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Porównanie wybranych metod oceny niezawodności człoieka

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COMPARISON OF SELECTED METHODS FOR HUMAN RELIABILITY ASSESSMENT

Abstract

There are many different methods which are used in the field of human reliability assessment. It should be noted that each method has its own specificities that make it more or less suitable for a particular use in practice. Therefore, this paper is focused on characterizing and comparing of the selected first generation methods THERP, HEART and SPAR-H. This comparison is aimed to possibilities of methods application, the availability of sources of information, the utilization of the dependence of tasks, the amount and the positive or negative influence of the performance influencing factors and the way of determining the human error probability.

PORÓWNANIE WYBRANYCH METOD OCENY NIEZAWODNOŚCI CZŁOWIEKA

Streszczenie

Istnieje wiele różnych metod, które są używane w dziedzinie ludzkiej oceny niezawodności. Należy zauważyć, że każda z tych metod ma swoje specyficzne cechy, które czynią ją mniej lub bardziej odpowiednią dla konkretnego zastosowania w praktyce. Dlatego ten artykuł koncentruje się na charakterystyce i porównaniu wybranych metod pierwszej generacji THERP, HEART i SPAR-H. To porównanie ma na celu porównanie możliwości zastosowania metod, dostępności źródeł informacji, wykorzystania zależności od zadań, ilości i pozytywnego lub negatywnego wpływu czynników na wydajność i sposób określenia prawdopodobieństwa błędu ludzkiego.

Introduction

The human reliability assessment (HRA) in the man-machine systems (MMS) has becoming more and more necessary in regard to the increasing risk. In the probability risk assessment (PRA) often appear the situations, when the analyst has to assess the probability of the unsuccessful performance of operators within the scope of the system too (e.g. in the area of the nuclear power plants controlling).

The approach to the HRA is significantly different from the machine reliability assessment. Since man is a highly interactive and sensitive element of the working system, it is not easy to create a general method. Following development and improvement in the HRA methods, number of methods with theirs specifications has been created. The knowledge of the differences between these methods leads to the selection of the appropriate one.

1. THERP (Technique for Human Error Rate Prediction)

THERP is the total methodology for the prediction of the human error and for the assessment of the man-machine system degradation after occurrence of the human error [1]. Primary, this technique was focused on the nuclear power plants. However, its principles make it a general tool for the human reliability assessment. It can be seen e.g. in the medical and offshore applications [2, 6].

The basic tool in the THERP is the HRA event tree. With the help of HRA even tree task sequences are modelled. There are only possibilities of the "success", "fail" and in the reasonable cases "recovery" in the HRA event tree [1].

The THERP handbook contains the tables with the single-point estimates of the nominal HEP and with the adjunct error factor (EF). EF creates the symmetric area around the nominal HEP. This area should contain 90 % of the HEP. The interval for these uncertainty bounds is obtained:

- by multiply the HEP by the EF – the upper uncertainty bound,
- by divide the HEP with the EF – the lower uncertainty bound [1].

The exception is the use of the higher HEP, because their calculated upper uncertainty bound exceeds 1.0 (e.g. HEP = 0.25 with EF = 5). In this case, the real upper uncertainty bound has to be lower than 1.0. If it is, it leads to the modification of the symmetric uncertainty area around the median of the lognormal distribution (represents nominal HEP) to the asymmetrical area [1].

In the handbook there are defined nominal HEPs as the HEPs that do not take into account plant- and situation-particularity. These aspects are taken into account in the HEP (the movement of the HEP in the scope of the interval, which is defined by EF) by considering the factors affecting the performance, in terms of THERP known as performance shaping factors (PSFs). The handbook contains the list of 67 PSFs. These are divided into 3 base groups and theirs subgroups:

- external factors:
  - situational characteristics,
  - job and task instructions,
  - task and equipments characteristics,
- internal factors:
  - organismic factors,

- stressors:
  - psychological stressors,
  - physiological stressors [1, 9].

However, HEP in THERP does not depend only on the nominal HEP and PSFs, but it has to consider the certain dependence level of the successful or unsuccessful task performance too. Therefore, THERP considers the working process aspects as the mutual control of the co-operators and the suitable situation of the controls. In dependence on them, the nominal HEP is changed to a certain extend [1].

2. HEART (Human Error Assessment and Reduction Technique)

According to the applicability of HEART, it is considered to be a general method that is utilizable in any situation or sector, where the importance of the human factor is highlighted. The fact that HEART is the cross-sector tool for the human reliability assessment is obvious. It has been utilized in the nuclear, chemical, rail and medical field [2], [6].
There are defined 8 ("A" – "B") + 1 ("M") types of the generic tasks with their nominal amount of the human unreliability and the 5th – 95th percentile bounds in HEART. The type of the generic task "M" with its values is determined for the case, when the others generic task do not contain the suitable description for a considered task [4].
To make the nominal HEP closer to the real conditions of the task performance, HEART utilizes the list of the 38 Error-Producing Conditions (EPCs) with their maximum amount by which can influence the human reliability negatively. It is obvious from the previous sentence that as regards EPCs in HEART, EPCs degrade the probability of the successful task performance exclusively, let us say, they increase the human unreliability [4].
Establishing the human error probability in carrying out the selected task is performed by the following formula:

$$HEP = nHEP \times \prod \{[(EPC_i - 1) \times (proportion\ of\ affect\ EPC_i)] + 1\} \tag{1}$$

where:
HEP - total human error probability,
nHEP - nominal error human probability given by the generic task table,
EPC_i - maximum amount of the selected EPC by which can influence the human reliability negatively,
proportion of affect EPC_i - proportion of the affect of the total potential of EPCs selected in the scope 0 – 1.0 (subjective judged) [4].

HEART suggests strategies and remedial measures aimed to the error reduction, so that it can ensure the effective solution of the high HEP. These recommendations are linked to the specific EPCs [4].

3. SPAR-H (Simplified Plant Analysis Risk Human Reliability Assessment)

SPAR-H represents a simple HRA method. It is utilized to estimate the human error probabilities linked with the operator or crew activities and with the decisions that are received in the context of initial event occurred [5].
The human reliability assessment in the condition of the SPAR-H considers two main categories of the activity with their own nominal HEP:

- category “actions” (nominal HEP = 0.001) – it is represented by actions, in which it is not necessary to consider the suitability, eventually the intensity of their performance. In addition, they are mostly carried out as a process item (after step 1 do step 2; if decrease “A”, start equipment “α” etc.), e.g. operating the device, start-up, start of the pumps, calibration etc.
- category “diagnosis” (nominal HEP = 0.01) – it characterizes the effort of the operator to understand a process or situation on the basis of information resulting from its manifestation (value A increase, value B decrease → it is probable a technology damage in location XY) and the effort to assign a priority to planned actions. This is based on working experience and knowledge got from training [5].

According to PSFs affecting the nominal HEP in the SPAR-H method, it states 8 PSFs that have a potential to affect the nominal HEP both in the positive and negative way. As the PSFs in the condition of this technique are considered:

- available time,
- stress and stressors,
- experience and training,
- complexity,
- ergonomics (including the human-machine interface),
- procedures,
- fitness for duty,
- work processes [5].

The level of the dependence between analysed tasks is in SPAR-H taken into account, similarly as in the THERP. The scale of the dependance level comes from THERP, which was defined in the NUREG/CR-1278, however, the SPAR-H offers an improved basis for a dependence assignment [5].
The main working tools are so called “SPAR-H worksheets”. Their samples and use examples are mentioned in the document NUREG/CR-6883, which describes these techniques [5].

4. Comparison of THERP, HEART and SPAR-H methods

The comparison of the methods is focused on the selected characteristics. They are applicability, sources of the information, a way of determining the HEP, task dependences and used PSFs/EPCs. In Table 1 is shown a comparison of THERP, HEART and SPAR-H methods for assessment of human reliability.

Table 1: Comparison THERP, HEART and SPAR-H

	THERP	HEART	SPAR-H
APPLICABILITY	mainly nuclear power plants [1], however the principles of THERP are usable also in other sectors, e.g. offshore and medical sectors [2], [6]	general use for man-machine systems engineers [4], e.g. for the areas such as nuclear power plants, chemical, aviation [2], medical [6] and rail [7]	mainly nuclear power plants, but base principles and data about HEP are usable for other areas too [2]
INFORMATION SOURCES	available data and procedures set necessary for carrying out the total HRA in NUREG/CR-1278 report [1]	available data and procedures set necessary for carrying out the assessment and human error reduction for individual tasks in paper [4], in which the method was published	available data necessary for determining the total HEP in worksheets, which are a part of the document NUREG/CR-6883 [5], a step-by-step procedure of the method is available in the handbook INL/EXT-10-18533 [8]
DEPENDENCE	YES [1]	NO [4]	YES [5]

PSFs/ EPCs	67 PSFs, positive/negative effect on the nominal HEP [1]	38 EPCs, negative effect on the nominal HEP [4]	8 PSFs, positive/negative effect on the nominal HEP [5]
DETERMINING THE HEP	According to the selected nominal HEP, the uncertainty bounds are set. Then, on the base of presence of PSFs and task dependence level on others tasks, the analyst decides about movement of a nominal HEP more closely to an upper or lower uncertainty bound. Total HEP of any task, which consists of subtasks are carried out on the base of formulas in the handbook [1].	The most appropriate task is selected from the list of generic tasks and effecting EPCs. Then, it is assigned a proportion of the effect of EPCs on the scale 0 – 1.0. Obtained values are used in a formula. An outcome of this formula is a total HEP [4].	On the dependence of the type of activity in the analysed task, the worksheet for diagnosis or action is selected. Filling the worksheet is carried out according to instructions, which are together with the required values for the HEP calculation available in the worksheet itself [5].

5. Conclusion

The presence of many HRA methods allows the options for the selection of the most suitable method for application to a selected area. However, it is necessary to be familiar with their characteristics and comparison of the selected aspects.

By brief description of the methods THERP, HEART and SPAR-H and their tabular comparison was made a simple basis for selecting the most appropriate method HRA from these tree options.

Regarding to the complex human factor analyze in human-machine systems, of the three considered methods, THERP seems to be the most suitable technique. THERP represents a total methodology for the HRA and the handbook clearly points to the aspects of human reliability. Although it is focused on the area of nuclear power plants, mentioned principles allow in the case of availability of the necessary data, utilize it also in other areas. Higher time consumption can be expected during using it.

HEART is a suitable technique for the assessment of individual, independent tasks. Its general definition of a set of generic tasks and Error-Producing Conditions (EPCs) are widely applicable. However, there have to be taken into account its tendency to pessimistic estimates and be ensure that the considered EPCs was not already included in the description of the selected generic task. If an analyst realizes these properties of HEART, he will get the tool to relatively a rapid quantitative assessment of a human reliability in carrying out the selected tasks. In connection with its strategy of reducing the negative impact of EPCs it can be an effective tool for a practice.

From the tree selected methods, SPAR-H is the only one that uses prepared worksheets for the assessment. Layout of their content and the content itself can be very helpful in the evaluation. Firstly, prepared by filling the fields are provided documenting the most significant information. Second, knowledge of the worksheets structure allows faster control, search for the required information and empty fields point to the omission of step or information. Thirdly, using the dependence table provides easy and quick way to choice the level of dependence. On the other hand, similarly to HEART, neither SPAR-H is a total methodology and for the initial steps of HRA it is necessary to use different techniques (e.g. ATHEANA). In case of availability of the necessary data, the principles of the SPAR-H evaluation can be used also in other areas besides nuclear power plants.

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