Electrical Power and Energy Systems 73 (2015) 782–786

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

An approach to the semi-quantitative assessment model on human errors for decommissioning of nuclear facilities

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ARTICLE INFO

Article history:
Received 24 April 2014
Received in revised form 13 May 2015
Accepted 10 June 2015
Available online 20 June 2015

Keywords:
Assessment
Decommissioning
Human errors
Nuclear facilities

ABSTRACT

This paper is to suggest the assessment model on human errors for decommissioning of nuclear facilities. On the basis of evaluation items, the structure of the model was systematically established and the method for the model was quantitatively designed. The categories of evaluation items consist of 'psychological', 'physical', 'man-machine', and 'environmental'. The method is composed of scaling and weighting factors. Feasibility study of the method was accomplished by applying a scenario.

Introduction

Decommissioning of nuclear facilities has high radioactivity and hazardous environment. Because of complex components and processes, probability of accidents from workers is high. To protect workers and reduce accidents during decommissioning, safety assessment of workers needs to be assessed [1,2].

In this paper, the model was suggested to analyze and evaluate human errors during decommissioning of nuclear facilities. Items for the assessment model were classified. Structure of the assessment model was established. Method for the assessment model was designed. Feasibility study of the assessment model was practically proved to be reliable.

Analyses of decommissioning activities

Decommissioning activities consist of several phases. As presented in Fig. 1, a decommissioning object is selected. Before decommissioning activities, radioactivity survey is done. After decontamination, the object is cut. The contamination of waste is measured and classified by the type. The wastes are divided as radioactive waste and release waste. After final contamination of waste is measured, it is packaged and transported.

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http://dx.doi.org/10.1016/j.ijepes.2015.06.015
0142-0615/

The assessment model based on human errors for decommissioning of nuclear facilities

Items of the assessment model

According to the reports and experts of decommissioning, items of the assessment model on human errors were categorized and classified as shown in Table 1. Items of the assessment model on human errors could be categorized as 'psychological evaluation', 'physical evaluation', 'man-machine evaluation', and 'environmental evaluation'.

Method of the assessment model

The structure of the assessment model on human errors for decommissioning of nuclear facilities is as shown in Fig. 2. The flow of assessment on human errors is to evaluate detailed items by weighting, to evaluate categories by weighting, and to sum the results of evaluated categories.

The method of the assessment model is as below mathematical formula. Final evaluation is made by summing results of each category.

$$20 \leqslant \alpha \sum \omega_i X_i + \beta \sum \omega_j Y_j + \gamma \sum \omega_k Z_k + \delta \sum \omega_m W_m \leqslant 100$$

In this formula, α is the weight of psychological evaluation, β is the weight of physical evaluation, γ is the weight of human–machine evaluation, and δ is the weight of environmental

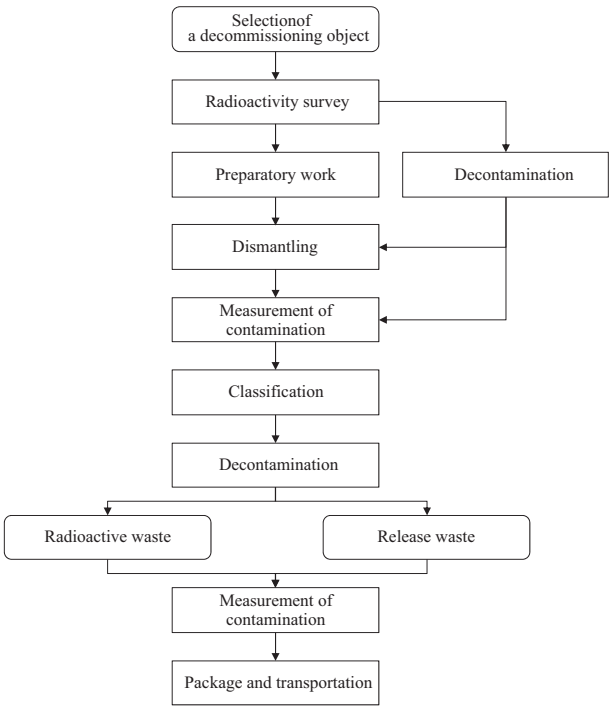

Fig. 1. A general flow of decommissioning activities.

Table 1
Items of the assessment model on human errors for decommissioning of nuclear facilities.

Categories of items	Detailed items
Psychological evaluation of worker	• Experience and training • Pressure of time • Damage of failure
Physical evaluation of worker	• Narrow space and high location • Excessive behavior and posture • Interference of protective equipment
Human–machine evaluation	• Difficult of handling equipment • Difficult of working information • Difficult of working modifications and stops
Environment evaluation	• Radiation exposure • Temperature and brightness • Dust and noise

evaluation ($\alpha + \beta + \gamma + \delta = 100$). ω_i is the weight of the detailed items in psychological evaluation category ($0 \leqslant \omega_i \leqslant 1$, $i = 1, 2, 3, \ldots$), ω_j is the weight of the detailed items in physical evaluation category ($0 \leqslant \omega_j \leqslant 1, j = 1, 2, 3, \ldots$), ω_k is the weight of the detailed items in human machine evaluation category ($0 \leqslant \omega_k \leqslant 1$, $k = 1, 2, 3, \ldots$), and ω_m is the weight of the detailed items in environmental evaluation category ($0 \leqslant \omega_m \leqslant 1$, $m = 1, 2, 3, \ldots$). $\sum \omega_i X_i$ is to sum the detailed items in category of psychological evaluation ($0.2 \leqslant \sum \omega_i X_i \leqslant 1$, $i = 1, 2, 3, \ldots$), $\sum \omega_j X_j$ is to sum the detailed items in category of physical evaluation ($0.2 \leqslant \sum \omega_j X_j \leqslant 1$, $j = 1, 2, 3, \ldots$), $\sum \omega_k X_k$ is to sum the detailed items in category of human–machine evaluation ($0.2 \leqslant \sum \omega_k X_k \leqslant 1$, $k = 1, 2, 3, \ldots$), and $\sum \omega_m X_m$ is to sum the detailed items in category of environmental evaluation ($0.2 \leqslant \sum \omega_m X_m \leqslant 1$, $m = 1, 2, 3, \ldots$). Final evaluation can be made on the basis of $\alpha \sum \omega_i X_i + \beta \sum \omega_j Y_j + \gamma \sum \omega_k Z_k + \delta \sum \omega_m W_m$.

Fig. 3 shows the procedure of the assessment model on human errors for decommissioning of nuclear facilities. As shown in Fig. 3, 'selection of an object' means that this is to select a decommissioning object for assessing on human errors. 'Establishment of the scenario' is to establish the decommissioning scenario of the object. 'Weighting of categories' is to weight the four categories including psychological evaluation, physical evaluation, man–machine evaluation, and environmental evaluation. 'Weighting of detailed items' is to weight the twelve items including each three items of psychological evaluation, physical evaluation, man-machine evaluation, and environmental evaluation. 'Scaling of the detailed items' rates and calculates each three detailed items of four categories. 'Summation of scaling of the detailed items' sums the scaling results of each category. 'Summation of the categories' sums the results of four categories. 'Final evaluation of permit' defines whether the scenario is allowed to proceed or not according to the results of scenario. If the scenario is not permitted, actions of hazard reduction have to be taken.

The detailed items of psychological evaluation consist of 'experience and training', 'pressure of time', and 'damage of failure'. The three detailed items of psychological evaluation could be scaled as shown in Fig. 4. In the psychological evaluation, scales for evaluation on experience and training consist of very high (0.2), high (0.4), medium (0.6), low (0.8), and very low (1.0). For pressure of time, scales for evaluation are made up of very low (0.2), low (0.4), medium (0.6), high (0.8), and very high (1.0). And for damage of failure, scales for evaluation are composed of very low (0.2), low (0.4), medium (0.6), high (0.8), and very high (1.0).

The detailed items of physical evaluation consist of 'narrow space and high location', 'excessive behavior and posture', and 'interference of protective equipment'. The three detailed items of physical evaluation could be scaled as shown in Fig. 5. In the physical evaluation, scales for evaluation on narrow space and high location consist of very good (0.2), good (0.4), medium (0.6), bad (0.8), and very bad (1.0). For excessive behavior and posture, scales for evaluation are made up of very good (0.2), good (0.4), medium (0.6), bad (0.8), and very bad (1.0). And for interference of protective equipment, scales for evaluation are composed of very good (0.2), good (0.4), medium (0.6), bad (0.8), and very bad (1.0).

The detailed items of human–machine evaluation consist of 'difficult of handling equipment', 'difficult of working information', and 'difficult of working modifications'. The three detailed items of human–machine evaluation could be scaled as shown in Fig. 6. In the human–machine evaluation, scales for evaluation on difficult of handling equipment consist of very easy (0.2), easy (0.4), medium (0.6), uneasy (0.8), and very uneasy (1.0). For difficult of working information, scales for evaluation are made up of very easy (0.2), easy (0.4), medium (0.6), uneasy (0.8), and very uneasy (1.0). And for difficult of working modifications, scales for evaluation are composed of very easy (0.2), easy (0.4), medium (0.6), uneasy (0.8), and very uneasy (1.0).

The detailed items of environmental evaluation consist of 'radiation exposure', 'temperature and brightness', and 'dust and noise'. The three detailed items of environmental evaluation could be scaled as shown in Fig. 7. In the environmental evaluation, scales for evaluation on radiation exposure consist of very low (0.2), low (0.4), medium (0.6), high (0.8), and very high (1.0). For difficult of temperature and brightness, scales for evaluation consist of very good (0.2), good (0.4), medium (0.6), bad (0.8), and very bad (1.0). And for dust and noise, scales for evaluation consist of very good (0.2), good (0.4), medium (0.6), bad (0.8), and very bad (1.0).

In the procedure of the assessment model, the final phase, 'final evaluation of permit', could be made decisions under the criteria as shown in Table 2.