Candu Energy's Aging and Obsolescence Program & It's Application to Operating Facilities and New Plant Design

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Abstract

While plant aging is inevitable, predictable and "graceful "aging" behavior can be achieved through the implementation of a comprehensive and integrated Plant Life Management (PLiM) program. Despite organizations like the IAEA and INPO placing more emphasis on equipment reliability, there is still a lack of completely integrated programs in the industry as evidenced by:

- Piece-meal, often crisis-driven, implementation comprising many different, partial solutions
- Duplication of effort often seen when different groups work in 'silos'

A strategy which fits with existing plant processes and programs, and which coordinates a broad range of equipment reliability activities is key to achieving the desired results. An example of such a program is the Aging and Obsolescence Program (AOP).

AOP follows application of INPO AP-913 guidance for equipment reliability. The program is augmented to include single point vulnerability identification, unified approach to short and long lived components, risk management, spare parts management, and the identification and resolution of obsolescence issues.

The systematic nature of the program provides the needed foundation to old and new stations alike. For existing operating stations some of the key uses include outage interval extension, reduced forced outages, and/or outage time reduction, any of which can translate into improving plant performance, competitiveness, and significant dollars saved. Program elements applied to new plant design are commensurate with the industry direction to "design for reliability", and has allowed Candu Energy to learn and to improve upon what it can offer to operating stations.

This paper intends to describe the basic elements of Candu Energy's Aging and Obsolescence Program and will share some of the experience having applied it to existing operating stations, consider applications to support expanding regulatory requirements, and describe the integration into the design of new plants, promoting continuous improvement throughout the plant life cycle.

1. Introduction

There continues to be an increasing focus seen in plants world wide to apply more systematic processes; to move Operations & Maintenance (O&M) to be more proactive rather than reactive. Best practices are now seen as bringing all the elements of aging management, preventive maintenance, knowledge management, and business decisions together. The most prominent example is INPO AP-913 [1] and related standards. Such practices, although relatively simple in concept, are not easily implemented in a consistent manner.

Many programs elements are needed to address all aspects and these can be created independently. While this achieves short term goals, and establishes basic elements of the programs, there is a high risk of each element remaining independent. Similarly, there tend to be organizational divsions. The Equipment Reliability program, driven from Engineering typically, needs inputs from Safety, Maintenance, and intereacts with Supply Chain. Within Engineering, there needs to be interactions between predictive maintenance, engineering design, system engineering, and component engineering. However, if Engineering defines SPV components, but the definition and implications of SPV identification are not cascaded throughout the organization then SPV identification can remain as only identification. The desired benefits of risk reduction will not be realized.

As the equipment reliability concepts further expand to include Generation Risk Assessment (GRA) the potential level of integration across programs and across functions within the organization increases. Yet, the typical short term focus of project implementation, traditional communication challenges of large organizations, and economic realities make it difficult to complete longer term and costly projects. This is despite the even larger potential benefits gained from successful implementation. The benefits, however, are very difficult to quantify and ascribe to equipment reliability efforts alone. Without dedicated, and knowledgeable champions, plants will tend to lose the focus when day to day operating challenges emerge.

One way to improve the chances of success is to be able to articulate a vision for the program that can be understood and carried out throughout the origanization. The program that Candu Energy promotes has been articulated as a single comprehensive approach for a decade. This approach has deveoped into the Aging and Obsolescence Program. This paper will look at the AOP program, with an explanation of how it builds upon the fundamental AP-913 concepts to develop an overall approach. Some of the experience Candu Energy has gained in implementing the program and areas to address to enhance the chances of succes will be discussed. Finally, the AOP program forms a road map for Candu Energy's approach to overall program development together with focused aging and equipment realibility program improvement, and in New Build thinking. In this way, the concept of how an overall vision can provide a framework can be examined.

2. The Aging & Obsolescence Program

Figure 1 provides a simplified view of the overall flow of the program. The diagram reflects the overall relationship between programs that in turn provide feed back to update and improve. The primary elements of AP-913 are reflected in the loop of Risk Proiritization, Aging Assessment, Station Programs, and Health Monitoring.

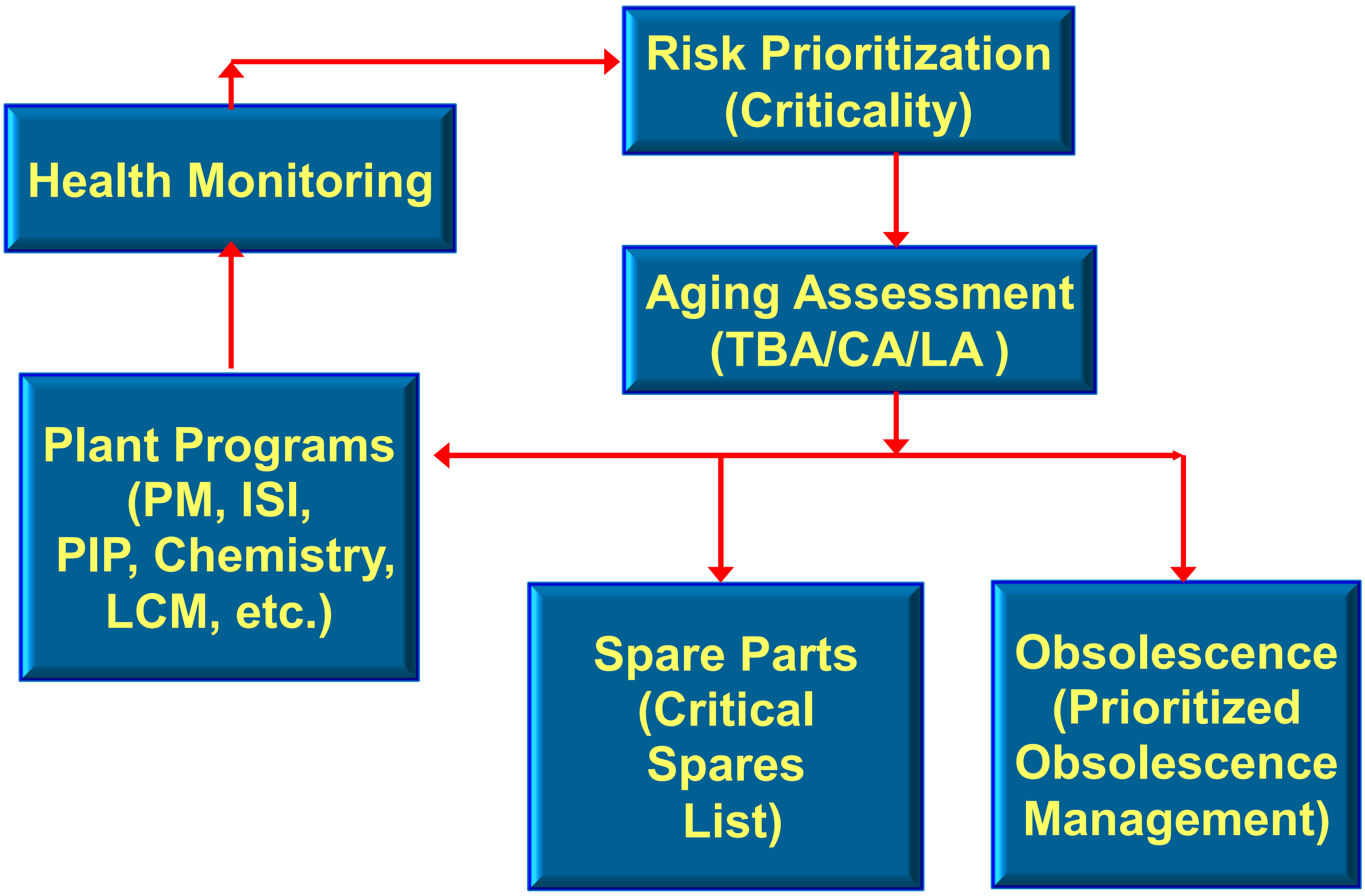

Figure 1: Simplified Aging and Obsolescence Program Flow Diagram

2.1 Risk Prioritization of SSCs

Risk Prioritization entails identification of those SSCs that pose the greatest risk to safety, environment, production or those that can serve to provide the most significant impact on overall plant performance (e.g., Criticality Category 1 & 2 components).

The first step of AOP is to complete risk priority ranking of the SSCs based upon consequence of failure, likelihood of failure, and a current state factor. All components for which the AOP process is applied require a risk prioritization .

2.1.1 Criticality

Criticality determination, following an failure modes and effects approach, is based upon the consequence of failure of each component which are compared to predefined categorization criterion. The assessment requires the establishment of the component function within the system and then establish the appropriate category for the component based upon criticality criterion.

2.1.2 Augmenting Criticality

The basic criticality assessment can be augmented to create a better understanding of risk. This includes SPVs which are generally being defined as SSCs whose failures result in Reactor Trip, Turbine Trip or derate of >10%. This criteria can be introduced into the criticality criterion for the highest criticality components. Therefore, when the risk prioritization form is complete, if the SPV criterion has been selected, the component is automatically flagged as an SPV.

To further enhance the evaluation of risk, the process takes advantage of the fact that criticality crtieria are in fact consequences of failure. That is, these critieria represent one part of the risk equation. By defining a scaling or weighting factor, the basic criticality can be expanded to reflect relative priorities of the station.

The second parameter of risk is likelihood which can be added to the criticality evaluation in a basic liklihood scale. This allows the process to define a risk-based prioritization. For this purpose, a set of simple criteria that ranges between “not likely to occur” through to “certain to occur” is given in the evaluation form to facilitate a consistent determination of the likelihood of occurrence.

The resulting risk can be used throuhgout the AOP program to support prioritization. This information has the primary purpose to prioritizing what components to assess first in the aging assessment stage. Secondary uses include prioritizing critical spares and obsolesence strategies. The same information can also be augmented to provide a risk review of changes to the health strategy for individual components. This is described further in augmenting the aging assessment.

Another feature that can be implemented in this activity is a mechanism to identify redundancy. As redundancy can impact on component criticality, it should be noted as part of a complete justification. This knowledge can have additional benefits in managing the effects of loss of redundancy in the field. Adding in a simple means to identify and later extract a listing of affected components can have significant benefits. This is discussed further under implementation.

The Risk Prioritization is intended to be a relatively quick assessment based upon information on hand. There is opportunity to refine this thinking at a later stage. However, this concept also opens up opportunities to incorporate risk based thinking from other assessment strategies. For instance, Generation Risk Assessment (GRA) or safety focused Probalistic Safety Assessment (PSA), provide a systematic approach to evalauting risk that can be integrated with the criticality thinking. The risk information allows for an improved prioritization. Linking to the probablistic modelling adds a stronger basis for criticality and provides a stronger link to safety reliability assessments.

2.2 Aging Assessment

The Aging Assessment Methodology is used to perform the appropriate level of assessment of critical structures, components, and commodities (SCCs) that are important to safety and power generation. The assessment covers both short lived components and long lived components typically considered under Life Cycle Management (LCM). These are considered together as generally all the assessment types have the main objectives to:

- Establish current condition and identify relevant failure causes or aging related degradation mechanisms (ARDMs) of the critical SCC.

- Identify efficient/effective maintenance, surveillance and inspection (MS&I) strategies to support management of the ARDMs identified.

There are two (2) assessment types used as “Aging Assessments”. These assessment types are:

- Short Lived Component Technical Basis Assessment

  The focus is on components that are primarily managed through the preventive maintenance program. These components tend to have short term maintenance requirements to maintain reliability. In principle this assessment is similar to RCM or PMO thinking. Typically the assessment does not require as in depth assessment to determine an appropriate MS&I strategy.

- Condition Assessment

  Condition assessments are typically applied to longer lived components with passive functions (eg. Pressure boundary or structures). It can be applied to any component as needed, but the depth of the assessment is greater then the previous assessment. These assessments can be extended to support Life Cycle Management (LCM)

The aging assessments form part of a living program with a current condition review element and a forward looking element intended to ensure potential risks not yet experienced are appropriately addressed in the strategy.

2.2.1 Augmenting Aging Assessment

Using a single overall approach to health strategy development for short lived and long lived components is in itself an augmentation. It has the benefit of having all components categorized and risk managed using a single overall plant strategy. The strategies developed by these assessments also provide inputs to the appropriate station programs (e.g. preventative maintenance program, inspection programs, predictive programs, chemistry management, etc.). Simultaneously, these inputs can be carried forward to complete a spare parts assessment.

Finally, there is also the potential for contributing to the management of risk through the concept of the risk reduction factor.

2.2.1.1 Critical Spares

There are two aspects of the critical spare program.

- The appropriate Replace/Repair strategy: The program identifies the maintenance strategy for an SSC based on cost of repair, removal and the impact of environment (i.e. space limitations, high dose costs). This review can provide feedback to the original maintenance, surveillance, and inspection strategy.

- The required spare parts to support the maintenance, surveillance, and inspection strategy: Once the required spares are defined, the second aspect of the assessment is to ensure the appropriate spares are stocked when needed. The spare assessment includes:

  - Defining critical spares (ensures adequate focus)

    A critical spare is defined as being a critical component or part (Critical SSC – i.e.; Cat 1 or 2 component) that has been opted to have readily available. Here the understanding gained in the aging assessment provides input to understand the critical components. Not all potential critical spares are included.

  - Establishing the stocking parameters to support the maintenance, surveillance, and inspection strategy

Stocking parameters are set to optimize spare parts inventory, which is intended to meet both planned and un-planned demand. The parameters are established using EPRI processes **Error! Reference source not found.**.

2.2.1.2 Obsolescence

Obsolescence of spare parts is of key importance to the AOP program. There is opportunity to identify potentially obsolete components throughout the assessment process. Ultimately the potential for obsolescence needs to be confirmed. This is accomplished through application of the Proactive Obsolescence Management System (POMS) database or through verification by the supply chain. Once identified, the components are ranked for priority and enter into the obsolescence resolution process. The program from this point follows the guidelines provided by NUOG **Error! Reference source not found.**. As with critical spares, the results of obsolescence management can impact on the overall component strategy.

2.2.1.3 Prioritization of Actions (Risk Reduction Factor)

The recommended results from the aging assessment can be prioritized under AOP. A risk reduction factor (RRF) can be applied to identify the highest priority items to be implemented. The RRF provides a quantitative measure of the value of elements of the maintenance, surveillance, and inspection strategy while providing risk based input to prioritize the implementation of all updates to station programs supporting equipment reliability.

This thinking has further direct links into GRA. The aging assessment elements provide a systematic review of risk elements. Further assessment of the potential impact of various health strategy actions can then be used to estimate the potential reduction in risk. This can be used to further identify risk reduction for GRA purposes as well.

2.3 Interface with Station Programs

Figure 1 reflects input from the Aging Assessment process into plant programs. Outcomes from Aging Assessment range from changes in categorization to changes in program strategies. Program strategy chages may include changes to the Preventive Maintenance (PM) program, changes to inspection, predictive maintenance, and chemistry programs, and changes to life cycle management (LCM) plans.

The implementation of the outcomes results in changes in the field, which in turn will impact on equipment reliability. Overall, equipment and system reliability is reflected in the station health reporting program. The system health monitoring program is then the principle means of feeding back issues into the overall process. Other feedback mechanisms such as corective actiion assessments, are also triggers to initiate strategy reviews.

3. Implementation

Candu Energy works with the overall understanding of the program based upon AOP and tailors the application to the unique station requirements. This includes identifying existing elements, overall station organization and responsibilities and fitting those within the overall AOP framework. This allows the program implementation to focus on those elements or gaps specifically needed by the station.

The development of a program in itself does not assure success. Implementation can be hampered by a lack of clarity and consistency in application. A number of examples have been identified that need to be addressed during implementation.

- The use of criticality definitions that are not clear or that can be misinterpreted make the application of the criteria difficult and creates inconsistent results.
- Single failure criteria not applied consistently when determining criticality is a typical problem. Similarly, the treatment of hidden failures, how to address redundancy, and how to include operator actions, need to be clearly defined.

SPV definitions are clearly defined, but problems arise when what constitutes a single failure or what operator actions can be credited is not well defined. If not clear, and understood throughout the organization then the results can be questioned. This can lead to undermining of the efforts to effectively manage SPVs. Further if the intent of defining the SPVs is not clear and consistent throughout the organization, the purpose can be lost or not be dealt with consistently.

- Redundancy will have an important impact on the criticality of a component. As the consequence of failure will be reduced, the criticality of the component would likely also be reduced.

  When redundancy reduces component criticality, it can have a secondary impact. A lower criticality component can have a lower priority for repair or have an increased likelihood of maintenance deferral. When a redundant component is in need of repair, the remaining redundant component will effectively have a higher consequence of failure. In some cases, this can mean components become SPVs until the repair is affected. A means to manage this potential is a useful addition to the program.

  An alternate perspective is to note that even when components are named as "run to failure", there is an implicit intent that the repair occurs within a reasonable time following failure. When stations focus on critical components at the expense of maintaining the lower criticality equipment this can result in other latent risks.

- Clear documentation of the technical basis for each component's health strategy is important. If not clear, the attempts to change or improve the strategy over time will have increased risks. The implementation of the AOP program encourages the use clear justification for criticality and technical basis to assure the clarity. This also helps to be clear when elements can be removed. It has been observed that adding maintenance tends to be a simpler thing for stations to do then deleting maintenance tasks. Clarity is required to provide assurance that deletion will not have adverse effects.

- Consistent maintenance templates are an important aspect of the program. While generic templates can provide a good basis for maintenance decisions, station specific templates allow the more generic information to be focused to be consistent with station resources, risk tolerance, experience, and consistency with station programs. The templates need to reflect the predictive and condition based maintenance, and health monitoring programs.

  A self consistent, clear, and complete template that addresses all potential applications can realize considerable savings in assessment effort while ensuring consistent results. Achieving this quality of template requires that the process and requirements of template development be well defined. Training of staff to create consistent templates can also improve the template quality. High quality templates translate into improved results and facilitate the management of the templates with time.

- The aging assessment approach lends itself to different levels of depth in the analysis. Realizing that the assessment of 1000s of components can be prohibitive if too much effort is expended on each component, it is important to define the depth required. This also needs to be clearly communicated to all parts of the organization to prevent inconsistent expectations. Having mutually understood goals, understanding of the assessment process, and the benefits of the program provides a basis to ensure expectations are consistent and improves the likelihood of success.

- The investment to truly apply a systematic and integrated program is significant. Having a single overall approach provides one method to reduce overall cost by ensuring synergies are maximized and many needs are served. Having consistent templates, a clear technical basis, and clear level of detail also ensures more efficient application. Including risk in the process assists in deciding what to do first, but also what is economically viable. In addition, appropriate grouping of components, again based upon systematic organization, can reduce the overall effort. Finally, software tools built to support this work provide a way to minimize the effort. Candu Energy has developed and implemented the SYSTMS™ software to support this last aspect.

- Program development needs an effective means to measure progress through metrics. If applied in a systematic manner, it can take time to reach the point where significant impact on station performance is achieved. Further, the success can be difficult to demonstrate. Metrics designed to measure program progress and to measure the program impact are critical to demonstrate results. This includes having a baseline to measure against.

A complimentary organizational element is the need for a program champion that can defend the program, and advocate within the organization. Without a clear and articulate understanding being consistently promoted, it is easy for the focus to be lost and the program direction to be distracted. Specifically, the bigger picture goals can be lost in favour of short term gains.

4. AOP – An Enveloping Infrastructure

The Aging Management standards and plant programs continue to evolve and it is true of regulator requirements in Canada as well. Consistent with IAEA documentation, the Canadian regulator developed draft standards such as RD 334 [4]. Following such regulation requirements, the aging management program requirements are moving more towards an integrated program. This includes linking safety margins into the overall equipment management. Similarly, as is a common theme in IAEA documents, links are needed between preventive, condition based and corrective maintenance as they together form the basis of programs overall.

The Candu Energy AOP program has been developing for more than a decade. Today the program structure provides the framework to address key implications of regulatory requirements. This includes providing the infrastructure for defining the relationships between engineering, safety, maintenance, operations, and supply chain in support of aging management. Similarly, it covers all aspects of aging management from establishing individual component health strategies, component programs, major equipment programs, buried piping, predictive maintenance, system health programs, spare parts management, obsolescence, single point vulnerabilities, with links to risk based reliability and periodic inspection programs.

The same infrastructure can be used to support individual aspects of the overall program such as the assessment of increased outage frequency. True outage frequency extension requires that component reliability be assured from a production perspective. The aging assessment methodology provides a systematic approach to establish that basis and provide the means to improve as a learning organization. The overall program can then be used to address other supporting program improvements needed to support the technical basis.

When considering New Build applications, the AOP program can again provide the basis on which to establish what is necessary to meet the high performance requirements imposed on new plants. At the component level, a complete design philosophy considers the needed combination of system configuration, component requirements and features, and the necessary maintenance strategy that complements the design. For instance, considering valve performance in existing plants as feedback into the maintenance basis, the root of valve problems can be identified and an appropriate solution can be defined. Through such an approach, the concept of buying quality components can be defined practically within the system context and maintenance solution.

The fundamental elements of the AOP program encourage a systematic approach. This forms the basis of the criticality and aging assessment methodology. The basic technical information used for criticality thinking can be used for multiple applications. The systematic understanding of system function and impact of failure can be used to support Human Factors review and be used to support Probabilistic Safety Analysis. At the same time safety categorization provides basic thinking that can also be used as input into component categorization for maintenance purposes. This creates a more highly integrated design strategy

The aging assessment considers both the role of the component to meet station functions, and the management of the component capabilities over the station life. This entails understanding the inherent margins and how those margins are maintained over time. These margins are key elements for safety related components. Using the AOP thinking, margins for safety are identified, current condition monitored, and management programs established.

Following this same thinking, the condition assessment used for determining life extension needs, support of Periodic Safety Review, and for day to day component management are one and the same.

Once established, AOP thinking manages the program going forward, providing support for longer term planning or point in time assessments as required without additional effort.

Finally, having a complete strategy facilitates an understanding of the information development and management requirements. In effect, AOP provides for configuration management of the maintenance technical basis, including what is critical and why, what maintenance is needed and why, including how the plant operating history has influenced that strategy, together with the supporting spares and obsolescence basis. This is in addition to the health monitoring information that needs to be collected, assessed, and appropriately acted upon. To support the information management, Candu Energy has developed and continues to work to enhance software to meet these needs such as SYSTMS™ and SMART CANDU®. This approach then can be applied within the context of new design, allowing for integration with design information, which itself is managed at an increasingly higher level of detail and automation. This provides a path to enhanced capabilities in new designs.

5. Summary

While the industry places more emphasis on equipment reliability, covering all equipment whether short or long lived, many programs continue to have a lack of overall integration. This results in inefficiencies and ultimately results in increased risks to operating stations. To combat these challenges, one step is define a program that provides for the necessary linkages. An example of such a program is the Aging and Obsolescence Program (AOP) as developed by Candu Energy.

AOP has as its foundation the application of INPO AP-913 guidance for equipment reliability. The process is augmented to incorporate integration of stations needs such the identification of single point vulnerabilities, incorporation of risk identification, and development of the technical basis to support maintenance, surveillance and inspection of all equipment. The program extends to include replace or repair strategies, identification of critical spare parts and stocking parameters, through to the identification and resolution of obsolescence issues.

The systematic nature of the program provides the needed foundation to support the system and component health programs, spare parts management, and obsolescence programs. Further, program elements can be built up based upon the technical basis that is established. Finally, the elements can serve to support the safety story and enhance procurement specifications.

However, having such a program foundation will not ensure the successful implementation of an integrated equipment reliability program including aging management. A number of lessons learned have identified that steps are needed to ensure clarity and consistency during implementation and throughout the organization.

Finally, having AOP thinking as a foundation is also useful in new build designs. The systematic processes lend themselves to support equipment reliability. This serves to further enhance the link between aspects of the design and organization, such as safety and design. The same foundation also provides a basis for understanding information development needs and how they need to be managed with time. For Candu Energy, this facilitates continued development of existing software capabilities to support a highly integrated design.

6. References

[1.] INPO AP-913 "Equipment Reliability Process Description", December 2007, Rev.2

[2.] Nuclear Maintenance, Applications Centre , Considerations for developing a Critical Parts Program at a Nuclear Power Plant, EPRI 1011861, September 2007

[3.] Nuclear Utility Obsolescence Group (NUOG) Obsolescence Program Guideline December 2003, INPO NX-1037, Rev.1

[4.] Aging Management for Nuclear Power Plants Regulatory Document RD-334, Canadian Nuclear Safety Commission, 2011.