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# **Periodic Safety Review: Valuable Insight Tool into the Plant Safety Standards**

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# Overview

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# Introduction

Throughout the plant life-time level of safety should not be eroded but:

**HOW SAFE IS SAFE ENOUGH?**

Safety is ensured by:

- Plant design
- Processes
- People

but perception of the balance differs!

# Reasons for Changes of Plant Safety Level

- Changes in national and international safety standards, technology, underlying scientific knowledge or analytical techniques;
- Cumulative effects of plant modifications or the accessibility and usability of the safety documentation;
- Ageing effects;
- Accumulation of relevant operational experience;
- Means of how the plant is, or will be, operated;
- Management structures in plant operating organization and the regulatory body;
- Staffing levels and knowledge preservation; and
- Nearby environment (development of new facilities, objects and transportation routes).

# Objective of PSR

- Confirmation that the plant is as safe as originally intended and to determine the extent to which the licensing basis remains valid
- To demonstrate to which extent plant conforms to current national and/or international safety standards and practices;
- Demonstration of the validity of the safety documentation;
- Confirmation of adequacy of the way the plant is managed and operated.

# Goals of PSR

- Comparison of the plant against modern safety standards and assessment techniques;
- Check of adequacy and effectiveness of the measures that are in place to maintain plant safety until the next PSR or until the end of planned operation (i.e. whichever comes first);
- Determination if there are any SSC that could limit the life of the plant in the foreseeable future;
- Identification of improvements that would be beneficial at justifiable cost.

# PSR in IAEA Standards

- NS R-2 (Operation) Chapter 10

- Requirement 10.1 for Periodic Safety Review:

- “Systematic safety reassessments of the plant in accordance with the regulatory requirements shall be performed by the operating organization throughout its operational lifetime, with account taken of operating experience and significant new safety information from all relevant sources.”

- Safety Guide NS-G-2.10

- Developed to provide recommendations for conduct of PSR to utilities/operators of nuclear power plants, involved technical support organizations as well as by regulatory bodies.
  - Provides rationale and methodologies for this purpose.
  - Applicable to NPPs of any age including plants considering life time extension.

# PSR in IAEA Standards (continued)

International experience in the implementation of NS-G-2.10 indicated need for additional recommendations on:

- use of PSR as an input in assessing long term operation (LTO) aspects, e.g. the impact of ageing (mechanical and thermal fatigue),
- follow-up PSRs (i.e. 2nd, 3rd, etc.),
- management systems and safety culture,
- more detailed global assessment.

# Performing PSR

## ■ First PSR

- Information and documentation on the design basis of SSCs important to safety requires large effort to update it in accordance with actual configuration with proper justification (This effort is reduced for plants with proper configuration management)

## ■ Second or subsequent PSRs

- The effort can be considerably reduced compared to that for the first PSR;
- Focus on changes in requirements, plant conditions, operating experience and new information;
- Subsequent PSR should confirm validity of the earlier PSR (e.g. in light of the time elapsed since it was performed).

# PSR Phases

- Phase 1 Preparation of the PSR project
  - Defines the scope and timing of the review and the codes and standards that will be used (usually agreed between operating organization and regulator)
- Phase 2 Plant review and assessment
  - The operator (by itself or helped by contractor) performs the review of safety factors in accordance PSR Basis Document. This review identifies findings (which may be positive (strength) or negative (deviation))
- Phase 3 Global assessment
  - Operator proposes safety improvements and an integrated implementation plan based on the prioritization and ranking of the identified issues

# PSR Phases (Continued)

- Phase 4 Regulatory review
  - The regulator reviews the operator's PSR reports and proposed safety improvements, identifies additional regulatory issues (e.g. whether further safety improvements need to be considered), reviews the proposed integrated implementation plan and determines whether the licensing basis for the NPP remains valid
- Phase 5 Development of PSR Action Plan
  - Finalization of the integrated implementation plan – the integrated implementation plan, comprising reasonable and practicable safety improvements to timescales agreed with the regulator, is finalized and plan for the plant improvements until next PSR is developed

# Project Plan for the PSR

- Identifies all the activities to be performed for the PSR, together with associated timelines and responsibilities:
  - Organization of the project;
  - Time schedule (realistic and reasonable, including sufficient allowance for completion of reviews by the regulatory body);
  - Quality management processes;
  - Training;
  - Internal communications;
  - Plan for communications with the regulatory body.

# Documentation of PSR

Documents produced during PSR provide necessary information on the process used to carry out the PSR and the obtained results, including required safety improvements:

- Phase 1 -The basis document for the PSR;
  - ◆ the scope, major milestones, cut-off dates, methodology, safety factors, applicable standards, codes and practices;
  - ◆ process for categorizing, prioritizing and resolving findings.
- Phase 2 - Main Report, Topical (safety factor reports) and Supporting References
  - ◆ Review checklists and safety factor report(s);.
  - ◆ Internal documentation (working papers, interviews, calculation notes or analysis outputs)

# Documentation of PSR (cont.)

- Phase 3 - Global assessment report;
  - ◆ Summary of significant PSR results, prioritization and risk ranking; 'Global risk' judgment on the acceptability of continued plant operation
- Phase 4 - Review document;
  - ◆ Review of the findings from Phases 2 and 3; regulatory inputs, revision of global assessment based on regulatory inputs
- Phase 5 - PSR summary report, including the integrated implementation plan.
  - ◆ Summary of reports from Phases 2, 3 and 4
  - ◆ Implementation (action) plan for plant improvements until next PSR/End of Lifetime

# Safety Factors

- Comprehensive and systematic review of the plant safety requires consideration of all plant conditions (including accident conditions) and should be assessed against current national and applicable international safety standards and practices.
- To that aim, plant areas and relevant safety factors are identified as primary means in assuring previous requirement.
- Number of Safety Factors is country specific, (Current IAEA recommendation is 14)

# PSR Safety Areas and Safety Factors

Safety Areas	PSR Safety Factors
Plant	<ol style="list-style-type: none"> <li>1. Plant design</li> <li>2. Actual condition of systems, structures and components (SSCs)</li> <li>3. Equipment qualification</li> <li>4. Ageing</li> </ol>
Safety Analysis	<ol style="list-style-type: none"> <li>5. Deterministic safety analysis</li> <li>6. Probabilistic safety analysis</li> <li>7. Hazard analysis</li> </ol>
Performance and feedback of experience	<ol style="list-style-type: none"> <li>8. Safety performance</li> <li>9. Use of experience from other nuclear power plants and of research findings</li> </ol>
Management	<ol style="list-style-type: none"> <li>10. Organization, Management system and safety culture</li> <li>11. Procedures</li> <li>12. Human factor</li> <li>13. Emergency planning</li> </ol>
Environment	<ol style="list-style-type: none"> <li>14. Radiological impact on environment</li> </ol>

DS 426 Draft Rev. of N-SG-2.10

# The Schedule of the Review of Safety Factors

- Review of safety factors is an iterative process that requires communication between PSR teams, starting from the preparation phase of PSR throughout the review process.
- The outputs from the review of some safety factors may be relevant as inputs to the review of other safety factors:
  - The outputs from the review relating to use of experience from other plants and research findings (SF 9), can be used as early inputs to the reviews of other safety factors (except the safety factor relating to safety performance).

# Safety Factors Interface Matrix

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N-SG-2.10

*Provides input to:*

	(1) Plant Design	(2) Actual Condition Of SSC	(3) Equipment Qualification	(4) Management Of Ageing	(5) Deterministic Safety Ana	(6) Probabilistic Safety Anal	(7) Hazard Analysis	(8) Plant Safety Performanc	(9) Use Of Experience From Other Plants And Research Findings	(10a,b) Safety Management Systems And Safety Culture	(11) Plant Procedures	(12) Human Factors	(13) Emergency Planning	(14) Radiological Impact On Environment
(1) Plant Design	X	X	X	X	X	X	X	X		X	X		X	X
(2) Actual Condition Of SSC	X	X	X	X	X	X	X			X	X		X	X
(3) Equipment Qualification	X	X	X	X	X	X	X			X	X			X
(4) Management Of Ageing	X	X	X	X	X	X	X	X		X	X			
(5) Deterministic Safety Analysis	X	X	X	X	X	X	X			X	X	X	X	X
(6) Probabilistic Safety Analysis	X	X	X	X	X	X	X	X		X	X	X	X	
(7) Hazard Analysis	X	X	X		X	X	X	X		X	X	X	X	
(8) Plant Safety Performance	X	X	X	X	X	X	X	X		X	X	X		X
(9) Use Of Experience From Other Plants And Research Findings	X	X	X	X	X	X	X		X	X	X	X	X	X
(10a,b) Safety Management Systems And Safety Culture	X	X	X	X	X	X	X	X	X	X	X	X	X	X
(11) Plant Procedures	X		X	X	X	X	X	X		X	X	X	X	X
(12) Human Factors	X				X	X	X			X	X	X		
(13) Emergency Planning	X				X	X	X			X	X	X	X	
(14) Radiological Impact On The Environment	X	X	X	X	X	X	X	X		X	X	X	X	X

# Inputs to the PSR

## ■ Plant documents

- SAR, relevant studies, routine and special safety reviews, as well as activities relating to licensing, compliance or operations

## ■ Safety regulations and standards

- adequate national standards or/and international codes and standards (IAEA, ISO, IEC)
- codes and standards of a recognized organization of a particular State (ASME, Kerntechnischer Ausschuss, IEEE)
- safety standards issued by the State of origin of the technology

The selection and hierarchy of safety standards and practices to be met should be clearly stated in the PSR basis document.

## ◆ Ongoing plant programs and processes

- configuration management;
- ageing management, and
- maintenance programs

# Safety Area - Plant

## 1) Plant design

- Review of SSCs important to regarding:
  - ◆ prevention and mitigation of events (faults and hazards);
  - ◆ application of defence in depth and engineered barriers;
  - ◆ safety requirements – engineering design rules (e.g. on the dependability, robustness and capacity of SSCs);
  - ◆ design codes and standards

## 2) Actual condition of SSCs

- Verification that actual condition of SSCs meets their design requirements regarding operating history;
- Condition of SSCs is properly tested, maintained and documented,

# Safety Area – Plant (cont.)

## 3) Equipment qualification

- Capability of SSC's important to safety to perform intended safety function under postulated conditions, e.g. those imposed by various changed conditions in the plant (hazards, extreme environment conditions – seismic, high-energy line breaks etc.)
- Adequacy of plant programs, procedures, practices and records to maintain qualification of the equipment over the intended lifetime of the plant

## 4) Ageing

- Identification of relevant SSC's and degradation mechanisms
- Ageing management of all SSCs important to safety through adequate implementation of ageing management programme and procedures, including long term operation/life time extension

# Safety Area - Safety Analysis

## 5) Deterministic safety analysis

- Adequacy of PIE and inputs to the DSA including actual condition of SSC, operating modes and fuel management,
- Validation, verification and qualification of the used computer codes
- Current methods, recent experimental data

## 6) Probabilistic safety analysis

- Scope and methodologies of the PSA regarding international current standards and good practices
- Adequacy of PSA models and results regarding current plant status and coverage of operational modes

## 7) Hazard analysis

- Identification and characterization;
- Hazard-induced damage states and plant response;
- Accident sequences evaluation.

# Safety Area – Performance and Feedback of Experience

## 8) Safety performance

- Programme for recording and evaluation of operating experience,
- Technical elements of the operating experience programme, safety performance indicators, methods and protocols
- Effectiveness of the operating experience programme feedback
- Discharges of radioactive effluents, radiation doses, contamination and radiation levels;
- Generation of radioactive waste

## 9) Use of experience from other plants and research findings

- Process for assessing and implementing experience relevant to safety and arrangements for collecting data from other NPPs, non-nuclear plants and industries, and from research findings;
- Adequacy of access to international information sources;
- The effectiveness of such programs and their output;

# Safety Area – Management

## 10)a Safety management systems,

- Roles and responsibilities of the plant owners and the plant management;
- Concept, approach and the effectiveness of the integrated management system;
  - ◆ Management of plant resources, including human, financial, information, and infrastructure and work environment;
  - ◆ Operating process by which NPP makes business with due consideration of safety as the top priority;
  - ◆ Measuring, assessing and improving of the plant safety performance in the context of their effectiveness and efficiency;
  - ◆ Organizational structure of the plant
- Interfaces with the regulatory body and other external organizations;
- The plant quality assurance programme;
- The plant configuration management

# Safety Area – Management (cont.)

## 10)b Safety culture,

- Safety policy and the management;
  - ◆ The plant practices (procedures and procedural compliance, conservative decision making, systematic risk analysis, prioritization of safety issues etc;)
  - ◆ Self-assessment and the attitudes of individuals to managing, performing and assessing their work;
  - ◆ Communication on safety matters between individuals and groups at all levels of production and decision making process;
  - ◆ Proactive improvement approach;
- Organizational culture and arrangements that contribute to the continuous improvement of safety at the plant;
- Training devoted to safety culture and regular assessments of safety culture.

# Safety Area – Management (cont.)

## 11) Procedures

- Formal system and process for maintenance, modification, approval and documentation of all safety related procedures
- Review audits and evidence to determine understanding acceptance and conformation of procedures by management and on-site staff

## 12) The Human Factor

- Staffing levels, systematic and qualified staff (operating, maintenance, technical and managerial), fitness for duty;
- Man machine interface and design of the control room;
- Systematic assessment of operator actions for consistency with safety analyses (probabilistic, deterministic and hazard analyses);
- Feedback of operating experience into safety analysis and training

## 13) Emergency planning

# Safety Area – Management (cont.)

## 13) Emergency planning

- Adequacy of on-site equipment and facilities for emergencies.
- Efficiency of communications in emergency cases, in particular the interaction with organizations outside the plant.
- Status of the content and efficiency of emergency training, performed exercises and check records of experience from these exercises.
- Emergency plans and procedures and their regularly update.
- Security arrangement for emergencies.
- Review the changes in the maintenance and storage of emergency equipment, and of residential developments around the site.

# Safety Area - Environment

## 14) Radiological impact on the environment

- On-site and off-site monitoring and trending of contamination levels and radiation levels, as well as concentrations of radionuclides in air, water soil, agricultural products and animals;
- New sources of radiological impact;
- Revised release limits (if any) for effluents been recognized;
- Records of effluent releases;
- Alarm systems to respond to unplanned releases of effluents from on-site facilities;
- Publishing of appropriate data on the environmental impact of the plant.

# Results of the Safety Factor Review

## ■ Strengths and deviations

- No changes in safety standards or in the plant is relevant result and should be included in the report;
- Deviations for which no improvement is necessary or no improvement can be identified;
- Deviations for which safety improvements are necessary.

Deviations should be justified by the operating organization and agreed by the regulatory body

## ■ Safety improvements

- Urgent corrective actions to cope with immediate significant risk should be submitted to the regulatory.
- Solution to deviations including updating/or extending of plant documentation, including operating procedures

# Selected Findings - Plant

## 1) Plant design

- Replacement of the SSC (e.g. Power Operated valves susceptible to pressure locking/thermal binding, re-qualification of the PRZ instrument line in steam space)
- Upgrade of defence in depth (e.g. addition of new AC source)

## 2) Actual condition of SSCs

- New testing frequencies for SSC's
- Replacements of SSC
- Installation of additional instrumentation for monitoring the status of SSC
- New tests

# Selected Findings - Plant (cont.)

## 3) Equipment qualification

- Replacement of non-qualified equipment
- Addition of protection measures to prevent high-energy line breaks
- Relocation of SSC in another locations

## 4) Ageing

- Program, procedures, scope and measurements update
- SSC replacement
- New calculations or installation of additional measurements

# Safety Area - Safety Analysis

## 5) Deterministic safety analysis

- Consideration of new PIE (shutdown states),
- Calculation of safety margins using BEPU
- New BDBA (hydrogen distribution)

## 6) Probabilistic safety analysis

- Treatment of AM in PSA
- Shutdown PSA
- Common-cause failures
- Consideration of screened-out hazards

## 7) Hazard analysis

- Re-analysis of internal fire and flood analysis
- Floods/tsunami;
- Aircraft impact.

# Selected Findings - Performance and Feedback of Experience

## 8) Safety performance

- New training plans
- Additional monitors for discharges of radioactive effluents;
- Changes in the radioactive waste treatment and storage

## 9) Use of experience from other plants and research findings

- Low personal resources, the activity was not considered important,
- A systematic search on operational, research and other industrial events, experience and findings was not established,
- The plant management relies on plant computerized information system only, without professional analysis and guidance

# Selected Findings - Management

## 10)a Safety management systems

- Clarity of policy statement
- Control of documents, products, and records
- Safety criteria have low priority in case of the selection of suppliers. Costs have a dominant position
- Purchasing process – control on quality

## 10)b Safety culture,

- Safety culture training
- Lack of honesty in regular safety culture assessments
- Safety requirements are not incorporated in managerial rules and procedures
- Modifications of plant or corporate organization are not subjects of systematic safety analysis before their implementation..

# Selected Findings -- Management (cont.)

## 11) Procedures

- Process for development, elaboration, validation, acceptance, modification, and withdrawal of procedures inadequate
- Clarity of procedures (checked in the training) low
- Effectiveness and adequacy of procedures not checked
- Training of plant personnel in the use of specific procedures is not sufficient due to limited time.
- Operational procedures don't reflect plant modifications, or there is a delay in the process of updating of procedures.
- Missing Human Factors analysis prior to implementation of important (or new) procedures

## 12) The Human Factor

- Long-term staffing plan and individual personal "history" missing
- Plant staff don't believe that the top management respects priority of safety
- Inappropriate use of external technical resources,
- Low motivation for safety culture and decreasing level of individual satisfaction with the job at NPP.
- A limited open communication between organizational levels.

# Selected Findings - Management (cont.)

## 13) Emergency planning

- Connection and interrelation with the national emergency preparedness organizations insufficient
- Telecommunication and data communication systems not checked in appropriate conditions
- Frequency of emergency planning preparation, trainings, excercises inadequate as well as revisions and approval of the emergency preparedness plan
- Facilities and resources of emergency management inappropriate
- Action plan for accident management missing

# Selected Findings - Environment

## 14) Radiological impact on the environment

- Environmental radiation situation, impact on the environment, analysis of the data from the environmental radiation monitoring system not regularly updated
- Lack of comparison of radiological data with the benchmark
- Missing assessment of the effectiveness of environmental monitoring program
- Management and storage of low, medium, and high activity liquid and solid radioactive waste inadequate

# Global Assessment

- Performed by an interdisciplinary team with appropriate plant operation, design and safety expertise who participated in the review process.
- The level of plant safety determined by a the combined effects of all safety factors.
- Findings from the review of individual safety factors may indicate that plant safety is acceptable, however a global assessment of safety at the plant should be carried out to review their interaction with other safety factors (it is possible that a deviation in one safety factor can be compensated for by a strength in another safety factor).

## Global Assessment (cont.)

- The global assessment provides a justification for any shortcomings that cannot be reasonably and practicably corrected.
- The global assessment takes into account all the strengths and/or deviations of the nuclear power plant and the corrective actions and/or safety improvements proposed.
- The risks associated with any unresolved shortcomings should be assessed and an appropriate justification for continued operation should be provided.

# Categorization and Prioritization

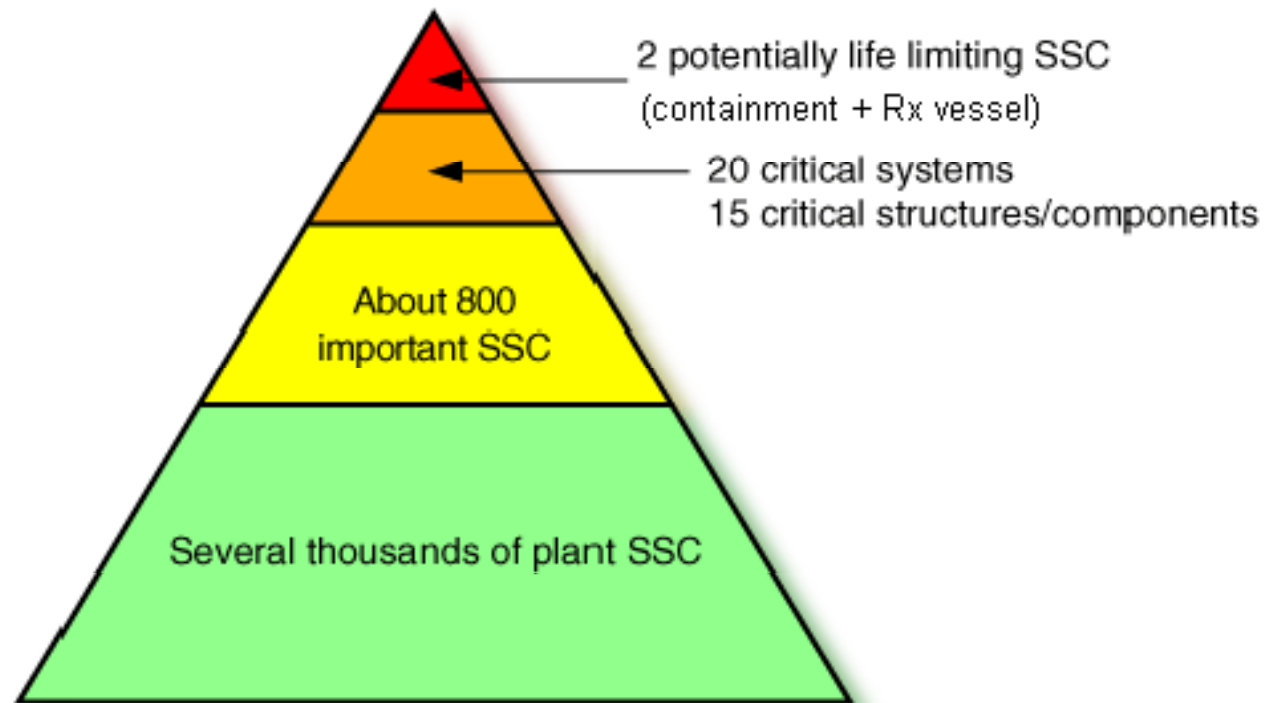
- The categorization and prioritization of safety improvements may be performed on the basis of PSA considering deterministic analyses,, engineering judgement, etc.
- These safety improvements, along with safety improvements resulting from the global assessment, should be included in the integrated implementation plan.

# Experience from NPP Krsko PSR

- NPP Krsko – 2-loop Westinghouse PWR licensed until 2023
- Required by regulatory after SG replacement and power uprate although licensing of the modernized plant has been granted
- Performed by subcontractors and the plant in three phases:
  - Phase 1: Preparation of Detailed 10-years PSR Program
  - Phase 2: Performing of 10-years PSR Program and preparing of associated documents (2001-2003), and
  - Phase 3: Implementation of the prioritized compensatory measures and modifications after agreement with the SNSA on the design, procedures and time-scales (2004-2010).

# Scope and Goals of Krsko PSR

**To demonstrate that the plant is as safe as originally intended;**  
**To evaluate the actual plant status** with respect to ageing 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;



# Review and Prioritisation Process

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
<b>Total</b>		<b>346</b>

# Review and Prioritisation Process

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
	<b>Total</b>	122

- Identified space for improvement of plant practices/processes
- No major safety issue has been found

# Lessons Learned from Krsko PSR

- A comparison with modern safety regulations is necessary, but broader prospective of weak points are identified with PSA.
- Advances in safety assessment methodologies and analysis techniques should be systematically addressed.
- Issue prioritization process is needed to decide what actually should be done.
- A review of operational points (organisation, documentation, safety culture, training) is important and is an essential part of the safety upgrading.
- Plant organization must acquire sufficient knowledge to understand and control design and licensing bases.

# Personal Feedback from 1st PSR

- Local subcontractors involved only at the very beginning and the concluding part of the 1st PSR (more integrated approach needed)
- 1st PSR mostly performed by subcontractor companies, resolution of the PSR issues mostly performed within the plant with the support of subcontractors (not the same that did PSR) - (sometimes missing link during issue resolution)



## QUESTION

Is it efficient to spend time and money for a PSR?

# Benefits of PSR

## Benefits of PSR for the licensee

- Demonstration of overall safety and conformance with the requirements (both for the authorities and public)
- Identification of the safety issues and measures to be taken
- Prioritisation of the measures
- Enhancing the knowledge of the personal and TSO involved into the PSR
- Control of validity of plant documentation
- Opportunity to preserve knowledge through involvement of the new plant/regulatory staff

## Benefits of PSR for the regulator

- Provision for the interactive assessment of plant safety
- Assurance that the plant safety is ensured for the next PSR period

# Conclusions

- Since 1994 PSRs have been considered an effective way to obtain an overall view of actual plant safety, to determine reasonable and practical modifications that should be made in order to maintain a high level of safety.
- PSRs can be used as a mean to identify time limiting features of the plant in order to determine the NPP operation beyond the designed lifetime. The Periodic Safety Review process can be used to support the decision making process for long term operation or licence renewal.
- PSR is a good method for reviewing the overall safety of operational NPPs in a systematic and comprehensive manner. However the PSR is normally carried out once in a 10-year period and cannot substitute other regulatory and plant routines or occasional reviews.

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Thank you for your attention!