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NPP KRŠKO DECOMMISSIONING CONCEPT

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ABSTRACT - At the end of the operational lifetime of a nuclear power plant (NPP) it is necessary to take measures for the decommissioning as stated in different international regulations and also in the national Slovenian law. Based on these requirements Slovenian authorities requested the development of a site specific decommissioning plan for the NPP KRŠKO.

In September 1995, the Nuklearna Elektrarna Krško (NEK) developed a site specific scope and content for decommissioning plan including the assumptions for determination of the decommissioning costs. The NEK Decommissioning Plan contains sufficient information to fulfill the decommissioning requirements identified by NRC, IAEA and OECD - NEA regulations. In this paper the activities and results of development of NEK Decommissioning Plan consisting of the development of three decommissioning strategies for the NPP Krško and selection of the most suitable strategy based on site specific, social, technical, radiological and economical aspects, cost estimates for the strategies including the costs for construction of final disposal facilities for fuel/high level waste (fuel/HLW) and low/intermediate level waste (LLW/ILW) and scheduling all activities necessary for the decommissioning of the NPP KRŠKO are presented.

INTRODUCTION

Decommissioning, as defined for nuclear facilities, is a set of activities taken at the end of the facility's operating life to ensure the continued protection of the public from any residual radioactivity or other potential hazards present in the facility. Dismantling of the retired nuclear power plant was always considered a part of the successful implementation of a nuclear energy. Until now more then 70 nuclear facilities were decommissioned in various countries worldwide. Based on the accumulated experience, decommissioning of nuclear power plants is considered technically matured undertaking. The legal and technological framework for plant decommissioning is already in place and tested, although further improvements and enhancement are expected in the future.

SELECTION OF DECOMMISSIONING STRATEGIES AND SCENARIOS

The development and selection of appropriate strategies for the decommissioning of the NPP Krško is executed in two steps:

- The selection of basic strategies based on international standards and experiences
- The definition and selection of scenarios within the strategies, considering exemption levels, occupational exposure limits, waste management etc.

The main criteria for the selection of an appropriate decommissioning strategy for the NPP Krško are the international definitions and experiences given in Table 1.

Table 1: International Decommissioning Strategies

IAEA Definitions	
Stage 1	Systems and components are closed, all barriers are kept in a state appropriate to the remaining hazard
Stage 2	Systems and components which can be easy dismantled are removed
Stage 3	All radioactive inventory is removed, the residual contamination has been reduced below regulatory limits
US Decommissioning Strategies	
DECON	Immediate removal of the complete radioactive inventory, the residual contamination has been reduced below release limits
SAFSTOR	Removal of the radioactive inventory after a safe storage period of 30 to 50 years, the residual contamination has been reduced below release limits
ENTOMB	Enclosure of the radioactive inventory in a monolithic concrete structure for a period of 100 to 300 years, after entombment the enclosed components are non-radioactive
German Decommissioning Strategies	
Immediate Dismantling	Immediate removal of the complete radioactive inventory, also the buildings are removed
Later Dismantling	Removal of the radioactive inventory after a safe storage period of 30 years, also the buildings are removed

Every strategy include some more aspects of the national conditions and requirements of the Republic of Slovenia and the technical, radiological and economical influences. This aspects are valid for all decommissioning strategies and called "scenarios". The legal requirements and licensing basis for the NPP Krško decommissioning plan are presented in the law of Republic of Slovenia supported by international guidelines, standards and industry practice. Regulatory rules are needed to control the impacts of decommissioning to the environment and define acceptable limits to man and society. Regulations exist or are still under development to control these effects. International recommendations for exemption levels are given in the IAEA Safety Series No. 89 and the EC Radiation Protection No. 43. Detailed site release criteria or specific exemption levels in terms of radioactivity contents have so far not been established in most countries. Hence most decommissioning plans are still based on assumptions in this respect.

Protection of workers is an important consideration particularly in keeping with the principle of "As Low As Reasonable Achievable" (ALARA) for exposure reduction. The regulatory dose limits for the workers at nuclear power plants are similar in most countries and corresponding to the ICRP recommendation of 50 mSv/year.

In the Republic Slovenia the Agency for Radwaste Management is responsible for the establishment of the general strategy for fuel/HLW- and LLW/ILW-management. Regarding the spent fuel management an overview of the international practice and an analysis of the existing possibilities in Slovenia have been completed resulting in some studies. The conclusion provided by these studies was that at present the reprocessing of the spent fuel from NPP Krško is not considered as an optimal solution for a country with such a small nuclear program as it is in Republic of Slovenia. The direct disposal of spent fuel and with this a deferred solution has been recommended.

The decommissioning gives rise to a considerable amount of radioactive waste. At nuclear power plants most of this is usually low-level waste, but a comparatively small amount of intermediate-level waste (e.g. Rx vessel internals) is also produced. One of the most important factors affecting decommissioning strategies and costs are the treatment, handling and final disposal of the radioactive materials and waste.

Based on the specific radiological and economical conditions and requirements of the Republic of Slovenia, the following three strategies are selected:

- STRATEGY IMMEDIATE DISMANTLING (SID) - The SID gives a result depending on the highest level of radioactivity and dose rates. The site is useable as fast as possible.

- STRATEGY LATER DISMANTLING (SLD) - The SLD shows the influence of the radiation decay to the dismantling work. The SLD includes a safe storage period of some decades. In this period an operating expenditure is necessary. Comparing the SLD to the SID lower cost for the dismantling are assumed (based on the lower level of radioactivity) but the expenses during the safe enclosure period are additional to the dismantling cost.

- STRATEGY ENTOMBMENT (SET) - The meaning of the SET in this study is to use the advantage of a decay period of some decades preventing the operating expenditure of the SLD. The entombment is terminated after the same time like the SLD safe enclosure period. The difference to the SLD is spending more expenditure on the preparation of the entombment than on the preparation for the safe enclosure but to prevent the operating expenditure in the decay period.

BOUNDARY CONDITIONS AND ASSUMPTIONS

A cost calculation is understandable and repeatable if the boundary conditions and assumptions are well defined. For this purpose the main assumptions (in addition to already given statements) are listed below:

- The decommissioning of the plant is planned for the year 2023.
- At the beginning of decommissioning activities all systems and installations on site necessary for the execution of decommissioning are in an operable condition.
- Parts and materials exposed to neutron radiation during operation are activated and contaminated. All other non-activated parts and materials from the controlled area are assumed to be contaminated unless control measurements reveal that there is no contamination above the release limits.
- Requirements pertaining to licensing procedure are based on the US NRC 10 CFR Regulations and Slovenian laws.

- In the strategy "Later Dismantling" a common license for the preparation for safe enclosure and for the safe enclosure period itself is applied. The same holds true for the preparation of entombment and the entombment period.
- The documents to be submitted for obtaining the license represent the total plan for the decommissioning. After the issue of the license a detailed documentation of the decommissioning phases according to the supervisory proceedings of nuclear law is submitted to the authorities.
- The demolition of the controlled area buildings is executed after the decommissioning of the controlled area. All other buildings are demolished parallel to the decommissioning activities.
- The non-radioactive concrete arising from the demolition of buildings can be recycled. Foundations are also removed. As much as possible of the non-radioactive concrete is used to fill up the pits.
- For the purpose of the study is assumed that the work is carried out by the plant personnel as much as possible. For other tasks external Slovenian companies are taken into account.
- The price level of the estimated cost is Dec. 31, 1995.
- The exemption levels are assumed based on the recommendation of the European Commission (EC Radiation Protection Recommendation No. 43).
- The occupational dose limits are regulated in Slovenia based on the "ALARA" principle.
- The spent final disposal is in a deep geological repository with a depth of about 500 m.
- The spent fuel is packaged in copper/steel canisters like the Swedish model. The costs for the construction of the final repository for spent fuel are estimated on the calculated Swedish and the German repository costs. For storing the Krško fuel a five year operating period of the final disposal is estimated. The final disposal is closed after the Krško fuel are stored.
- For the theoretical case "no final disposal is available at the time of decommissioning the Krško plant" a cost sensitivity analysis for a temporary storage period is generated like follows: The fuel elements are dry packaged in cast iron casks (e.g. German CASTOR cask) and stored in a external storage facility. For the temporary storage a period of 20 years is assumed. At the end of the temporary storage period the fuel elements have to be repackaged into final disposal canisters. After re-packaging of the fuel elements the cast iron casks are decontaminated and can be reused or recycled. The interim storage facility is decommissioned after the final disposal of the fuel elements.
- Operational LL-/IL-waste and treated operating media are packaged in 200 l drums and TTC's, solid decommissioning LL-/IL-waste in 10 foot container, treated liquid decommissioning LL-/IL-waste in 200 l drums and TTC's and decommissioning secondary LL-/IL-waste in 200 l drums and TTC's
- To reduce the amount of intermediate level waste to be stored the Rx-internals, the Rx and the high contaminated components will be stored on site for a period of 60 to 100 years. At the end of the storage period the components can be handled and cut manually, expensive remote controlled techniques are not necessary.
- One near surface disposal for LLW/ILW and one deep geological disposal for fuel/HLW are assumed
- Two near surface disposals for LLW/ILW and two deep geological disposals for fuel/HLW (Slovenia and Croatia) are assumed for sensitivity analysis purposes

The amount of labor necessary for decommissioning and dismantling of the plant is calculated by STILLKO 2 for each working package. On the basis of the assumed local radiation levels, the required number of personnel in the controlled area and the required duration, the total exposure to radiation of the personnel is determined.

RESULTS

Based on definitions of strategies and scenarios, the costs for the three decommissioning strategies are calculated as absolute values (Table 2). The price level for the calculation is Dec. 31, 1995. For all three strategies the cost for planning and construction of the final repository is estimated at 293 MioDM and the post-operational fuel handling cost at 152.8 MioDM.

Table 2: Main Results

	Immediate Dismantling-	Later Dismantling	Entombment
Total cost	295.0 MioDM	339.0 MioDM	244.5 MioDM
Cost in the POP except fuel	74.0 MioDM	74.0 MioDM	74.0 MioDM
LL-IL-Waste repository: planning, construction and operation cost	71.0 MioDM	71.0 MioDM	71.0 MioDM
Melting facility: planning. construction and operation cost	12.2 MioDM	12.2 MioDM	12.2 MioDM
Waste management LLW/ILW including decay storage	49.1 MioDM	22.7 MioDM	8.2 MioDM
Decommissioning cost	88.7 MioDM	159.1 MioDM	79.1 MioDM
Duration of decom. activities	13.75 year	6.4 year	10.4 year
Total duration including storage	95.5 year	96 year	163.7 year
Man-power of decommissioning activities (except External Preparation for final disposal)	5075 man-year	5258 man-year	4178 man-year
Expected occupational exposure-for decommissioning activities	8.2 Sv	2.4 Sv	2.7 Sv

The results of the mass distribution with respect to the individual decommissioning strategies have shown that the radioactive LL-/ILwastes are in each case less than 4% of the total mass.

Related to the radiological and safety aspects the- following advantages are given:

- The surveillance and the supervision of the decay storage in the SID gives a better confidence as the entombed concrete block in the SET. The safe enclosure period generates the highest expenses because the building structures, the systems and components remain in the original state and have to be maintained.

- All decay storage periods can be terminated if technical, economical or political requirements are satisfied. In such a case the expenses of the SID decay storage are the lowest because only the stored components have to be removed. The termination of the safe enclosure period and of the entombment period need a lot of additional expenses and the advantage of this strategies (using the nuclear decay) is lost.

- The expected occupational exposure for the personnel is observed the highest with the SID and the lowest with the SLD.

Risks in Costs and Sensitivity Analyses

The cost calculation for the decommissioning of the NPP Krško is based on some assumptions for the decommissioning strategy and the decommissioning scenarios. Since the project is far away in the future it is probable that the designed conditions do not occur in the supposed form. For the most important assumptions the risks in cost are shown in Table 3. below:

Table 3: Risks in costs

Risk Factor	Assumptions	Additional Cost
Temporary storage of fuel	100 Castor Casks,20 years storage	225 MioDM
Two repositories (Slo/Cro)	60% of calculated costs for one repository and then doubled for two separate repositories: - planning: from 57 to 68,4 MioDM - construction: from 220 to 264 MioDM - operation: from 16 to 19,2 MioDM - total: from 293 to 351,6 MioDM	59 MioDM
Temporary storage of LL-/IL-waste	Planning, construction and operation	12 MioDM
Two repositories (Slo/Cro)	80% of calculated costs for one repository and then doubled for two separate repositories: - planning: from 14 to 22,4 MioDM - construction: from 50 to 80 MioDM - operation: from 7 to 11,2 MioDM - total: from 71 to 113,6 MioDM	43 MioDM
Contingency in fuel disposal cost	+ 50 o/o of total costs (293 MioDM)	146,5 MioDM
Contingency in LL-/IL-waste disposal cost	+ 50% of total costs (71 MioDM)	35,5 MioDM
Longer decay storage period	Increase from 80 to 120 years	16 MioDM
Longer safe enclosure period	Increase from 80 to 120 years	8 MioDM
Recycling not possible after decay storage period	Disposal as low level waste	0.8 MioDM
Wages	10% increase	5.8 - 8.5 MioDM

The above mentioned possible risks in the estimated costs give a good example how important are the boundary conditions of a decommissioning project relating to the costs. The sensitivity analyses are considering the cost categories with the strongest influence on the decommissioning costs.

From this point of view it is recognizable that the decision about a final repository is the most important factor. It is necessary to decide about this point as early as possible to minimize the elements of uncertainty relating to (order of list has no reference to importance), e.g.: number of repositories, type and size of the repository, necessary cutting of dismantled components, casks and containers, radioactive inventory of casks and containers, dose rates at surfaces of parts to be disposed off (e.g. containers or complete components, other acceptance requirements of the repository.

CONCLUSIONS

In the NIS study three decommissioning strategies for the decommissioning of the NPP Krško are defined and described. The feasibility on the state-of-the-art is shown for all three strategies, so for the recommendation of an optimal strategy now following criteria have to be taken into account:

- Radiological and safety aspects
- Costs and economical aspects and
- Political aspects.

All calculated strategies and scenarios are optimized to minimize radioactive waste generation. This will be provided by using mechanical cutting techniques to avoid aerosols, using only mechanical decontamination techniques to avoid acids and other agents as liquid secondary waste, dismantling of complete components as large as possible, utilizing the decay of the radionuclides before the components are disposed. The costs and economical aspects are discussed relating to manpower, duration, social effects and site aspects.

Taking into account the total costs and the total manpower there are no big differences in the results. But in the SID and in the SET the finances are needed earlier then in the strategy SLD (after the 80 years of the storage period). In the SID and SET the decommissioning activities are carried out by the NEK personnel using the experience and the procedures of the former operation. So the staff of the NPP Krško could be employed for a period of more than 15 years after the final shut-down. The site of Krško is useable earliest in the SID and the SET except the storage building respectively the remaining entombment concrete block. The operating costs of the safe enclosure period are the highest of all three strategies. Additional risk in the operating costs is given if more maintenance activities would be necessary.

Based on the calculation results of this study one repository for all wastes (fuel/HLW and LLW/ILW) is recommended available prior to the commencement date of decommissioning.

FINALLY, TAKING INTO CONSIDERATION ALL THE ABOVE MENTIONED BOUNDARY CONDITIONS IMMEDIATE DISMANTLING STRATEGY SEEMS TO BE THE MOST FEASIBLE OPTION FOR THE NPP KRŠKO DECOMMISSIONING.

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