plant personnel and Westinghouse experts:
- Testing and Inspections Procedures,
- Maintenance Procedures,
- Meteorology and Population,
- Modification Procedures&Processes,
- Krsko NPP Technical Specification Status, and
- Krsko PSA (Level 1 and 2)

Plant responsible engineers are currently reviewing the three preliminary topical reports: PSR-NEK-2.2.A (Operating Limits), PSR-NEK-2.2.B (Operating Procedures) and PSR-NEK-2.4
(Modification and Back-fitting Procedures). Preliminary reports already identified some minor recommendations and potential actions but generally speaking, no safety issue has been found. Project is continued according to the planned (contractual) schedule. Krsko NPP, according to good practices, sends periodically to SNSA PSR project status report (PSR-NEK-URSJV-02-001 and 002).

**Table 1**

**CONTRACTUAL SCHEDULE**

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<td>Site visit check lists</td>
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**REFERENCES**


[4] SNSA request for PSR NEK No. 390-01/00-23-26662/DL by date 11.01.2001,


[7] ADP-1.0.737, “PERIODIC SAFETY REVIEW PROJECT PROGRAM(PSR PROJECT)”, Rev.0, Krško NPP, 2001,