FEASIBILITY STUDY OF ENGINEERING AND ORGANIZATIONAL SOLUTIONS FOR NUCLEAR FACILITY DECOMMISSIONING WITH NRS PROVISIONS BEING ACCOUNTED FOR

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The report presents a flowchart and an algorithm allowing the selection of optimal process operations for the decommissioning of nuclear facilities. It also allows to evaluate the sustainability of the selected option considering the uncertainties associated with the initial data for the comprehensive engineering and radiation survey, which also generates uncertainties in the indicators available under the selected options. The choice of the optimal option is based on a complex indicator integrating particular indicators in the form of a linear superposition for each considered decommissioning option. The optimal option is selected by repeated implementation of particular indicators for each considered option using the Monte Carlo method. Then the options are ranked according to the complex indicator in a descending order with the total number of positions calculated for each option. The best option is the one with the minimum total number of positions.

Keywords: *radioactive waste, nuclear facilities (NF), decommissioning (DE), process operations, optimal option, particular indicators, complex indicator, the Monte Carlo method, sustainability of the selected option.*

Assessment of decommissioning options for nuclear facilities

Listed below are a few key physical characteristics typical for structures that are required to calculate the indicators of a facility subject to decommissioning.

Each design has uncertain numerical characteristics set via a pair of values — the average value (mathematical expectation), P_{av} and standard deviation, σ_p:

1) material volume (weight, area, length indicating the qualitative characteristics of materials taken into account in the calculation of process indicators for dismantling, decontamination, processing, transportation, disposal and others operations);

2) characteristics (indicators) of radiation contamination (RW volume, its type, etc.).

Each design (element) corresponds to a set of several possible decommissioning operations. For each pair of “structure — process operation”, particular indicators with errors described by standard deviation are calculated — σ.

The below set was taken as basic partial indicators characterizing both the "structure — process operation" pair and the choice of process operations in general:

1) cost of work — CP_i, σ_{CPi};
2) duration of work — DL_i, σ_{DLi};
3) dose load on personnel — DNP_i, σ_{DNi};
4) dose load on the population — DNN_i, σ_{DNNi};
5) impact on the environment (volumes of emissions and discharges of radioactive substances) — BC_i, σ_{BCi}.

CP_i DL_i, DNP_i, DNN_i, BC_i stand for average partial indicators; σ_{CPi}, σ_{DLi}, σ_{DNi}, σ_{DNNi}, σ_{BCi} — standard deviations for these indicators.

For each decommissioning option with several possible process operations ($i = 1,\ldots, n$), a complex indicator K_i is calculated:

$$K_i = \alpha_1 CP_{Hi} + \alpha_2 DL_{Hi} + \alpha_3 DNP_{Hi} + \alpha_4 BC_{Hi} + \alpha_5 DNN_{Hi}, \quad (1)$$

where α_j, $j = 1, \ldots, 5$ — introduced (accepted) priority coefficients for partial indicators $0 \leqslant \alpha_j \leqslant 1$, $\Sigma_{j=1}^{5} \alpha_j = 1$, CP_{Hi}, DL_{Hi}, DNP_{Hi}, BC_{Hi}, DNN_{Hi} — normalized values of partial indicators calculated, for example, for the indicator CP_{Hi} according to the following equation (2):

$$CPH_i = (CP_{max} - CP_i) / (CP_{max} - CP_{min}), \quad (2)$$

where: $CP_{max} = \max(CP_1, \ldots, CP_n)$; $CP_{min} = \min(CP1, \ldots, CP_n)$.

Similarly, the rest of the indicators and their standard deviations are normalized.

Partial indicators K_{ijk}, $k = \overline{1, N}$, are played for each option representing a possible set of process operations $i = 1,\ldots, n$, $j = 1,\ldots, 5$ (k is the number of a draw). For Monte Carlo simulation, the normal distribution of a random variable $N\left(\bar{K}_{ij}; \sigma_{ij}\right)$ is used.

For each option representing a possible set of process operations, a histogram of a complex indicator distribution is plotted (Figure 1).

Selection of an optimal decommissioning option

Complex indicator is ranked (for each specified $k = \overline{1, N}$, separately):

$$K_{(1)k} \geqslant K_{(2)k} \geqslant \ldots \geqslant K_{(n)k} \quad (3)$$

and the total number of positions in (3) is calculated for each option representing a possible set of process operations:

$$n_i^+ = \sum_{k=1}^{N} (n)_{(i_k)k}, \; i = \overline{1, N}, \quad (4)$$

where $(n)_{(i_k)k}$ is the position number of the i-th option representing a possible set of process operations during the k-th drawing.

Option i^* with the smallest n_i^+ ($n_{i^*}^+ = \min\limits_{i=1,n} \{n_i^+\}$) is considered optimal.

In particular, if $n^+_{i^*} = N$ (the minimum possible), then the i^*option will be called absolutely priority or absolutely stable, otherwise, $n^+_i > N$, then the option representing a possible set of process operations with the number i^* will be called relatively stable.

The stability index is calculated as follows:

$$St_{i^*} = (nN - n^+_{i^*}) / (nN - N). \quad (5)$$

For the optimal set of process operations with the number i^*, it is equal to 1 if this option is absolutely stable.

The higher is the St_{i^*} (closer to 1) for a possible set of process operations with the number i^*, the more stable is this optimal option.

Figures 1 and 2 show stability histograms based on the calculated complex indicators and stability indicator using the Monte Carlo method for four options representing possible sets of process operations.

Based on Figures 1 and 2 one can see that the second option representing possible set of process operations with a stability index of 0.796 is optimal and conditionally stable.

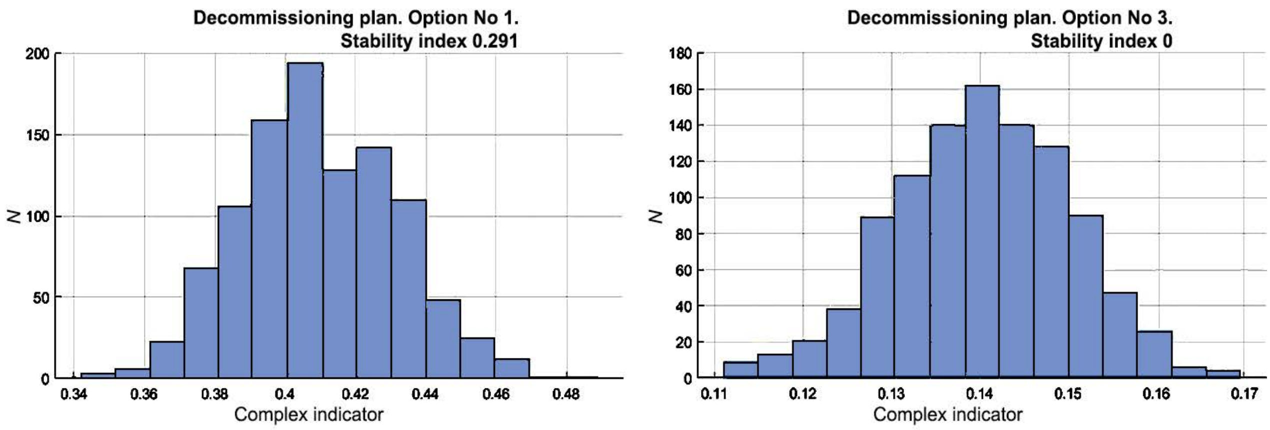

Figure 1. Stability calculations by the Monte Carlo method for options No. 1, 3 assuming equal priority coefficients of partial indicators

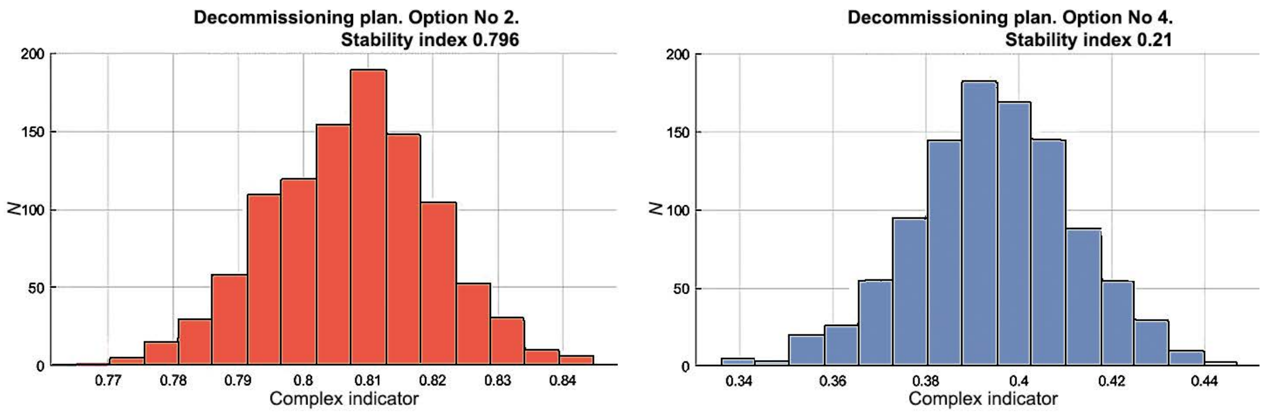

Figure 2. Calculated stability by the Monte Carlo method for options No. 2, 4 with equal priority coefficients of partial indicators

Conclusion

It should be noted that a number of papers [1—7] was devoted to various aspects relevant to the evaluation of possible nuclear decommissioning options and their implementation. The flowchart presented in this article is used in the system supporting optimal decision-making in the field of nuclear decommissioning [8]. The paper presents the scientific research performed under contract No. 313/1685-D funded by JSC Science and Innovations.

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Bibliographic description

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