The use of risk indicators for establishing inspection and control priorities

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Risk-informed approach (RIA) used to support decision-making related to in-service inspections was considered in order to identify ways for establishing inspection and control priorities. The in-service inspection of piping in the Ignalina NPP has been selected as the object for research application. The inspection process studied was modelled using the integration of deterministic and probabilistic analysis methods. In order to optimise the inspection process, the focus was set on the highest risk measured as the conditional core damage frequency. It was produced by quantitatively estimated probabilities of different degradation states and conditional failure consequence probabilities. Comprehensive databases for calculation of such indicators (measures) were collected and analysed. The failure statistical analysis as well as the evaluation of inspection efficiency expressed by the probability of defect detection was also used. The databases were further investigated with a closer attention to the data variation and comparison of risk measures using the developed software. The developed software was used to perform and administrate all the risk evaluations and ensure the possibilities to compare different options and perform sensitivity analysis. The risk measures helped to define an adequate inspection program and to focus inspections on the more important locations of the study systems. This approach allowed an optimisation of the inspection program while the probabilistic and fundamental deterministic safety requirements were maintained. The approaches to define an acceptable level of the inspection program were also considered. These approaches to define an acceptable risk were considered together with the means to reduce the number of inspection sites and the cumulative radiation exposure to the NPP inspection personnel with a reduction of overall risk. The investigated issues provided a good basis for drawing conclusions about the inspection priorities, to evaluate the influence of inspection interval and to compare alternative inspection programs. The developed risk modelling methodology, the risk measures application cases and requirements were used as an initial approach to investigation of other risk-informed models of the inspection process and risk control.

Key words: risk-informed approach, in-service inspection, risk indicators, inspection and control planning

1. INTRODUCTION

Equipment at nuclear power plants (NPPs) is inspected periodically during service by non-destructive examination (NDE) in order to provide information on its current conditions and any damage, defects or degradation that may be present. In-service inspection (ISI) is a key tool in the management of NPP safety and is an important process to assure the integrity and the avoidance of failure.

The incorporation of risk insights in the ISI programs can help focus inspections on the more important locations. The RIA-supported ISI broadly consists of ranking the elements for inspection according to their risk significance and developing the inspection priorities. It provides a framework for allocating inspection resources in cost-effective manner and helps focus the activities where they are most needed.

For this purpose, the RIA can be applied as a tool for decision-making. The RIA can be used to support a new ISI program, taking into account the relative risk of the components or locations. It also can be used to optimize the level of inspection and maintenance activities corresponding to risk. The use of risk information in the optimization of the ISI program can help focus and allocate limited resources. In addition, one of the outcomes of the optimization process may be a reduction in overall operational and maintenance costs while maintaining a high level of safety.

The definition of risk is generally accepted as the product of the measure of the undesirable consequence resulting from an initiating event and the probability of that event occurring with a given period of time. In an NPP, failure or degradation of a component is clearly an initiating event that can give rise to risk.

Practical experience indicates that Inter-granular Stress Corrosion Cracking (IGSCC) is one of the most important degradation mechanisms in various NPPs. In 2000–2001, a project with the acronym IRBIS (Ignalina Risk Based Inspection pilot Study) has been implemented with the objective to perform a quantitative risk analysis and to define a new inspection priorities for some stainless steel welds in the Ignalina NPP Unit 2 [1, 2].

2. OBJECTIVES OF THE NEW INSPECTION PROGRAM

The main objectives of the RIA-supported ISI program are usually related to the estimation of the likelihood of severe damage (*e.g.*, core damage) and consequences (*e.g.*, large release of radio nuclides) and application of this information in order to select most risky components and locations for ISI and maintenance.

Using the Risk-informed Approach presented in this paper, it is possible to estimate and compare the existing ISI program with a set of new possible RIA-supported programs, and according to the safety and acceptability requirements and the optimization criteria to suggest the ISI program improvements.

In general, the risk-informed objectives and assessment steps of the new inspection program can be expressed using the following list:

- to analyze the dynamic degradation and failure mechanism;
- estimate the probabilities (P) of degradation per year (*e.g.*, estimation of pipe leak and rupture frequency);
- assess the consequences of different degradation cases and evaluate their severity according to the conditional probabilities (C) of the worst consequence due to degradation;
- formulate risk indicators (measures) (R) by the probabilities P of degradations per year and probabilities C of consequences;
- perform the risk ranking for each component or location;
- define the frequency and sites of new inspection program based on the components with the highest risks;
- estimate risk changes (*e.g.*, a new risk case – an old risk case);
- estimate costs and positive effects of the new ISI program relative to the present ISI program;
- make the appropriate recommendations to improve the operation and maintenance.

Moreover, the ISI with RIA should be considered as a living program and therefore, as part of its implementation process, the performance monitoring, periodic updating and corrective action program need to be established.

3. RISK-INFORMED ASSESSMENT

The first task for the RIA-supported ISI program is determination of the high-risk components or locations. The procedure for ISI selection can be based on the division of the overall system risk into so-called components risks, which can be expressed as the product of each component degradation frequency and a consequence expressed as the probability to degrade the overall safety.

If there are some degradation states *k* (*e.g.*, crack with a small leak, crack with a large leak) up to the maximum degradation state *D* – failure (*e.g.*, pipe rupture), the total conditional risk due to the influence of component *i* degradation on the main system can be expressed as a sum:

$$R_i = \sum_{k=1}^{D} n_i \cdot P_{i,k} \cdot C_{i,k} \,. \qquad (1)$$

Here each summand reflects the conditional risks due to the influence of the component *i* degradation state *k* on the main system, and they are assumed mutually exclusive. In fact, the risk R_i reflects the risk of a single ($n_i = 1$) component *i* or the risk of similar group *i* components with n_i components to influence the overall risk to degrade the safety of the system. As an example, in nuclear industry the influence of the overall risk can be expressed as Conditional Core Damage Frequency (CCDF), where the overall system risk reflects the total Core Damage Frequency (CDF). The conditional risk due to some subsystem S specific degradation states influence the overall system safety and can be expressed as follows:

$$R_S = \sum_{i=1}^{N} R_i = \sum_{i=1}^{N} \sum_{k=1}^{D} n_i \cdot P_{i,k} \cdot C_{i,k} \,. \qquad (2)$$

In practice, the conditional probability to degrade the safety of a system (consequence $C_{i,k}$) can be assessed as the safety barrier. As an example, the CCDF for different postulated Loss of Coolant Accident (LOCA) events can be used as such a safety barrier. These safety barriers in most cases can be taken from PSA evaluations. The calculation of degradation state occurrence frequencies (probabilities of occurrence per time unit) usually needs a separate model, which includes the information and assumptions related to inspection procedure and reliability.

In most cases, the probability of failure per year is considerably less than other degradation state probability: $P_{i,D} < P_{i,k}$, where $k < D$. However, the risk is not so predictable, because it also depends on the consequences, for which a corresponding comparison usually gives the opposite inequality: $C_{i,D} > C_{i,k}$, where $k < D$.

As an example, the CCDF profile per weld, for two degradation states (weld leak and rupture) of ISI case before 2001 in the Ignalina NPP are presented in Fig. 1.

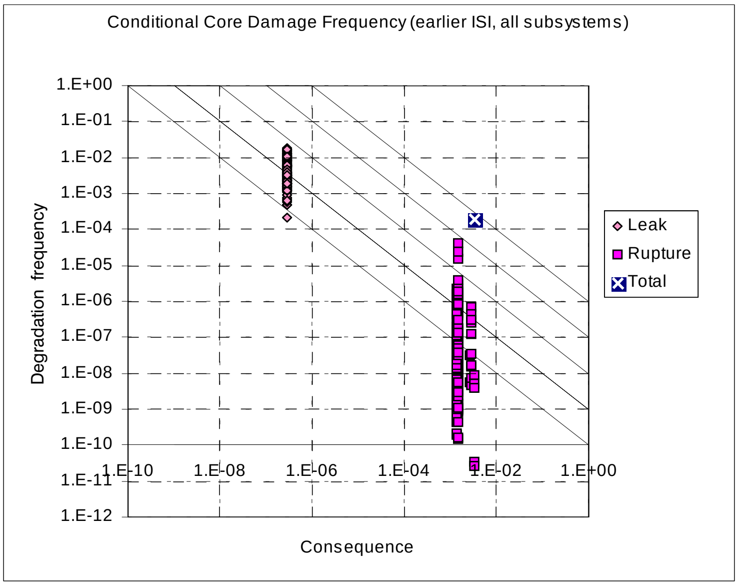

Fig. 1. Conditional Core Damage Frequency

The C and P values are estimated for each state of degradation for each similar weld in a pipe subsystem. In order to simplify the CCDF chart interpretation according to the predominant risk, it can be defined only by two generalized values, C_{Plot} and P_{Plot} (only one point coordinate), for each component.

In case of two degradation states,

$$R_i = n_i \cdot P_{i,1} \cdot C_{i,1} + n_i \cdot P_{i,2} \cdot C_{i,2} = P_{i,Plot} \cdot C_{i,Plot}; \tag{3}$$

$$C_{i,Plot} = \begin{cases} C_{i,1} \text{ if } P_{i,1} \cdot C_{i,1} > P_{i,2} \cdot C_{i,2} \\ C_{i,2} \text{ if } P_{i,1} \cdot C_{i,1} \le P_{i,2} \cdot C_{i,2} \end{cases}; \quad P_{i,Plot} = \frac{R_i}{C_{i,Plot}}. \tag{4}$$

In case of D degradation states

$$C_{i,Plot} = \arg\max_{C_{i,k}} \max_{k \in (1,D)} (P_{i,k} \cdot C_{i,k}); \; P_{i,Plot} = \frac{R_i}{C_{i,Plot}}. \tag{5}$$

The total risk R^* coordinates can be expressed as follows:

$$C^* = \arg\max_{C_{i,Plot}} \max_{i \in (1,N)} C_{i,Plot} \text{ and } P^* = \frac{R^*}{C^*}. \tag{6}$$

This general model of risk-informed assessment and result visualization can be used in modeling various complex inspection processes. As examples of the partial case with additional assumptions for assessment of the frequencies of inspected pipe leak and rupture, references [1, 3] can be used.

4. RISK CATEGORIZATION AND RANKING

When the risk for all components is determined, a procedure for risk ranking can be applied in order to define the high risk components. The objective of the risk-ranking process is to form the component groups with different risk category and to focus inspection activities on the risk-significant components in order to decrease the failure frequency or possible undesirable consequences of this failure. The risk categories can be used for this purpose. They are directly dependent on failure category and consequence category. The failure category is an engineering estimate of the likelihood of failure. The consequence category is based on the margin in system capacities to mitigate the component failure and the margin in safety-important systems to reach a critical level. The consequence severity can be used to classify the component failures in different categories of safety significance. The likelihood of failure allows to focus the inspection on the most critical parts or the subsystems. If it is important to determine risk significance, the risk categories and risk ranking can be used to guide the ISI selection, without separate ranking according to the categories of failure and consequence. As an example, the five risk levels (categories) defined according to the profile (see Fig. 3) of CCDF values of different welds at the Ignalina NPP are presented in Table 2. The risk ranking and suggestion for a new program was based on the CCDF for only earlier inspections in the P-plot *versus* C-plot format.

Table 1. **Risk levels defined according to CCDF**	
Relatively Very High Risk	1E-08 ≤ CCDF
Relatively High Risk	1E-09 ≤ CCDF < 1E-08
Relatively Medium Risk	1E-10 ≤ CCDF < 1E-09
Relatively Low Risk	1E-11 ≤ CCDF < 1E-10
Relatively Very Low Risk	CCDF < 1E-11

The relative risk levels are specified so that the very high-risk level always contains the most significant risk component. The application of such risk levels can be also related to a specific risk profile (see Fig. 3) of each subsystem. As an example, the different amount of welds can be selected, if the inspection extent less than 100% is used for any risk level in the whole risk profile and separately in each subsystem. The selection according to each subsystem is more conservative (*e.g.*, Fig. 3).

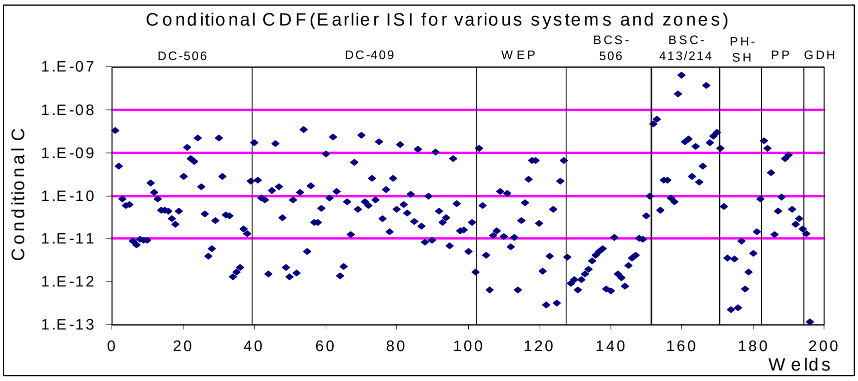

Fig. 2. CCDF value profile for different pipe subsystems

The number of risk levels and the risk interval assigned to each level are the subject of global optimization. Typically, the interval of each risk level is of the same length. The equal intervals are more effective for the management with a relative risk. The amount of intervals is directly proportional to the possibilities of inspection management and is inversely proportional to the complexity and amount of different combinations.

It should be noted that expressions concerning risk levels are used only in a relative sense. In the risk-informed methodologies, it is recognized that there are many variables in calculating the risk, and the determination of absolute risk numbers is often not cost-effective. Risk-informed inspections are more focused on a systematic determination of relative risks. In this way, facilities, units, systems, equipment, or components can be ranked based on the relative risk. The relative risk serves to focus the risk management efforts on the highest-ranked risks without considering the more uncertain absolute values of risk.

5. INSPECTION INFORMATION RELIABILITY

The probability of not detecting a degradation is only one of the many functions in the risk model, which can be improved in the new inspection program. The determination of this function usually is a complex task, however, separation of controllable parameters and construction of at least a relatively representative model are very useful for risk managing. The probability of not detecting a consequence of degradation (*e.g.*, leak) typically is not managed, as this is related to some features of detection techniques and assumptions (*e.g.*, leak before break), which are related rather to the physical characteristics of the equipment and system.

One clearly important factor which affects other factors of the reliability of inspection is inspection availability and components accessibility. For example, the following three accessibility groups were separated using the accessibility index in the Ignalina NPP. The values of such indices by experts were defined as follows:

1 – good accessibility (automatic and manual inspection);

2 – normal accessibility (manual inspection only);

3 – poor accessibility (manual inspection with difficulties).

This index can be used for classification of inspection effectiveness. In order to define the quantitative values showing inspection effectiveness, the model of Probability of Detection (POD) can be used. Then the probability of not detection degradation is

$$P_{ndd} = 1 - P_{dd}, \quad (7)$$

where for definition of the detection probability P_{dd} a suitable lognormal or logit models can be applied. The P_{dd} in the case of the lognormal distribution model has the following form:

$$P_{ss}(s) = \Phi(c_1 + c_2 \cdot \ln(s)), c_1 \in R, c_2 \geq 0. \quad (8)$$

The P_{df} in the case of the logit distribution model is as follows:

$$P_{ss}(s) = \Phi(c_1 + c_2 \cdot \ln(\frac{s}{1-s})), c_1 \in R, c_2 \geq 0. \quad (9)$$

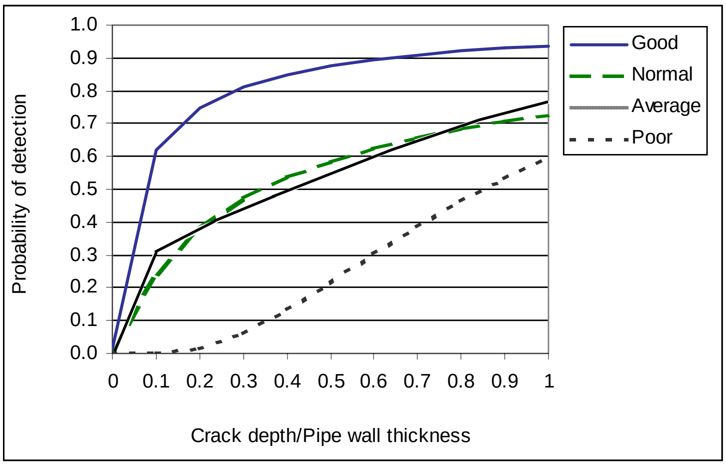

Fig. 3. Probability of detection *versus* relative size

Here Φ denotes the normalized Gauss distribution function, c_1 and c_2 are the parameters of the corresponding regression model and represent the appropriate inspection effectiveness. It should be also noted that in the case when the degradation sizing s is N-dimensional, these models can be extended. When the detection probability is determined from "hit / miss" data, the probability of detection as a function of the relative degradation size $P_{dd}(s)$, is estimated from the binary information. If there is no such information, the relative and robust expert estimations can be used. As examples, in Fig. 4 and Table 3 are presented the estimations used for modeling IGSCC cracks' ISI at the Ignalina NPP.

Table 2. **Lognormal model coefficients**

Type of inspection efficiency	c_1	c_2
Good efficiency (good accessibility)	1.526	0.533
Normal efficiency (normal accessibility)	0.600	0.560
Poor efficiency (poor accessibility)	0.240	1.485

In the case when the empirical data are available, the information can be analyzed statistically. The empirical or experimental degradation sizing data consist of the measured degradation sizes and the corresponding true degradation sizes. Often the simplest form of the statistical models applied to the measured size *versus* true size data is a linear regression. Instead, the more precise Bayes' probability updating approach can be used [4].

6. REQUIREMENTS FOR INSPECTION PROGRAMS

The inspection program can be defined by using RIA to solve the problems presented in Fig. 1. A good ISI supported by RIA shall be able to solve these problems. The benefit of the RIA-based new program should be quantified in measurable values. Such measures in nuclear industry can be changes expressed using the total system CDF or Large Early Release Frequency (LERF). The change of CDF (or correspondingly LERF) can be defined as follows:

$$\Delta CDF = CDF(\text{new program}) - CDF(\text{current program}). \quad (10)$$

The possible new ISI program can be based on different locations of inspection, on intervals between inspection, and on inspection techniques. The additional inspection activities on high-risk locations in separate subsystems causes ΔCCDF ≤ 0 and, at the same time, ΔCDF ≤ 0 and ΔLERF ≤ 0. In addition, if very low risk locations from the ISI program will be removed, the total inspection activities and unnecessary radiation exposure to the plant personnel can be reduced with possibly only a small increase in ΔCDF and ΔLERF. For different combination of inspection activities, it is possible to evaluate the ΔCCDF. In this way, the benefit of the new ISI supported by RIA can be quantified in relation to the current ISI program.

The Lithuanian Nuclear Regulation requires: "In order to avoid the necessity of evacuating the population to distances beyond the limits laid down in the standards for nuclear plant sitting, an effort should be made to ensure that the probability of the worst possible emergency release of radioactive materials specified in the standards does not exceed 10^{-7} per reactor year". In addition, there is stated that the target CDF per reactor year is less than 10^{-5}. However, in Lithuania as well as in the majority of IAEA member countries there are still no formal requirements for ΔCCDF evaluated for PSA-supported ISI.

The USNRC has adopted Probabilistic Safety Criteria (PSC) for assessing changes in the plant design or operational practices. In the regulatory guide RG 1.174 [3], PSC have been established that can be used to justify changes in the plant's licensing basis, taking into consideration the impact on plant risk to assess when changes in plant risk might be acceptable.

Based on the mentioned practice, the following acceptable guidelines for changes in risk measures can be proposed:

- If ΔCDF ≤ 0 or ΔLERF ≤ 0, then the change is acceptable.

• If ΔCDF > 0, then the change should be 10 times smaller than the absolute CDF (similar criteria can be used for LERF).

The second statement above differs from the NRC guidelines, in order to have a more conservative acceptance criterion, which is based not on an absolute measure of risk. Depending on the chosen PRA procedure, there will always be a certain degree of uncertainty in the absolute CDF values. The alternative criterion based on relative risk values can be as follows:

$$\Delta\text{CDF} \;/\; \text{CDF} < 0.1. \tag{11}$$

This means to require that the increase of CDF in a relative sense should be small or negative. In practice, a combination of absolute and relative acceptance criteria is probably the best. A criterion based on an absolute measure of the CDF can still be desirable to achieve as a general objective to reach a sufficiently small total CDF for the plant.

The new ISI program can be regarded as a very good inspection program where the CCDF for an inspected system, the total CDF together with the number of future inspections and radiation exposure are reduced compared to the currently planned inspection program. The RIA is a systematic evaluation approach, which can be used to satisfy the defined requirements and to optimize the inspection program.

7. NEW INSPECTION PROGRAM OPTIMIZATION

The RIA methodology involves a systematic and quantitative risk consideration for components, subsystems, and systems. Risk assessment is used to address the severity of consequences and the likelihood of degradation. The combination of these two parameters allow determination of the risk significance of the different components (*e.g.*, pipe welds) to be considered for the inspection programs. The relation between risk and inspection activities can help determine an adequate and optimum inspection program. The following target function for optimization of risk and inspection activities can be proposed:

$$F_{IR}(I) = \sqrt{I_N^2(\text{Activities}) + R_N^2(\text{Risk})}\,, \tag{12}$$

where I_N and R_N are normalized measures of inspection activities and risk (corresponding to a normalized ISI amount and normalized CCDF). The notation I represents a set of parameters specific of the concerned inspection program.

Then the task of optimization, developing of a new ISI program, can be defined by minimization of this target function F_{IR} and satisfying the requirements mentioned in the previous section. The optimal ISI program can be defined as follows:

$$I^* = \arg_{r\in(1,2,\ldots,L);\; p_r\in \underset{(0,\ldots,T)}{\min};\; e_r\in(0\%,\ldots,100\%)} F_{IR}(I(p_r, e_r)), \tag{13}$$

where $I(p_r, e_r)$ is interpreted as an ISI program with the following parameters: p_r – the period between inspections for risk level, r and e_r – the extent of each inspection for risk level r. The highest risk lever index $r = 1$. The amount of risk levels is denoted as L. In general, the minimization should be performed according to all possible p_r and e_r on each risk level r. The number of such combinations can be very huge. In order to decrease the number of unnecessary combinations, the additional conditions can be used [2]. The automatic optimization typically use the conditions that are more formal and require less man recourses, so there are more possibilities to find a most optimal solution and to confirm that with a given precision it is the best. The developed software can perform and administrate all risk evaluations, ensure the possibilities to compare different options and find the most optimal one.

8. CONCLUSIONS

An overview of the objectives and needs for inspection and maintenance programs was presented together with Risk-Informed Approach (RIA). For risk-related systems, the RIA-based model with a range of risk measures is an efficient tool to identify the relative importance of the system components. Therefore, a RIA-supported deterministic assessment can be used in connection with PSA in order to identify the safety significance of inspection activities, to focus the analysis and activities on the key components, and to optimize inspection and maintenance both from the safety and the economic standpoint.

The total amount of inspection sites and the cumulative radiation exposure to the NPP inspection personnel can be reduced together with total risk. This was demonstrated by presenting RIA-based formal models, using assumptions and requirements proposed criteria of acceptability, optimization approach, some examples related to the Ignalina Nuclear Power Plant (RBMK-1500) piping components and developed software.

Using the above approach, a new efficient risk-informed inspection and maintenance program can be suggested and compared with other alternatives. The proposed integrated modeling method and the general model of inspection process can be used as a base for other risk-informed models of inspection process control and risk monitors of complex dynamic systems.

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RIZIKOS RODIKLIŲ PANAUDOJIMAS NUSTATANT KONTROLĖS IR VALDYMO PRIORITETUS

S a n t r a u k a

Į riziką atsižvelgianti metodika naudojama priimant sprendimus, susijusius su eksploatacine kontrole. Straipsnyje nagrinėjami kontrolės ir valdymo prioritetų nustatymo būdai, panaudojant šią metodiką. Tyrimų taikymo objektas – Ignalinos AE vamzdynų eksploatacijos kontrolė. Tiriamajam kontrolės procesui modeliuoti naudota metodika, jungianti deterministinės ir tikimybinės analizės metodus. Kontrolės procesas optimizuotas atsižvelgiant į didžiausią riziką, išreikštą sąlyginiu aktyviosios zonos pažeidimo dažniu. Jis gautas kiekybiškai įvertinus skirtingų degradacijos būsenų bei sąlygines gedimų pasekmių tikimybes. Šiems rodikliams skaičiuoti buvo sukurtos ir išanalizuotos išsamios duomenų bazės, atlikta statistinė gedimų analizė bei įvertintas kontrolės efektyvumas, išreikštas defekto aptikimo tikimybe. Šios duomenų bazės vėliau buvo išanalizuotos naudojant sudarytą programinę įrangą, atkreipiant dėmesį į duomenų kitimą ir lyginant rizikos rodiklius. Sudaryta programinė įranga buvo naudojama rizikai įvertinti ir patikrinti, taip pat skirtingoms alternatyvoms palyginti ir jautrumui analizuoti. Remiantis rizikos rodikliais, buvo sudaryta kontrolės programa, akcentuojanti svarbiausių nagrinėjamos sistemos vietų kontrolę. Ši metodika įgalina optimizuoti kontrolės programą, atsižvelgiant į tikimybinius ir fundamentalius deterministinius reikalavimus. Greta priimtinos rizikos nustatymo būdų buvo nagrinėjamos inspektuojamų vietų skaičiaus ir spinduliuotės dozių kontroliuojančiam personalui mažinimo priemonės, kartu mažinant bendrąją riziką. Ištyrinėtos problemos pagrindžia išvadas apie kontrolės prioritetus, kontrolės intervalų įtakos įvertinimą ir alternatyvių kontrolės programų palyginimą. Tirtoji rizikos modeliavimo metodika, rizikos rodiklių taikymas ir reikalavimai buvo panaudoti kaip pradinė metodika kitų į riziką atsižvelgiančių kontrolės procesų ir rizikos valdymo modelių tyrimams.

Raktažodžiai: į riziką atsižvelgianti metodika, eksploatacijos kontrolė, rizikos įvertis, kontrolės ir valdymo planavimas

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ПРИМЕНЕНИЕ ПОКАЗАТЕЛЕЙ РИСКА ДЛЯ УСТАНОВЛЕНИЯ ПРИОРИТЕТОВ КОНТРОЛЯ И УПРАВЛЕНИЯ

Р е з ю м е

Основанный на риске подход применяется для принятия решений, связанных с эксплуатационным контролем. В настоящей статье исследуются способы установления приоритетов контроля и управления с использованием данной методики. Объектом применения исследований отобран эксплуатационный контроль трубопроводов Игналинской АЭС. Для моделирования исследуемого процесса контроля была использована методика, объединяющая методы детерминистического и вероятностного анализа. Инспекционный процесс оптимизирован относительно наивысшего риска, выраженного условной частотой повреждения активной зоны. Она получена количественно оценив вероятности различных деградационных состояний и условные вероятности последствий отказов. Для вычисления этих мер были произведены и проанализированы обширные базы данных. Также был проведен статистический анализ отказов и оценена эффективность контроля, выраженная вероятностью обнаружения дефекта. Базы данных далее были исследованы, используя разработанное программное обеспечение, привлекая внимание на изменение данных и сравнивая меры риска. Разработанное программное обеспечение использовалось для оценки риска и проверки, а также для сравнения различных вариантов и анализа чувствительности.

Использованные меры риска помогли разработать адекватную эксплуатационную программу, сосредоточенную на контроль более важных мест рассматриваемых систем. Такой подход позволяет оптимизировать программу эксплуатационного контроля, придерживаясь вероятностных и фундаментальных детерминистических требований. Также были рассмотрены подходы определения приемлемого уровня программы эксплуатационного контроля. Исследованные подходы определения приемлемого риска рассмотрены вместе со средствами уменьшения числа инспектируемых участков и радиационных доз для инспектирующего персонала, со снижением общего риска. Полученная информация обеспечила хорошую основу для выводов о приоритетах контроля, оценки влияния интервала между контролями и сравнения альтернативных программ контроля. Исследованная методология моделирования риска, случаи применения мер на основе риска и требования были использованы как исходная точка для других основанных на риске моделей процессов контроля риска и управления им.

Ключевые слова: подход, основанный на риске, эксплуатационный контроль, меры на основе риска, планирование контроля и управления