INTRODUCTION

In the past, routine safety reviews and special safety reviews were the primary means of the normal safety oversight process.

These reviews were often tied to license requirements: periodic license renewals (2, 3 years) and justifications for restart after normal scheduled plant outages.

Now, in most countries a PSR is either required by law or strongly encouraged by the Regulator Authority, in order to deliver a re-licensure for a NPP after a minimum 10 years of operation.

The PSR is a systematic reassessment of a nuclear power plant safety carried out at regular intervals to deal with the cumulative effects of ageing, modifications, operating experience, technical developments and siting aspects, and is aimed at ensuring a high level of safety throughout the operating lifetime of the plant.

The PSR concept was developed to review the design and current plant status against: significant developments in Safety Standards, Design Standards, Operating practices, Technology, Analytical methods and Scientific and technical knowledge; the need to review cumulative effects of plant modifications and ageing mechanisms and possibility of significant staffing changes of both NPP and regulatory organization (CNCAN) in Romania.

BUT WHY WE DO A PSR?

The PSR is 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 and to improve the safety of older nuclear power plants to a level approaching that of the advanced plants.

Also, PSR resulted from the commitment made to the European Union, the Romanian Regulator Authority (CNCAN) and the standards of the IAEA.

INTERNATIONAL AND NATIONAL REQUIREMENTS APPLICABLE TO PSR

The international requirements applicable to PSR were defined by IAEA and WENRA in the following documents:

- IAEA NS-G-2.10 “Periodic Safety Review of NPPs”, issued in 2003;
- “Harmonization of Reactor Safety in WENRA countries” issued in Jan 2006.

The Romanian requirements for PSR are defined by CNCAN Regulatory Norm NSN–10“Norme privind Revizuirea Periodică a Securității Nucleare pentru Centralele Nuclearoelectrice” issued in May 2006; this norm reflects the requirements of IAEA and WENRA.

PSR STRUCTURE AND METODOLOGY

The IAEA NS-G-2.10 “Periodic Safety Review of NPPs, 2003” defines 14 PSR safety factors which have been selected on the basis of States’ experience. These 14 safety factors are divided into five subject areas to facilitate the review and are presented in Fig. 1.

![Fig.1 – IAEA Safety Factors](image_url)

The approach used in Cernavoda NPP Unit 1 PSR Project will be shortly presented below in order to exemplify PSR structure, methodology and the manner to cover these IAEA Safety Factors.

The Cernavoda NPP Unit 1 is a CANDU 6 (CANada Deuterium Uranium) reactor, designed by AECL (Atomic Energy of Canada Ltd), and situated on a Danube channel. The reactor was commissioned in December 1996 (Fig.2 below).
The characteristics of a CANDU reactor are:

- heavy water (D2O) for moderator and coolant
- separate low pressure moderator and high pressure fuel cooling systems
- on-power refueling
- reactivity devices that are located in the cool low pressure moderator, and not subjected to high temperatures or pressures
- natural uranium fuel or other low fissile content fuel
- reduced consequences from accidental reactivity fluctuations — excess reactivity available from the fuel is small and the relatively long lifetime of prompt neutrons in the reactor precludes rapid changes in power levels
- two fully capable safety shutdown systems, independent from each other and the reactor regulating system.

The **PSR flow chart of the overall process**, as per IAEA NS-G-2.10 “Periodic Safety Review of NPPs, is illustrated in Fig.3 below.

**PSR PHASE 1**

The **Phase 1** consists of preparation of:

- documentation which establish the PSR scope and objectives;
- PSR schedule;
- List of all PSR documents which will be produced in Phase 2;
- The Nuclear Safety Assessment Principles (NSAPs) document.

**NSAPs**

The **NSAPs** document is developed:

- to provide a set of assessment criteria for the PSR which will enable the safety of Cernavoda to be evaluated in a consistent manner;
- to provide guidance on the evaluation of gaps between plant design and licensing basis, or plant design and current standards, determinations of whether those gaps form deficiencies, subsequent ranking of any deficiencies by their safety significance.

These criteria must be appropriate for the CANDU design and for a plant designed to earlier plant design and safety standards.

The NSAPs Structure is the following:

**NSAP 1 – Overall Aspects** - is an overriding principle which identifies the key factors which must be taken on board as part of any review of safety. It introduces the other principles and clearly states the requirements to apply all of those principles NSAP 2 – 5 for the PSR.

**NSAP 2 - Operational Safety** - covers review of normal operational safety, operating organisation, procedures, safety management systems and radiological protection.
NSAP 3 - Defence in Depth (Deterministic Assessment) - gives the structure for the basic assessment of defence in depth provision against the risk of a radiological hazard to the public for the five defence-in-depth levels:

- **Prevention** - of abnormal operation and systems failures;
- **Control** - of abnormal operation and systems failures;
- **Protection** - control of accidents within the design basis (prevention of significant core damage);
- **On-site mitigation** - control of severe plant conditions, including prevention of accident progression, and the mitigation of the consequences of severe accidents;
- **Off-site accident measures** - mitigation of the radiological consequences of significant releases of radioactive materials.

NSAP 4 - Engineering Functionality - provides for the engineering assessment of the functional capability for SSCs claimed under NSAP 3 and NSAP 5.

NSAP 5 - Probabilistic Limits and Goals - covers PSA methods, and all probabilistic limits and goals.

The NSAPs have two main purposes: as a SCREENING tool to identify those deficiencies against current international standards which should be considered as significant to nuclear safety, and therefore need to be raised as PSR Findings and as a CATEGORISATION tool to rank the PSR Findings by their safety significance.

PSR Findings Categorisation:

- **Class A = HIGH Safety Importance** - these are serious, currently applicable safety issues, and licence compliance issues. These required the following actions: immediately notify NPP of the PSR Finding for confirmation of the classification, report the PSR Finding in accordance with the existing NPP procedure, and implement some form of immediate remedial action.

- **Class B = MEDIUM Safety Importance** - these are significant safety issues, that are currently applicable or could apply in the next 10 years. These required the following actions: notify of the PSR Finding for confirmation of the classification, commit to complete Corrective Action either by PSR decision date where reasonably practicable, or to an agreed program (unless shown not to be justified by an ALARA review) and tabulate in relevant PSR Main Chapters (2, 3&4) and in the Summary Report (Chapter 1).

- **Class C = LOW Safety Importance** - these are minor safety issues where the current position is acceptable, however some form of corrective action to enhance safety is recommended in the longer term (unless shown to be not justified by an ALARA review). These required the following actions: notify of the PSR Finding for confirmation of the classification, include corrective actions in forward program and tabulate in relevant PSR Main Chapters (2, 3&4) and in the Summary Report (Chapter 1).

- **Class O = Observations of No Safety Importance** - these are not PSR Findings and so no remedial action is required. However, all such observations should be recorded for completeness and passed to the responsible manager within Cernavoda NPP.

NSAPs address the radiological risk posed to the general public, members of staff at the plant, and to the environment from the operation of Cernavoda, arising from:

- **Normal Operation of the plant**
- **Abnormal Events and Anticipated Operational Occurrences expected during the lifetime of the plant (Design Basis Initiating events or external events which could lead to the potential for damage of the fuel and possible radiological release to the environment)**;
- **Beyond Design Basis Accident Conditions leading to potential for severe core damage and large off-site radiological release**.

NSAPs apply to all aspects of the plant design, operation and supporting analysis, which are credited in order to limit the radiological risk to the public:

- **Plant Operation** (Operation and Safety Performance) - all normal, accident and severe accident management procedures, emergency plans, safety management features and programmes which contribute to managing radiological risk;
- **Plant Design** (Systems Structures and Components) - reactor and balance of plant systems, structures and components and all engineered safety features. Radiological risk from the fuel route, fuel handling and fuel storage facilities within the reactor building;
- **Plant Safety Analysis** - all deterministic, probabilistic and hazard analysis that are used in support of the nuclear safety case.

PSR PHASE 2

The Phase 2 implies the production of all PSR documentation; these will be structured in order to cover the IAEA Safety Factors defined in IAEA NS-G-2.10 (Fig. 1).
The approach used in Cernavoda NPP Unit 1 PSR Project to cover IAEA Safety Factors defined in IAEA NS-G-2.10 is:

- The safety overview of civil, mechanical, electrical and instrumentation design, equipment qualification and ageing, including assessment of new codes and standards implications is covered in 6 Discipline Reports (DRs);
- The specific safety review of:
  - Operation history and procedures (normal and abnormal), safety management, radioprotection, chemical control and emergency planning is reflected in 7 Topic Reports (TRs) series 2;
  - Structures, Systems & Components status (including safety design basis, equipment qualification, operation, ageing) is reflected in 29 Topic Reports series 3;
  - Safety Analyses (deterministic, probabilistic and external & internal hazards) is reflected in 3 Topic Reports series 4;
- The global assessment report consists in 3 Main Chapters Reports, one for each Topic Report Series, and a Summary Report. The Summary Report includes the PSR findings/issues resulted during PSR process and the resulted plant Corrective Actions Plan.

The first stage of the Phase 2 of the Cernavoda PSR project was the development of Evaluation Guides, defining the scope, content and boundaries for each Discipline Reports and Topic Reports. Phase 2 flowchart is presented in Fig. 4.

Evaluation Guides are developed to make sure there are no overlaps or gaps between reports. For each PSR report, the associated Evaluation Guides will define: the boundary of the topic area, the interfacing and related PSR documents, definition of all the activities required, the input data needed for the review and the national and international codes and standards to be used for that topic.

Discipline Reports (DRs) are developed to an initial review of generic issues, which are relevant to most of the Systems Structures and Components (SSCs) within the plant, to covers mainly the review against National and International current standards, plus overview of plant operational experience in that discipline area.

Fig.4 – PSR Phases 2 flowchart

The DRs objectives are:
- Identification of existing standards used in construction of Cernavoda Unit 1;
- Identification of current national and international standards;
- Assessment of changes in standards, and the impact these newer changes may have on the original safety report (FSAR) and the supporting design and safety analysis;
- Overview of plant operational experience (Cernavoda and other) in that “discipline” area
- Assessment of any issues arising from plant operational experience and from other plants.

Gaps and shortcomings identified during this overview are:
- Clarification Items with comments on their impact, and an indication of the systems and hence Topic Reports that the issues impact which will be considered by the Topic Report series 3 authors;
- Preliminary DR Issues which are applicable for all Topic Reports will be categorized as per NSAPs and will be considered in the Consolidated PSR Finding List and the Main Chapters.

Topic Reports (TRs) are developed in order to do a specific safety review of the NPP.

The TRs objective is to validate the existing Safety Case for the specifically related Systems by comparison of the scope, approach, methodologies and standards specified during design, construction, commissioning and subsequent modification against modern standards, developments and operational and international experience.

The purpose of the TRs is to review the design, operating/maintenance history and plant
condition of Systems against current standards in order to identify the gaps and deficiencies that can affect the safety role of the system for the next 10 years within the existing safety case and report them as preliminary safety issues.

The TRs also cover the Clarification items raised from DRs.

The TRs are divided in three main areas based on the structure of the NPP original safety report (FSAR):


*Fig. 5 – Topic Report Series 3 Structure*

**Topic Reports Series 4 - Safety Analysis** includes 3 review reports of Deterministic Analysis, Probabilistic Analysis and External & Internal Hazards.

The gaps and shortcomings, **Preliminary TR Issues**, raised from TRs in Topic Report Appendices A, B and C. These are the gaps found from:

- the review of specific system plant design and current plant state against the safety case and supporting documentation, using **DR Clarification Items** from Appendix A of the DRs as an input, as well as a detailed review of the system’s specific design documentation (recorded in Appendix A of the TR);
- the review of the impact of changes in standards for that system/topic using the **DR Clarification Items** in Appendix B of the DRs as an input (recorded in Appendix B of the TR);
- the review against system specific OPEX, using **DR Clarification Items** from the DRs as an input, as well as a detailed review of the system specific operation history (recorded in Appendix C of the TR).

These **Preliminary TR Issues** are subsequently screened out, with some being retained as additional PSR observations, and the remainder being categorised as **Interim PSR Findings**. These are the PSR “**Preliminary TR Issues**” which are identified as having nuclear safety implications and are classified as Class A, Class B or Class C using the Nuclear Safety Assessment Principles. A full justification will be provided for the screening and classification process.

Also in a handful of cases **Interim PSR Findings** may be raised directly from **DR Clarification Items**

*Note: Interim PSR Findings* which are designated as Class A will be raised to Station management attention and, if accepted, notified to CNCAN, through the Abnormal Condition Report process.

**CONSOLIDATED PSR FINDINGS LIST AND MAIN CHAPTERS**

During the process of developing the review, **Interim PSR Findings** from all Reports (DRs and TRs) will be collated onto a single spreadsheet, to be issued as a PSR document- **Consolidated PSR Finding List**. This document will be regularly updated and issued to NPP to confirm their acceptance of Consolidated PSR Finding, classification and to act as the basis of Corrective Action planning where appropriate.

Then, as each **Main Chapter 2, 3 and 4** (one for each Topic Report Series) is prepared there will be a **Consolidation Exercise**, to remove duplicate PSR Findings. As part of this Main Chapters preparation, the inclusion of PSR Findings and their classification will be finally confirmed. Where changes are made, the associated Topic Reports will be revised to ensure consistency.

The methodology used to develop Consolidated PSR Findings List and Main Chapters preparation is presented in Fig.6.
Only when Consolidated PSR Findings are developed will they be finally endorsed by station management and disclosed to the regulator, as part of the issue of the Main Chapter 1 – Summary Report, with the exception of the Class A Findings which already have been reviewed through the station Abnormal Condition Report process.

**PSR PHASE 3**

The PSR Phase 3 – The integrated Program of Corrective Actions and/or safety improvements is presented in Fig.7 below.

This phase implies to address PSR Findings and feedback from Regulator Authority, in order to prepare the detailed proposals for the implementation of corrective actions and/or safety improvements; these proposals should be prepared after receiving the feedback from the Regulator Authority on the submitted reports. This should include the outcome of discussions with the Regulator Authority regarding the scope and adequacy of the outline proposals of corrective actions and/or safety improvements.

In addition, the corrective actions and/or safety improvements should be prioritized. Different approaches exist for the prioritization of corrective actions and/or safety improvements on the basis of deterministic analyses, PSA and engineering judgment.

The Corrective Action judged to be required following application of the NSAPs will be one of the following types, or a combination there of:

- **Type 1** - Changes to operational practice, including procedures, practices, maintenance programmes or emergency and accident procedures;
- **Type 2** - Additional of enhanced safety analysis;
- **Type 3** - New inspection or monitoring regimes;
- **Type 4** - Physical modification to the Plant.

Preparation of an integrated implementation plan for the corrective actions and/or safety improvements that will takes into account possible interactions between individual corrective actions and/or safety improvements, including appropriate configuration control.

The integrated implementation plan should specify the schedules and resources needed. If the operator identifies a corrective action or safety improvement that provides significant safety benefit and is judged to be reasonably practicable, implementation should not await the completion of the PSR.

The aim is to complete as many of the corrective actions and/or safety improvements as is practicable within the time frame of a PSR; however, it is recognized that implementation of some corrective actions and/or safety improvements may require a longer time.

**Fig.7 – PSR Phase 3 flowchart**

Preparation of the Main Chapter 1 - Summary Report; this summary will presents the significant PSR results and the integrated implementation plan for the corrective actions and/or safety improvements.
The integrated implementation plan of corrective actions and/or safety improvements and the summary report should be subject to approval by the plant operating organization, who should commit the necessary human and financial resources to implement the planned corrective actions and/or safety improvements according to a reasonable schedule.

These approved documents should then be submitted to the Regulator Authority for review and final decision in accordance with national requirements and nuclear law. The approval of these documents represents the End point of PSR (see fig.2).

POST-REVIEW ACTIVITIES

The program of Corrective Actions and/or safety improvements implementation: safety is enhanced by implementing the corrective actions and/or safety improvements. Therefore, it is essential that both the operating organization and the Regulator Authority maintain adequate arrangements to ensure the timely completion of a committed plan of corrective actions and/or safety improvements.

Documentation from the PSR should be stored in a suitable system with sufficient detail to allow easy retrieval and interrogation, by both the operating organization and the Regulator Authority. The documentation should contain the last accepted version of the PSR documentation and information on lessons learned from the PSR.

Updating of plant documentation: the PSR and associated corrective actions and/or safety improvements will invariably necessitate changes to plant documentation. Therefore, the plant operating organization should update all plant documentation including, for example, the safety analysis report, operating and maintenance procedures and training materials to reflect the outcomes of the PSR.

Reporting PSR results: the operating organization and/or the Regulator Authority should report the outcomes to the government and the public in accordance with national legal requirements, custom and practice. The reporting arrangements required under international conventions will also apply.

CONCLUSION

The operating organization has prime responsibility for performing the PSR. The requirements for the PSR are specified by the National Regulator Authority and international Authorities (IAEA and WENRA) and agreed upon with the Regulator Authority before the start of the review. These requirements include clear statements of applicable safety goals, safety standards and the plant design basis.

These constitute a reference level for the review and would normally remain unchanged for the duration of the PSR.

Each safety factor is reviewed using current methods and the findings are assessed against current safety standards and practices. Reasonable and practicable corrective actions and/or safety improvements are determined and an implementation plan is agreed, with account taken of the interactions and overlaps between safety factors and hence of the effects of the corrective actions and/or safety improvements on all safety factors.

A global assessment report is prepared that presents significant PSR results (including plant strengths), the integrated implementation plan for corrective actions and/or safety improvements, and a ‘global risk’ judgment on the acceptability of continued plant operation with any shortcomings remaining after all corrective actions and/or safety improvements have been implemented. Interactions between safety factors, individual shortcomings and corrective actions and/or safety improvements, including compensatory measures, are considered in assessing the overall plant safety.

The global assessment should show to what extent the safety requirements of the defense in depth concept are fulfilled, in particular for the basic safety functions of reactivity control, fuel cooling and the confinement of radioactive material.

Although the PSR determines the divergences of the plant from current safety standards and practices for individual safety factors, the level of plant safety is determined by a global assessment which reflects the combined effects of all safety factors. Although shortcomings may be individually acceptable, their combined effect should also be reviewed for acceptability, by means of PSA where appropriate. It is also possible that a weakness in one safety factor can be compensated for by a strength in another safety factor. The review determine the status of each safety factor at the time of the PSR and whether the established operating regime will in future be capable of identifying and preventing or mitigating potential failures before they could cause a radiological incident. Age related degradation mechanisms that could lead to failures of key SSCs of the nuclear power plant and that could potentially limit the plant operating lifetime should be identified to the extent possible.

The PSR is now established internationally as a key regulatory instrument for maintaining the safety of the NPP until the next PSR.