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Success criteria time windows of operator actions using RELAP5/MOD3.3 within human reliability analysis

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Abstract

Human reliability analysis (HRA) contributes to assessment and to reduction of the impact of human operators to the risk of technologies and processes. The objective of this paper is to integrate realistic deterministic safety analysis and probabilistic safety assessment to show how deterministic safety analysis impacts the HRA, which is integrated into the probabilistic safety assessment. The RELAP5/MOD3.3 computer code is used for realistic safety analysis. Parametric safety analysis studies give time parameters for human actions as an input for selected HRA. Calculated human error probabilities are inserted into probabilistic safety assessment and the results are obtained, where the focus goes to the most important risk contributors. The method and the results are shown on selected HRA method through two selected representative human actions. Results show that realistic safety analysis represents an important standpoint for assessment of human error probabilities within HRA.

Keywords: Human reliability analysis; Success criteria; Probabilistic safety assessment; Deterministic safety analysis

1. Introduction

Nuclear safety is assessed and improved through the probabilistic safety assessment, which integrates (ASME RA-S-2002, 2002):

- Probabilistic models of components (Jordan Cizelj, Mavko, & Kljenak, 2001), logic models of safety systems and reliability analysis of operator actions,
- Scenarios and sequences of safety system actuations and operator actions (Čepin, 2005b), and
- Accident physical models (Leskovar & Mavko, 2006).

The experience with the results shows that human contribution to undesired events is still significant in spite of the automation of systems and processes. The importance of human contribution causes that the many methods are developed and many activities are performed in the field of human reliability analysis (HRA). This is not true only in the nuclear industry (Čepin, 2005a, 2007; Grobbelaar, Julius, & Rahn, 2005; Kennedy, Siemieniuch, Sinclair, Kirwan, & Gibson, 2007; NUREG/CR-1278, 1983; NUREG/CR-6883, 2005; Reer, Dang, & Hirschberg, 2004), but also in other fields such as in the chemical industry (Khan, Amyotte, & DiMattia, 2006) and in the air and space industry (Harris et al., 2005) for example.

The objective of this paper is to show how the probability of operator to perform an error depends on parameters obtained from safety analysis and what this means for the safety of the nuclear power plant. Namely, the parameters of safety analysis direct the amount of time in which operator has to perform its action and this amount of time is one of important parameters, which direct the human error probability (HEP), i.e. probability of operator to perform an error. Smaller human error probabilities may cause smaller risk and thus improved safety.

IJS-HRA (Institute Jožef Stefan—human reliability analysis) serves as the example method (Čepin, 2005a; Čepin, 2007) for quantification of human error probabilities of specific human actions. The probabilistic safety

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assessment model of a specific nuclear power plant serves as an example model, which shows how quantified human error probabilities relate to assessment of risk and thus safety. Probabilistic safety assessment is evaluated to assess and compare the measures of safety of the plant in two cases: if recovery is considered or not for each operator action separately. The decision, if recovery is considered or not, depends on the amount of additional time, which operators have to perform the required action (i.e. additional available time for action). The additional available time for action is determined from inputs from experience of training of operators on the plant simulator and from deterministic safety analysis.

Section 2 gives basic information about the IJS-HRA method, which is integrated with probabilistic safety assessment and with deterministic safety analysis. Section 3 focuses on determining the time parameters, which are important for HRA and which are obtained with deterministic safety analysis. Examples are selected, which demonstrate how the calculations were performed and what the results show. Section 4 shows the results of probabilistic safety assessment with emphasis on selected examples from HRA. Section 5 gives the conclusions and implications of the work.

2. HRA within probabilistic safety assessment

The operator actions are mostly only backup for the automatic actuations of the safety systems, which mitigate the accident if undesired initiating event occurs.

IJS-HRA integrates some features of existing methods and some new features such as contribution of the simulator experience in order to consider the newest requirements and recommendations in the field and in order to be integrated in a modern computerized probabilistic safety assessment (Čepin, 2005a; Čepin & He, 2006; NUREG-1792, 2005). More information about the method is written in another article of this journal issue (Čepin, 2007). Only the feature important for the contents of this paper is mentioned here: quantification of HEP is performed with consideration or without consideration of recovery.

If additional available time for action is larger than determined time interval, e.g. 10 min, than recovery as independent mode of verification is considered. If additional available time for action is shorter than determined time interval, recovery is not considered.

Additional available time for action (T_a) is defined as the difference between the time window of the action (T_w) and the actual time needed for performing the action (T_p), which is assessed based on real simulator scenarios:

$$T_a = T_w - T_p.$$

The time window of the human action actually represents the success criteria for the action. It represents the time interval in which operators have to perform the action in order that the plant is put in a safer state, i.e. the plant is put into a scenario that leads to a safe state and not to an accident state.

The actual time needed for performing the action is the realistic time in which operators perform the action and it can be obtained from the simulator experience.

The specified time windows are important for HRA due to the following reason. The HEP of certain operator action is lower if operators have more time available. In the control room of a nuclear power plant there is a team of operators, which is supervised by a shift supervisor. If operators have 10 or more minutes of additional time for action, it can be expected that colleagues or shift supervisor can observe and correct a possible error of their colleague. IJS-HRA method assumes that if the difference between the time window, in which the action has to be performed, and the actual time needed for performing the action is 10 min or more, a recovery can be modeled for the investigated action. If additional available time for action is shorter than determined time interval, recovery is not considered.

Consideration of recovery causes lower HEP and may cause a different impact of human error to the overall probabilistic safety assessment results.

Determination of the time window, in which operators have to perform the action, is obtained from deterministic safety analysis.

Fig. 1 shows integration of probabilistic safety assessment and deterministic safety assessment for improvement of HRA. Full arrows represent dependencies between the items, which are important for understanding this methodology. Dotted arrows on the figure represent dependencies between the items, which are not important for this methodology, but exist as part of processes of specific deterministic and probabilistic safety analysis in a nuclear power plant.

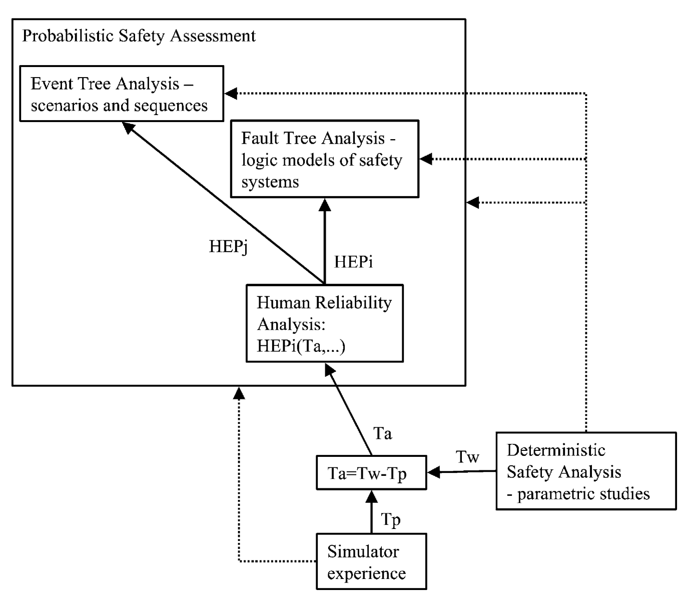

Fig. 1. Integration of probabilistic safety assessment and deterministic safety assessment for improvement of human reliability analysis.