DEVELOPMENT OF A RISK-INFORMED SAFETY MANAGEMENT SYSTEM AT THE GENTILLY-2 NUCLEAR GENERATING STATION

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Abstract

The paper presents an overview regarding current and future activities related to the management of safety and regulatory framework at the Gentilly-2 Nuclear Generating Station. The paper discusses alignment of these activities with the best Canadian and international practices. It also proposes manners to develop a consistent risk-informed safety management system**.** The paper takes particularly into consideration the impact of this new framework on the refurbishment project, and the operations after the refurbishment of the station.

Key words: Risk-Informed Safety Management, Regulatory Framework

1. Introduction

The regulatory framework is changing in Canada. Several activities and initiatives introduced by both the industry and the CNSC are discussed or being implemented. Changes relate both to new regulatory documents recently introduced or being introduced into license for nuclear power reactors and to the clarification of the licensing basis for safety and regulatory oversight. The latter includes the recognition that changes (to processes, organization, to the physical plant or to regulatory documents) are necessary and must be allowed to occur without imposing unjustified burden on plant operation and regulatory control and monitoring.

Specific initiatives such as Risk-Informed Decision-Making (RIDM), new Licensing Basis for Nuclear Power Reactors, Risk-Informed-In-Service-Inspections (RI-ISI), and Periodic Safety Review (PSR) have a significant impact on the way nuclear power plants in Canada operate, and comply with various regulatory requirements.

On the other hand, preventive and corrective maintenance and in-service inspections essential to safe and economic operation lead, in the context of plant ageing, new regulatory expectations and OPEX, to considerable efforts. Unit price energy and utility governance require that proper maintenance and inspection be realized at the right time on the right equipment using the right methods.

Moreover, Canadian Nuclear Power Industry functions within an international framework, which includes essentially collaboration and alignment with WANO and IAEA orientations including works performed by EPRI. It also comprises reviews of new activities/initiatives in other national regulations, in particular in the U.S.A., United Kingdom, France, Sweden, Finland etc.

The above activities/initiatives significantly impact on the Gentilly-2 Nuclear Generating Station operations. They are especially important within the context of the refurbishment of the station where they lead to implementation of significant changes to the plant. Risk informed decision making constitutes a key element for the realization of the target unit cost for the second life cycle of the plant operation.

The paper aims at presenting an overview upon current and future activities/regulatory framework at Gentilly-2 and their alignment with the best Canadian and international practices including ways to develop a consistent risk-informed safety management system**.**

2. Current and future industry activities/regulatory framework related to safety management activity

This section outlines both Canadian and international activities and regulatory structure already in place or under development, which will or may significantly impact course of future actions at Gentilly-2.

2.1 Activities and regulatory framework in Canada

The following activities and changes in the regulatory framework in Canada will influence activities at G-2.

- *Reliability Program and Standard S-98*

  The S-98 Standard was already included as a condition into the G-2 Power Reactor Operating License (PROL) in 2006. It introduces for the first time the notion of Systems Important to Safety (SIS), which include Special Safety Systems (SSS) and a part of Systems Related to Safety (SRS). S-98 requires determining Reliability Targets, and elaborating an adequate Maintenance and Surveillance program for the SIS. The importance of S-98 resides in the change of the whole safety philosophy of CANDU which was based on a concept of SSS and SRS. All the activities at the stations, their prioritization and corrective actions were based on this conception. Introducing the SIS requires some changes in organization in order to reflect this new context.

- *Probabilistic Safety Assessment (PSA) and S-294*

  The S-294 Standard was already included as a condition into the G-2 PROL in 2006. Its impact may be summarized as follows:

  - Since the G-2 SIS have been identified without using a PSA, finalizing this list would require an input from the site specific PSA.
  - It should be narrowly linked to the operational practices including Emergency Operating Procedures and Operating Procedures, maintenance and surveillance activities, permanent or temporary design changes and safety testing (particularly of the SIS).
  - Configuration management
  - Follow up of Initiating Event frequencies
  - Maintenance of a site specific Reliability Database
  - The PSA use in Risk-Informed Decision-Making at G-2.

- *Safety Analysis and RD-310*

  This standard is not presently a condition in the G-2 PROL. It sets out the requirements related to safety analysis, including the selection of events to be analyzed, acceptance criteria, safety analysis methods, and safety analysis documentation and review. RD-310 introduces a regulation based on the frequency of initiating events including Anticipated Operational Occurrences (AOO), Design Basis Accidents (DBA) and Beyond Design Basis Accidents (BDBA) defining their numerical values. The standard also states that credible common-cause events shall also be classified within the AOO, DBA and BDBA classes.

  The impact of RD-310 is anticipated in manner how to perform safety analysis, and consequently a potential impact of the site specific PSA.

- *Maintenance Program and S-210*

  S-210 is still not included in the G-2 PROL. Its purpose is to set out the expectations of the CNSC with regard to maintenance program requirements that nuclear power plant licensees shall implement. The range of maintenance activities includes monitoring, inspecting, testing, assessing, calibrating, servicing, overhauling, repairing, and replacement of parts. The type of maintenance activity and frequency applied to each system, structure and component (SSC) shall be commensurate with importance to safety, design function and required performance. This document is narrowly linked to S-98 but it appears that there is need for establishing some more consistency between two standards.

- *Life Extension of Nuclear Power Plants and RD-360*

  The purpose of this regulatory document is to inform licensees about the steps and phases to consider when undertaking a project to extend the life of a nuclear power plant. Since G-2 is to realize its refurbishment project starting in 2011, this document has a major impact on the overall organization of the whole work related to this activity.

  The document describes the following aspects:

  - Major elements to be taken into consideration while defining the scope of a refurbishment project.
  - Consideration to be accounted for while planning and realizing a refurbishment project.

- *Severe Accidents Management and G-306*

  The purpose of this regulatory guide is to help a person who applies for, or holds, a licence to construct or operate a nuclear reactor to develop and implement a "severe accident management (SAM) program," in accordance with the *Nuclear Safety and Control Act* (NSCA). The document introduces the following elements:

  - SAM goals and principles
  - Risk assessment, accident analysis
  - Preventive and mitigating actions
  - Evaluation of systems and equipment

- Assessment of material and resources
- SAM procedures and guidelines
- Information needs, personal training
- Organizational responsibilities and interfaces, communication interfaces

The work on this topic will require an inter-linkage with S-98, S-294, RD-310 and S-210.

- *Risk-Informed Decision-Making (RIDM)*

  Risk-informed decision making involves integration of probabilistic, deterministic and non-quantifiable elements such that, overall, the decisions made lead to a resolution of the issue being considered that is commensurate with its risk-significance and is superior to that likely to be reached if any approach is used in isolation. It also introduces a systematic use of both professional judgment and cost/benefit analysis. Probabilistic Safety Assessment (PSA) becomes very important element of the whole RIDM.

  The industry and CNSC have worked since 2004 on developing its own RIDM processes. This orientation to RIDM is aligned with the best international practices. COG has published the industry RIDM principles and process [4]. The CNSC continued the development of its RIDM process, and its last revision was published in December 2008 [2]. Both processes are based on the CSA Standard Q850 on Risk Management [1].

  A joint Industry/CNSC Working group is presently using the CNSC RIDM process in addressing Category 3 Safety Issues for CANDU, which also includes the problem of Large Break LOCA and void reactivity. The latest topic is analyzed in cooperation with LBLOCA Working Group. This activity is sponsored by CNUEF/CNSC Executive Forum.

  However, the use of RIDM in Canada is intended to go beyond works on Category 3 Safety Issues only. As international experience shows, this process has a significant potential of reaching high safety standards through an efficient use of available resources. G-2 is also aiming at developing a RIDM process adapted to its specific context.

- *Safety Operating Envelope (SOE)*

  Elaborating a Safety Operating Envelope (SOE) is a HQ commitment, and it is under work. The SOE parameters have to be measurable and controllable by operator. Safety limits and margins required to trigger a recovery action have to be directly linked to safety analyses and documented per system. The later shall have defined boundaries based on credited safety functions and basic assumptions used in safety analyses. This activity has direct linkage to RD-310, S-98, S-294, and RIDM. Other activities are also more or less linked to SOE.

- *Licensing Basis for Power Reactors*

  Both the Industry and CNSC are working on identifying a clear licensing basis, which is compliant with the legal requirements, and provides notification of changes to the regulator that are risk important. The licensing basis consists of the legal requirements that must be met to license a nuclear facility in Canada.

For a specific facility the licensing basis includes the information recorded in the license application, the safety case, the design basis, the issued license and any subsequent changes made to licensee documents in accordance with an agreed control processes.

This work is defining documents/process type and the level of control. Apart regulatory requirements, it is also using RIDM. The outcome of this effort will have a significant impact on the overall G-2 operations and management.

- *Plant maintenance Optimization (PMO)*

As mentioned above, unit price energy and utility governance require that proper maintenance and inspection be realized at the right time on the right equipment using the right methods. It means that the maintenance should be focused on critical equipment and components. The maintenance strategy should be adapted to address the most important degradation mechanisms on critical equipment and components.

PMO implementation at G-2 is initiated as a result of both findings from the project related to planned outage extension from 12 to 18 or 24 months, and the implementation of the S-98 Standard. The former activity demonstrated that the preventive maintenance has to be optimized since maintenance tasks performed at outage change their frequency and thus will affect equipment reliability. The latter activity required development of an adequate maintenance program for Systems Important to Safety (SIS).

The approach used in achieving this goal at G-2 is based on principles of WANO/INPO AP-913 Equipment Reliability Process, which represents the best industry practice. The outcomes of a major project undertaken in implementing PMO will significantly affect other activities at the plant including S-98, S-294, S-210, RI-ISI, etc.

- *Risk-Informed-In-Service-Inspections (RI-ISI)*

Both the Industry and CNSC have undertaken works in defining a framework related to Risk-Informed-In-Service-Inspections (RI-ISI). This activity aligns with the best international practices in this field. The objective of a RI-ISI program is to provide ongoing improvements in the overall plant safety, measured by risk, together with reduced doses to the personnel involved.

The CNSC has issued a draft document on RI-ISI [3]. This document addresses the expectations related to developing, monitoring, and updating RI-ISI programs for piping at nuclear power plants (NPPs). The industry has created a RI-ISI Working Group that jointly works with the CNSC in defining final attributes of this process. There are narrow links between RI-ISI and S-98, S-294, S-210 and RIDM.

2.2 Activities of importance at the international stage

- *Periodic Safety Review (PSR)*

IAEA has issued a safety guide on periodic safety review [6]. The purpose of this document is to provide recommendations and guidance on the conduct of a PSR for an existing nuclear power plant. A PSR is a comprehensive safety review of all important aspects of safety, carried out at regular intervals, typically of ten years. PSRs are 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 modern plants. In this connection, it is useful to identify any lifetime limiting features of the plant in order to help evaluate whether a proposed modification is worthwhile.

The objective of a PSR is to determine by means of a comprehensive assessment of an existing nuclear power plant: the extent to which the plant conforms to current international safety standards and practices; the extent to which the licensing basis remains valid; the adequacy of the arrangements that are in place to maintain plant safety until the next PSR or the end of plant lifetime; and the safety improvements to be implemented to resolve the safety issues that have been identified. The PSRs concept introduces 14 performance indicators.

The CNSC considers PSR as one of basic elements of a new licensing basis. As such, it will also have a significant impact on G-2 operations and management.

- *WANO/INPO AP processes, EPRI*

WANO/INPO has developed a series of AP processes aimed at holistically integrate all plant's activities in order to ensure high safety levels at an efficient manner [5]. Figure 1 depicts relationship between main AP documents. Those processes have been supported by numerous EPRI references, including Risk-Informed Asset Management (RIAM), RIDM, Equipment Reliability, Preventive Maintenance etc.

Such activities and orientation will have an impact on planning and organizing operation and processes at G-2. Works on implementation of AP-913 and AP-928 are undergoing. They also have links to S-98, S-294, S-210, RIDM, RI-ISI at G-2.

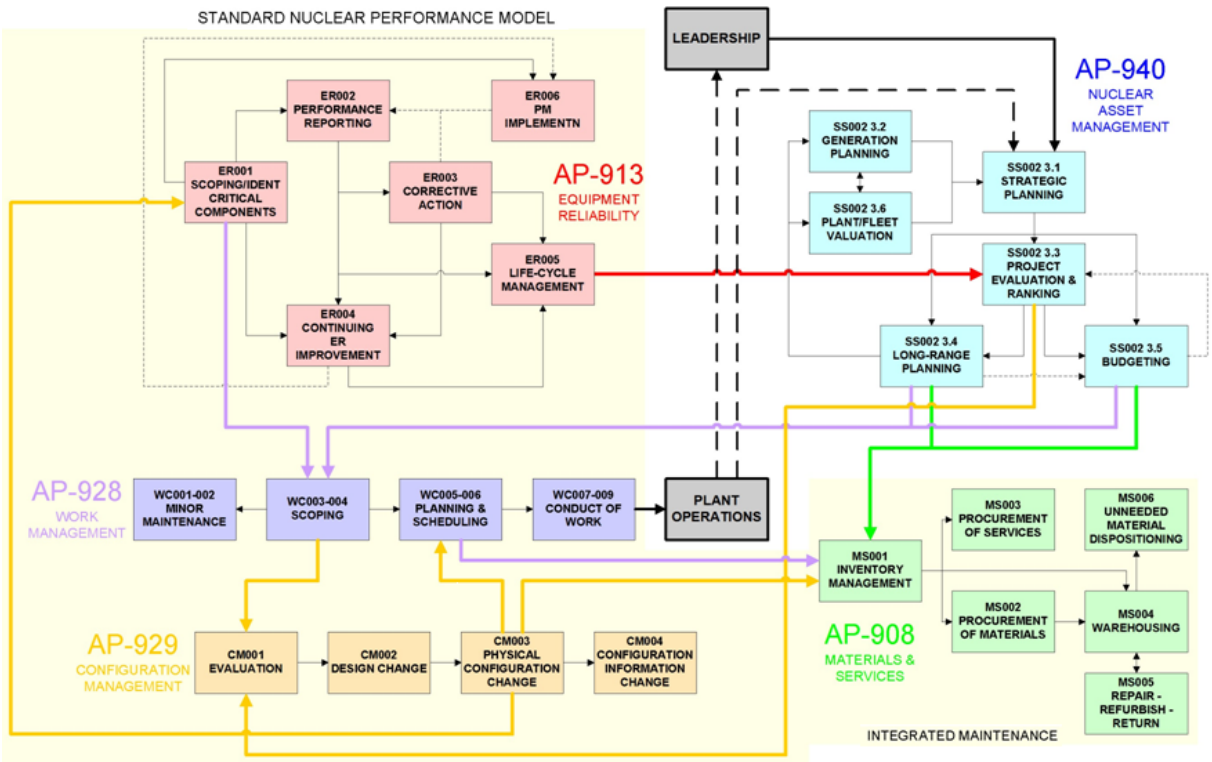

Figure 1: Relationship between WANO/INPO AP documents [5]

3. Challenges to G-2 refurbishment and refurbishment activities

Implementing the activities outlined above represents important effort for the management of the Gentilly-2 NGS. Although changes are expected in the end to be beneficial for both safety and unit cost operation, challenges in the next few years for G2 are two-fold:

- Activities are being introduced in a time frame where technical and management focus needs to be simultaneously put on operating the plant until the refurbishment and preparing for the 2011 refurbishment outage. Such a situation is leaving little, if any, margins for other developments.
- Activities affect the regulatory framework on which refurbishment scope was established; an update of the safety review will be required and could result in changes to the refurbishment or safety improvement plan scope.

As far as other above mentioned activities are concerned, implementing challenges at G-2 are perceived as follows:

- *Reliability Program and Standard S-98*

  Reliability data and models need to be updated to monitor reliability targets as opposed to previously reported un-availabilities. The SIS list is to be reviewed once the plant specific PSA completed.

- *Probabilistic Safety Assessment (PSA) and S-294*

  Changes in Operating Procedures and Emergency Operating Procedures will need to be aligned with the PSA objectives. Overall Maintenance Strategy will also need to take into consideration PSA results. As per S-294 requirements, the PSA will need to be updated to reflect current plant configuration and practices.

- *Safety Analysis and RD-310*

  Current Safety Analyses will need to be reviewed or updated to demonstrate compliance with RD-310 expectations for Anticipated Operational Occurrences (AOO), Design Basis Accidents (DBA) and Beyond Design Basis Accidents (BDBA). Decisions made in the evaluation of Category 3 Safety Issues and of the void reactivity issues could affect the refurbishment scope and the improvement plan for the second operation cycle.

- *Life Extension of Nuclear Power Plants and RD-360*

  The safety review completed to establish the refurbishment outage scope will need to be validated against the expectations of RD-360. Even if it is not expected that this will change the scope of the refurbishment outage, documentation of compliance with the recently defined requirements will put an additional burden on resources needed for the continued operation to refurbishment and for the preparation of the refurbishment outage.

- *Severe Accidents Management and G-306*

  Implementation of SAM guides represents a significant effort in the field, control room and on the emergency program.

- *Safety Operating Envelope (SOE)*

  Implementation of Safe Operating Envelope, with associated operational safety requirements may become part of the 2010 license requirements.

These works will require a transition period providing for a graded approach with regard to the compliance in the second life cycle. These activities need to be prioritised on the basis of net value added to safety. This in turn requires utilisation of a Risk-Informed Safety Management System or Process.

4. Path forward

Once implemented, the above presented standards, activities and initiatives will enable achieving high safety levels of the plant while preserving its economical viability. Given that they are issued or initiated by diverse interveners at different levels, there are also risks of some overlapping or duplicating of activities and/or inconsistencies in their application. Thus, it is essential for utilities to elaborate efficient structure which will allow their satisfactory integration and harmonization. Such an approach will enable an optimal use of valuable and limited resources, and reduce regulatory risks.

The G-2 Nuclear Generating Station is facing challenge in defining the best way to achieve this objective. It is two years ahead of a major plant refurbishment while operating in a regulatory environment in evolution. Such a situation requires keeping and ensuring safe and viable current operations while preparing an adequate risk-informed safety management program for the second life of the plant. The strategy to achieve this goal will be based on following principles:

- Take into account the specific G-2 work and operating environment
- Maximize use of existing processes and internal experience
- Minimize structural/organisational changes, and creating or improving functional inter-linkages
- Take into account the best national and international practices (including an efficient integration of relevant WANO/INPO AP processes)
- Use of a graded approach in implementing an integrated risk-informed safety management
- Buy-in at all levels of the plant organization

The implementation will be assisted through the plant IT system, which integrates more that 25 years of operating experience and expertise.

The implementation strategy should envisage creating functional relationship in short term. Long term objective comprises a fully implemented risk-informed safety management system integrating above discussed standards, activities and initiatives including new ones which may emerge.

5. Conclusions

The present paper discusses changes in the regulatory framework, current and emerged activities both in Canada and at the international stage, which will affect the way how the nuclear generating stations are operated.

The analysis focuses on the impact of those changes on the current and future G-2 activities given that the station will undertake a major refurbishment project in 2011. The paper proposes principles of a graded approach in implementing a risk-informed safety management at the G-2 Nuclear Generating Station.

6. References

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