Nuclear Refurbishment in Canada
A Case Study of Refurbishment activities at Ontario Power Generation

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Abstract

A nuclear refurbishment project is being performed to extend the operating life of the Darlington Nuclear Generating Station. The Initiation phase is currently being executed, which includes an Integrated Safety Review (ISR), Environmental Assessment (EA) and Integrated Implementation Plan (IIP). This paper outlines the phases involved in a refurbishment project and describes the methodology that OPG has developed to perform the Initiation phase of the Refurbishment project.

1. Introduction

As Canada enters the Nuclear Renaissance, all of the operating nuclear reactors will require refurbishment to continue operation. The government of Ontario suspended the procurement of a new nuclear plant to be built in Darlington on June 29, 2009. The reasons included the economic downturn, higher than anticipated bid prices, and only one compliant bid. The Ontario government has however, committed to maintaining fifty percent of the generation capacity in Ontario from nuclear. To fulfill this commitment a number of refurbishments of nuclear units need to occur.

Ontario Power Generation Inc. has 10 operating units, distributed between the Pickering NGS and the Darlington NGS. All these units are CANDU nuclear reactors, as are all nuclear generating stations in Canada. These reactors are designed to require a mid-life refurbishment outage after about 30 years of service. Refurbishment, also referred to as ‘life extension’ is a major and complex construction project. It requires significant planning, preparation and analysis to determine the scope of work required. This paper outlines the regulatory requirements, the general methodology and the phases of work involved in a refurbishment, with a focus on the current work being performed by Ontario Power Generation Inc.

2. Refurbishment in Canada

There are a number of recent and on-going refurbishment projects across Eastern Canada. Point Lepreau in New Brunswick is currently under-going refurbishment. Hydro-Quebec has announced a refurbishment of Gentilly-2 in Quebec. Bruce Power is currently performing a refurbishment of Bruce A. Ontario Power Generation Inc. (OPG) conducted an Integrated Safety Review (ISR) of the Pickering-B NGS beginning April 2006, with final submission to the CNSC on September 25, 2009. Most recently, on February 16, 2010, OPG publicly announced its future plans to refurbish the Darlington Nuclear Generating Station (NGS), while the Pickering-B NGS will be operated up until 2020 and then put into safe-storage. A drawing of the Darlington NGS is presented in Figure 1, Darlington Nuclear Generating Station (NGS).

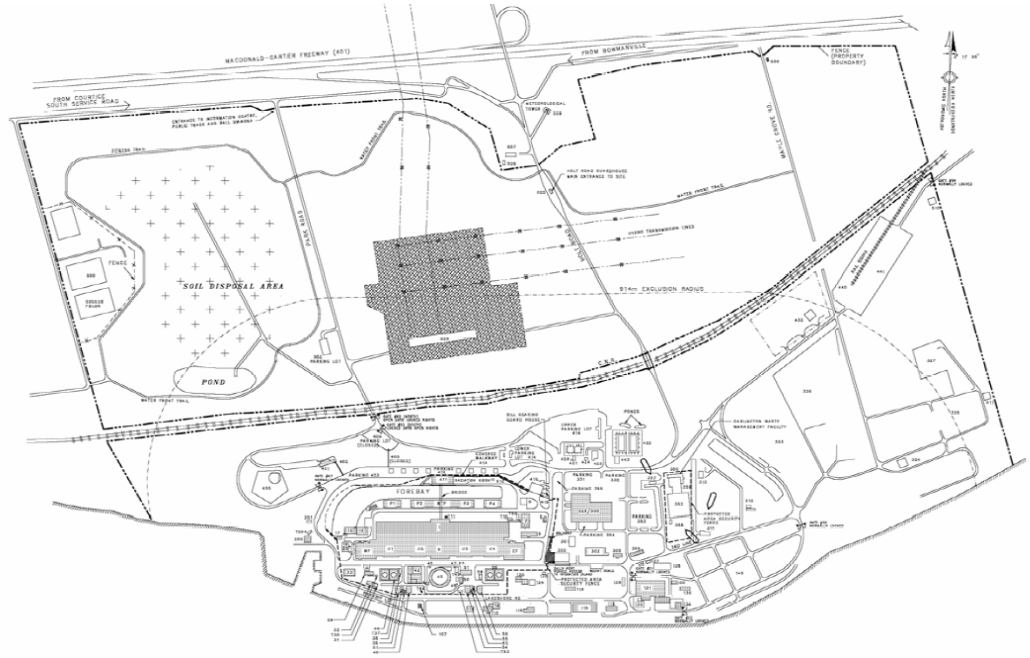

Figure 1. Darlington Nuclear Generating Station (NGS)

3. Refurbishment at Ontario Power Generation

The Plant Life Extension Project (PLEP) group in Ontario Power Generation was established in February 2006 to undertake feasibility studies for refurbishing and extending the life of the nuclear units at the Pickering and Darlington sites. The organization name was changed to Nuclear Refurbishment (NR) in November 2008. These feasibility studies are required as current medium confidence estimates indicate that the Darlington reactors shall reach their End of Service Life (EOSL) between 2018 and 2020. OPG's Senior Management, with approval by the Board of Directors and Shareholder, tasked NR to assess the feasibility of refurbishing Darlington NGS, plan and then execute the refurbishment to enable operations for an additional 25 to 30 years.

3.1 Regulatory Framework for a Refurbishment Project

The Canadian Nuclear Safety Commission (CNSC) is the Canadian regulatory agency of the nuclear industry. The *Nuclear Safety and Control Act* (NSCA), which is a piece of federal legislation, provides the objects of the Commission "to regulate the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information." As such, the CNSC has created a suite of regulatory documents (RD). The regulatory document entitled, "RD-360 Life Extension of Nuclear Power Plants"[1] informs licensees, for example, OPG, on a general methodology to consider when performing a project to extend the life of a nuclear power plant. The refurbishment activities described herein were developed to address the scope and intent of RD-360.

Each nuclear power plant in Canada is subjected to ongoing regulatory oversight by the CNSC, in order to ensure that the plants meet modern high level safety goals, and meet applicable regulatory requirements. It is at the return-to-service stage that the licensee must demonstrate that they meet all licence conditions. There are, however, on-going communications with the regulator to ensure a sound

process is followed and to ensure overall acceptability of the final documents which outline the processes involved in the refurbishment of the plant.

3.2 Phases of Refurbishment

OPG developed a phased approach to refurbish the Darlington NGS. The approach is consistent with industry practice and follows an appropriate governance to ensure each phase of the project is performed and documented to meet quality assurance and CNSC requirements documented in RD-360 "Life Extension of Nuclear Power Plants."

The main task prior to performing a refurbishment is to determine the station condition through a full assessment. Depending on the plant condition the refurbishment's scope of work can vary significantly but can potentially include replacement of fuel bundles, replacement of feeders, and the replacement of any life-limiting components, safety and environmental systems.

OPG has defined four phases for the refurbishment, the Initiation Phase, the Definition Phase, the detailed Engineering and Outage Preparation phase, and the Execution Phase. They are defined as follows:

(a) The Initiation Phase is where initial regulatory, outage and scope planning is done and a feasibility assessment on the economics of refurbishing and extending the operational life of the units by an additional 25 to 30 years is completed.

Deliverables in this phase include the following:

- Obtaining, to the extent possible, the necessary corporate, government and regulatory approvals in order that the Darlington reactors can be refurbished in a timely and cost effective manner. The Integrated Safety Review (ISR), Environmental Assessment (EA), Integrated Implementation Plan (IIP) are the regulatory related aspects of the Initiation Phase of the Darlington Refurbishment project.

- Performing technical studies, for example, a plant condition assessment.

- Identifying and approving the project scope and initial outage plans, including cost and schedules, based on results of the regulatory work programs and the technical work programs.

- Ensuring that where necessary long lead items are identified and procurement strategies are in place to support the refurbishment project.

- Incorporating lessons learned from OPG and external sources in determining the material condition of the plant and providing initial planning for the refurbishment of Darlington reactors, including recommendations on refurbishment outage timelines.

(b) The Definition Phase of the project includes preliminary engineering and detailed outage planning in order to finalize project scope, cost and schedule. In this phase, a quality estimate and Business Case Summary (BCS) is developed to support the project recommendations.

(c) The Detailed Engineering and Outage Preparation phase includes detailing the procurement of major component replacement packages and long lead materials, completing detailed engineering and field package assessments, site preparation, and finalizing a detailed project schedule and cost estimate for the outage execution.
(d) The Execution Phase of the refurbishment of the DNGS consists of the refurbishment outage execution and project closeout.

3.3 Initiation Phase

OPG is currently conducting the initiation phase of the project. Three overall studies are performed during this phase, the Integrated Safety Review (ISR), the Environmental Assessment (EA) and the Integrated Implementation Plan (IIP). Figure 2, The Initiation Phase of a Life Extension Project outlines the documents that are prepared, and how they are used to cover the intent of RD-360 "Life Extension of Nuclear Power Plants." RD-360 identifies that an Integrated Safety Review should address the *Safety* Factors from the International Atomic Energy Agency (IAEA) Safety Standards Series, Safety Guide No. NS-G-2.10, Periodic Safety Reviews of Nuclear Power Plants [2], as well as the CNSC safety areas and programs listed in RD-360.

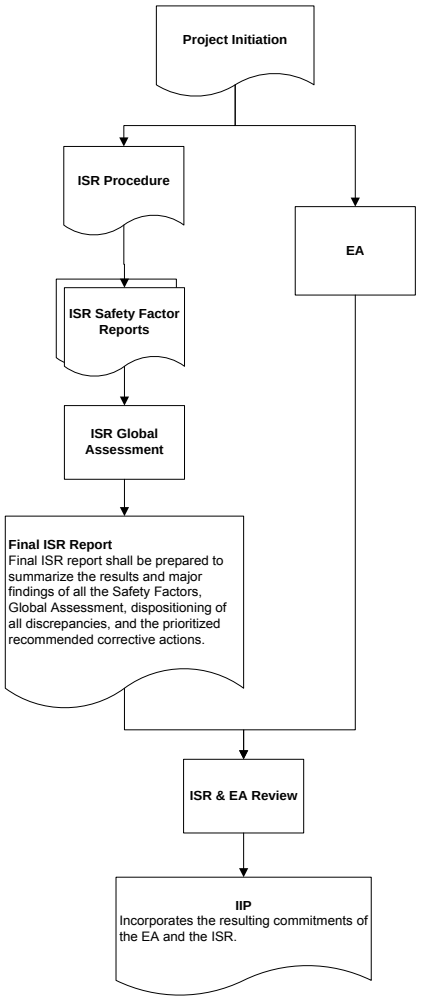

Figure 2. The Initiation Phase of a Life Extension Project

The ISR looks at the existing plant, its history including the programs under which it operates, its physical condition, and its performance whereas the EA is an assessment of the potential environmental impacts of the refurbishment and continued operation of Darlington NGS.

Performing the Initiation phase, as it is closely linked with the regulator, includes a number of activities with the CNSC. Figure 3, Initiation Phase with Integrated Implementation Plan (IIP) and interface with the CNSC outlines the overall process.

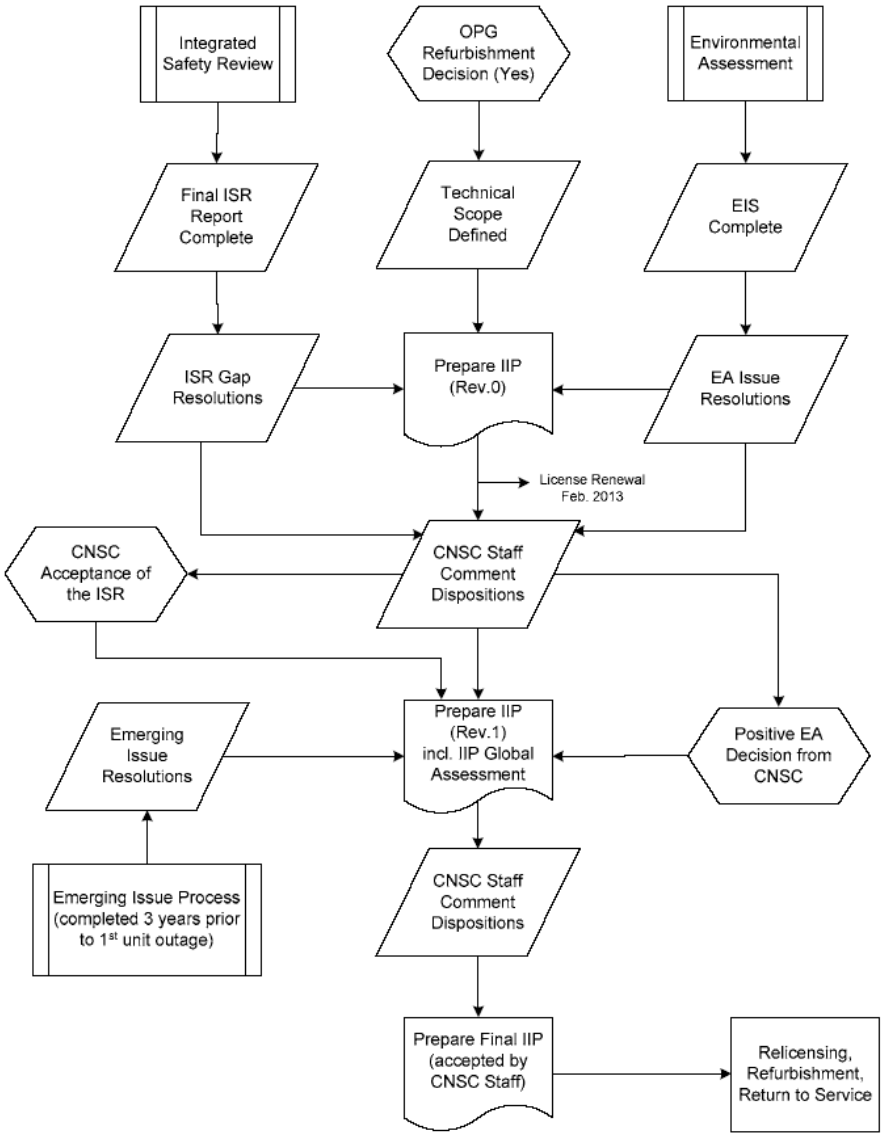

Figure 3. Initiation Phase with Integrated Implementation Plan (IIP) and interface with the CNSC

3.3.1 The Integrated Safety Review

The objectives of an ISR are to determine:

(a) Extent to which the plant conforms to modern high-level safety goals and requirements.
(b) Extent to which the *Licencing Basis* remains valid, where the *Licensing Basis* includes the CNSC regulatory framework, documents referenced in the station specific licence, documents submitted by the licensee in support of licence application, and documents referenced therein.

(c) Adequacy and effectiveness of the arrangements that are in place to maintain plant safety for long-term operation.
(d) Safety improvements to address gaps with respect to modern safety requirements identified during the assessment

These objectives are performed to identify any factors that would limit safe long-term operation, and to determine the required mitigating actions to resolve outstanding issues. A schematic of the ISR process is shown in Figure 4, Integrated Safety Review Process.

The Safety Factor Reports that are being prepared for the ISR are based on the Safety Factors included in the IAEA NS-G-2.10 and three additional Safety Factors recommended in RD-360, Security, Safeguards and Quality Management. The IAEA Safety Factors are grouped into five subject areas to facilitate the review. A sixth subject area was added to address Security and Safeguards, while the Quality Management Safety Factor was added to the Management subject area. These subject areas and corresponding Safety Factors are listed in Table 1, Safety Factors of the ISR. Each Safety Factor is further broken into Review Tasks which were generated based on the IAEA Review Elements listed in the IAEA NS-G-2.10. Each Review Task is addressed using governance, plant design condition assessments, safety analyses, operation, and related information. The scope of the review considers, as appropriate all expected modes of operation (i.e., normal operation, maintenance, refuelling, shutdown, and start-up activities) to determine whether there is any potential for increased or unacceptable levels of risk. A thorough review of the Darlington NGS safety analyses and OPG governance for operations in conjunction with the operating history of the plant addresses most of the topics that are covered by the ISR.

The ISR also includes a review against modern codes and Standards to assess the level of safety compared to that of modern NPPs. Any gaps that are identified between the current plant state and that required by modern Codes and Standards will be addressed using the Gap Management Process. A summary of the gaps identified in the code reviews will be included in the applicable ISR Safety Factor reports. The Gap Management Process will identify reasonable and practical safety improvements that should be made in order to maintain a high level of safety and to improve the safety to a level approaching a modern nuclear power plant.

The ISR also includes a review of historical and current licencing issues relating to the Darlington NGS as applicable to the various Safety Factors.

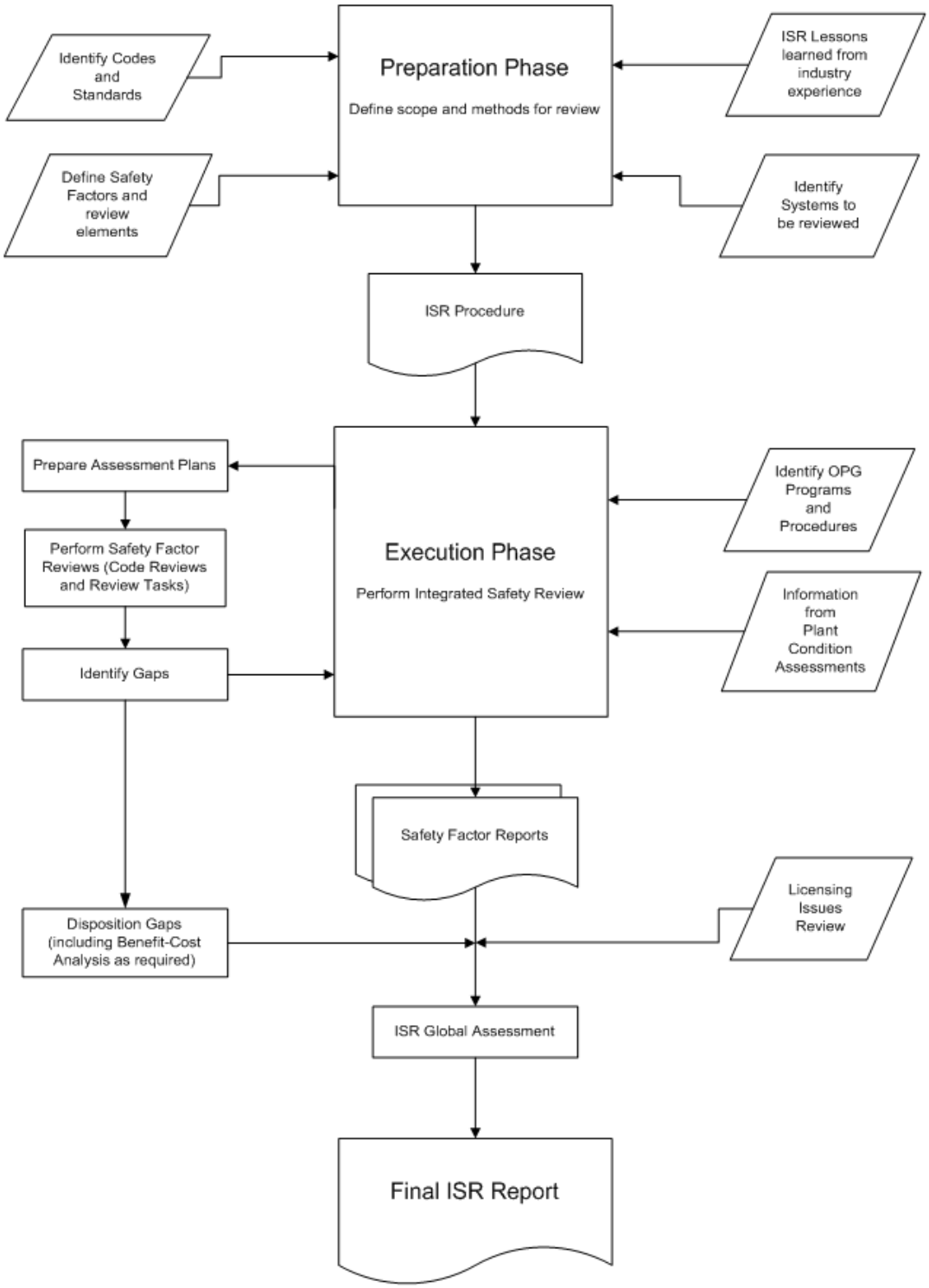

Figure 4. Integrated Safety Review Process

Subject Area	Safety Factor
Plant	Plant Design
	Ageing and Actual Condition of Systems, Structures and Components
	Equipment Qualification
Safety Analysis	Deterministic Safety Analysis
	Probabilistic Safety Assessment
	Hazard Analysis
Performance and Feedback of Experience	Safety Performance
	Use of Experience from other plants and of Research Findings
Management	Organization and Administration
	Procedures
	Human Factors
	Emergency Planning
	Quality Management
Environment	Radiological and Non-Radiological Impact on the Environment
Security and Safeguards	Security
	Safeguards

Table 1. Safety Factors of the ISR

Each ISR Safety Factor Report is being produced with the following Table of Contents:

Cover Sheet
1.0 Introduction
2.0 Scope and Methodology of Review
  2.1 Scope
  2.2 Methodology
3.0 Findings
  3.1 Code Reviews
  3.2 Review Tasks
  3.3 Issues for Review for Other Safety Factors
4.0 Results and Conclusions
  4.1 Results
  4.2 Conclusions

After the completion of the Safety Factor Reports to appropriate quality assurance, an ISR Global Assessment will be performed by a third party. The ISR Global Assessment will assess plant safety for long-term operation and will take into account all unresolved gaps, safety improvements and plant strengths identified in the individual Safety Factor Reports to determine the global risk. The ISR Global Assessment will review the results of the ISR, recommend safety improvements to address individual gaps or groups of gaps, recommend safety improvements resulting from identified opportunities to reduce the overall plant risk, and assess interactions between recommended safety improvements. The results will be prepared and incorporated into the Final ISR report, as seen in Figure 4, Integrated Safety Review Process.

3.3.2 Environmental Assessment

The Environmental Assessment (EA) is being performed in parallel with the ISR. It is carried out under the Canadian Environmental Assessment Act to identify whether refurbishing the Darlington NGS is likely to cause significant environmental effects. The EA is a planning tool to determine the significance of residual environmental effects after applying mitigation measures. It is a process where the environment is characterized, and environmental effects are predicted and assessed before any irrevocable decisions are made about the project.

The Environmental Impact Statement documents the results of the EA. It contains a series of Technical Support Documents (TSDs) which are prepared for different environmental components, such as atmospheric, aquatic, surface water, geology and hydrogeology, terrestrial, land use, transportation, socio-economic conditions, aboriginal interests, physical and cultural heritage, radiation and radioactivity, ecological risk assessment and assessment of effects on non-human biota, human health, emergency preparedness, accident and malfunction scenarios, and public consultation. Each TSD includes a detailed description of the baseline field conditions, methodology for the assessment, and assessment of any effects.

Public Consultation is a key element of the EA process. It employs a range of methods to ensure that the public is given notification and has opportunities to participate and may include, but is not limited to the following: notification advertisements, notification letters, stakeholder interviewers and briefings, workshops, community information sessions or open houses, community displays, newsletters, telephone contacts, and a project website.

3.3.3 Integrated Implementation Plan

The Integrated Implementation Plan (IIP) is an integration of the results of the EA and ISR which will identify all necessary safety improvements, proposed plant modifications, safety upgrades, compensatory measures and improvements to operation and management programs that will apply to both the life extension project and to long term operation. It will also indicate the schedule for implementing the safety improvements that need to be completed during the execution phase of the refurbishment project. Similar to the ISR, the IIP has a Global Assessment as part of the final document. Figure 2, Initiation Phase with Integrated Implementation Plan (IIP) and interface with the CNSC outlines the IIP process.

4. Conclusion

A safety review methodology has been developed to demonstrate that the safety and licensing review process for the Darlington refurbishment meets the intent of RD-360 and IAEA NS-G-2.10.

In developing and performing the Integrated Safety Review, the Environmental Assessment and the Integrated Implementation Plan, along with the associated review tasks and methodologies, Ontario Power Generation is confident that it can meet the requirements of the regulator and perform a successful refurbishment of the Darlington NGS through detailed planning and methodical implementation to extend the operating life by 25 to 30 years.

5. References

[1] CNSC RD-360, Life Extension of Nuclear Power Plants, February 2008

[2] IAEA Safety Standards Series, Safety Guide No. NS-G-2.10, Periodic Safety Reviews of Nuclear Power Plants, 2003