



## **OPTIMIZING IN-SERVICE INSPECTION**

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### **ABSTRACT**

In the present paper, the aspects of optimizing In-Service Inspection (ISI) is discussed. Slovenian Nuclear Safety Administration (SNSA) and its authorized organization for the ISI activities, Institute of Metals and Technologies, are permanently involved in the ISI process of the nuclear power plant (NPP) Krško. Based on this experience and additionally gathered by reviewing of the new ISI program, the decision was made to improve recent regulatory and professional practice.

Traditional criteria, standards and practice are bases for the further improvements. Improvements will be done by adding a new knowledge about the safety important components of the systems to the basic practice. It is necessary to identify conditions of the safety important components, such as realistic stress and fatigue conditions, material properties changes due aging processes, the temperature cycling effects, existing flaws characterization in the light of the previous detection and equipment technique used, assessment of the measurement accuracy on the results etc.

In addition to the above mentioned, risk assessment and evaluation of the whole ISI shall be done. To do this it is necessary to make risk evaluation, based on previous structural element probability assessment. Probabilistic risk assessment is important and one of the most powerful tools in the ISI optimization. Some basic work in the field of the risk informed methods related to the nuclear safety components has been already done. Based on reference documentation, the most important steps in risk informed ISI are discussed. Those steps are scope definition, consequence evaluation, failure probability estimation, risk evaluation, non-destructive examination method selection and possibilities of implementation, monitoring and feedback.

Recent experience on the ISI in the nuclear world show that such practice is very important during ISI decision making process and has some measurable effects too.

It is clear that classical criteria for the selection of ISI inspection locations are not completely in accordance with current measures of nuclear safety. ISI optimization shall give benefits to the operator of nuclear facility (on the resources and duration of the ISI inspections) and to the SNSA (more effective control of the safety important components, aging management control and overall nuclear safety).

## 1 INTRODUCTION

Slovenian Nuclear Safety Administration (SNSA) actively follows the In - Service Inspections (ISI) in Nuclear Power Plant (NPP) Krško (PWR, 701 MWe, Westinghouse type). Its authorized organization Institute of Metals and Technologies (IMT) helps SNSA staff during the outages to follow all important activities related to the ISI activities. Not only current ISI activities and findings are of SNSA interest, but also a systematic review of previous findings started. In these work, the IMT institute is actively involved. Some specific projects, related to ISI open questions started. In the light of recent events in nuclear world, in connection with ISI, the position of SNSA is that on the filed of ISI improvements have to be implemented.

The importance of In - Service Inspections (ISI) is very well known. Generally, the purpose of ISI is to identify conditions, that may be precursors to failure of the pressure boundary of the primary reactor coolant system piping and related components. The licensee follows the ASME Boiler & Pressure Vessel Code, Section XI, which governs overall ISI activities. Reviewing the previous ISI reports, taking into account current approach in nuclear world, the process for ISI optimization started on the field of regulatory and professional practice. On the other hand, NPP Krško initiated some Plant Life Management activities.

NPP Krško has Probabilistic Safety Assessment (PSA) studies (level 1 and 2). The results of this studies has to be used in the field of ISI too. Review of leading research projects on the ISI optimization in the world shows that all of them include PSA results. This is so called "Risk Informed Approach".

### 1.1 Inputs to the optimisation process

Starting the optimization, the following necessary steps has to be taken:

- Scope and ISI segments, subject to be optimized
- Review of existing documentation related to previous ISI
- Review of design stress analysis reports
- Operational loads in normal and transients conditions (fatigue monitoring)
- Reevaluation of aging effects
- Materials performance in the process environment
- Selection of the PSA segments to related to the ISI
- Assessment of the measurement equipment reliability

In addition to these initial steps, safety requirements and operability needs have to be taken into account. A clear decision has to be made early at the beginning and this is: to what level of optimization the overall ISI is brought and which are the goals of such process. Economic effects of the optimization are only one part of optimization. Regarding nuclear safety, the most important is to achieve more deep knowledge about real condition of the systems and components.

Classical ISI approach has been established on the basis of experience and expert knowledge from the first years of NPP operation. Based on the events and findings about safety important equipment degradation in recent years it is clear, that the existing ISI approach is not always appropriate. Many of the systems components and locations are inspected on the routine basis and in accordance with rigid time schedule. Even some portions of the primary reactor coolant pressure boundary are planned to be never inspected during whole plant design life. Some NPP's around the world are in process of introducing significant design basis changes, like "Leak Before Break Concept". Such changes requires much more

awareness to the reactor coolant system (RCS) pressure boundary, and they can be well supported by optimization of the existing ISI Program and related processes.

## 2 INSPECTION LOCATIONS

Using the PSA Study results, the probability of component segments can be assessed. In the cases, that is not possible, the use of other relevant data bases shall be used, like the industrial experience, databases of the similar installations and other sources. Effect of the failure of selected component segment shall be expressed in terms of failure probability, which then results with other failure probabilities in the "Core Damage Frequency" (CDF). On such way, the PSA assessment of the system segments should be used in reevaluation of CDF.

For described evaluation of system segments failure probability contribution to the CDF, appropriate computer code tool is available. The input parameters are usually:

- Operating conditions and loads
- Material properties
- Design limitations (stress, usage factor, other)
- Inspection reliability
- Most important degradation mechanism
- Fatigue sensitivity
- Defect growth rate estimation

Based on the engineering evaluation, the existing ISI Plans usually follow generic locations for inspection, which are:

- Welds and heat affected zones on connecting parts of RCS piping to the components and associates safe ends (reactor pressure vessel, pressurizer, primary reactor coolant pump, steam generator)
- Supports and pipe whip restraints
- Bolted connections
- Other structural elements

Detailed requests for the locations to be inspected are prescribed in Codes and standards, which are enforced to the licensee by the Regulatory Body.

To optimize location selection, licensee shall use the results of failure probability calculations described above. Considering fatigue probability calculations the new improved set of ISI locations will be established.

## 3 INSPECTION FREQUENCY

According to the existing ISI programs inspection frequency is chosen in a such way that all selected locations are inspected once in the prescribed period. In the case when optimization shows that some locations are more important than others, this fact will be taken into account in future planning of ISI inspection. It is important in the view of nuclear safety that frequency of inspections for the arbitrary ISI location is adjusted according to the newest assessment of importance of that location.

In the case of indication detection licensee shall repeat inspection on the same location more frequently, even in the case that indication is acceptable. The data need to be obtained early enough for the defect propagation assessment. The decision of more frequent ISI activities on the selected components of the systems shall be done on the detailed previous analysis. Usually the NPP operators are prepared to evaluate the indication with analytical tool, to

avoid additional examinations. To accept such possibility the opinion of the Regulatory body is necessary.

Some interesting findings about degradation of system components (like through wall leakage on safe end or control rod drive mechanism housing, boric acid degradation of pressure vessel, others) shall have strong impact on the inspection frequency. It is to expect that many of degradation mechanisms have under certain conditions much greater rate than it was expected. It means, that between last inspection and first next one unacceptable degradation can occur.

#### **4 QUALIFICATION OF ISI SYSTEMS**

To optimize ISI process it is necessary to evaluate the ISI systems in the light of their performance, reliability and overall ability to perform their function. From the many pilot projects and "Round Robin" tests it was shown that in several cases they are not completely adequate. Latest addenda to ASME Code Section XI react in several actions and international projects to assess the performance of ISI systems and to make technical justification of all relevant parameters entering ISI process.

In the light of ISI systems optimization, the group of following information shall be addressed:

- Adequacy of parameters like: component description, indication description, overall ISI performance assessment
- Inspection techniques and equipment like: adequacy of probes, data acquisition and analysis system
- Inspection procedures
- Role of new or improved technology

As the result some significant changes can be achieved in ISI program. First of all, more realistic knowledge about all segments of ISI can be obtained. That means on one hand economic benefits, on the other improvement of the nuclear safety trough more realistic and specific problematic oriented ISI activities.

It can be concluded that proper qualification of ISI systems can be treated like significant optimization of ISI system. It is foreseen that the qualification of ISI system will be done in the near future in the NPP Krško too. First steps of the above mentioned process are already done.

#### **5 OPTIMIZATION METODOLOGIES**

Reviewing different approaches from organizations like EPRI, WOG, SKIFS, EDF and others it is clear that regarding ISI optimization prevails so called "Risk Based" approach. Their experience and main goals to be achieved will be of importance for ISI effectiveness. To select an adequate risk based methodology it is necessary early in the beginning to establish appropriate selection criteria. Usually, the following criteria were put forward: technical soundness, regulatory acceptance, economic effects and consistency with licensee plant programs.

From the operator point of view the ISI optimization programs are living programs and should be monitored continuously in order to account for changing conditions in the plant. Periodic updates are necessary, based on the inputs and changes resulting from plant modification/design changes, plant procedures, equipment performance, examination results and industry failure information.

Some pilot studies performed in different countries on a selected systems have been established in recent years. Comparison of selected methodologies has been performed and the working groups published their conclusions and remarks. There are some common conclusions which are of practical importance for the countries which starts to begin optimization process:

- ISI scope and component definition: it is reasonable to divide the whole system into functional groups with the same consequence of failure
- Failure consequence evaluation: to address various failure modes and availability aspects
- Degradation mechanisms: use of quantitative and qualitative aspects, use of operating experience
- Risk evaluation: categorization of segments in selected number of risk important regions
- Expert panel work: additional validation of the categorized regions regarding safety significance
- Structural element selection: reevaluation of the existing structural elements selection regarding risk regions and safety significance
- Program updates: periodic update regarding changes in plant design (modifications), normal operating and transient loads and probabilistic analysis updates.

## 6 CONCLUSIONS

Performing ISI on a optimized way can be treated as an improvement of the nuclear safety. Slovenian Nuclear Safety Administration and its authorized organization Institute of Metals and Technologies follow the progress on this field in nuclear world. Above mentioned ISI optimization phases and milestones are under detailed evaluation in both organizations. First steps in this process are already done, that means, the scope of our activities has been determined. In addition, the reevaluation of previous ISI results started too. The main goal of this activity is to obtain clear, systematic database about status of the NPP Krško components and systems, which are subject of the ISI examination.

On the side of the licensee some improvements on the field of ISI has been done too. Their ISI group is well trained and has a lot of real, living experience. Their main efforts are oriented to new administrative requests regarding ASME XI and preparing for the third ten year period of ISI inspections. Both, regulators and ISI responsible persons from the power plant discuss frequently further actions, which are necessary. Recent important events that happened on the primary reactor coolant installations caused intensive research on different areas affecting ISI. It can be expected in near future that some optimization suggestions will be issued relating to optimization of ISI from this side too.

Generally, existing ISI practice in Slovenia can be assessed as successful, although there were no unacceptable findings in the structures and components and no corrective action were executed (with exception of degraded steam generator tubes, steam generators were replaced in year 2000). The sensitivity of the inspection techniques is sufficient. More work is in front of us regarding the frequency of future inspections, locations to be inspected and in some special cases, the need for augmented inspection has to be evaluated.

Another area, not finally regulatory determined yet is the ISI Performance Demonstration. On this topic the SNSA will need some help from the international projects, which are under progress. However, the current efforts to optimize ISI are under progress and all involved nuclear experts are aware about importance of this project. The common goal is to improve overall nuclear safety, taking into account all available knowledge and experience.

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