U.P.B. Sci. Bull., Series D, Vol. 74, Iss. 1, 2012 ISSN 1454-2358

STUDY ON THE MAIN FACTORS INFLUENCING HUMAN PERFORMANCE IN NPP OPERATION

M. FARCASIU[1], Ilie PRISECARU[2]

The purpose of this paper is to provide a good knowledge and understanding on the main factors influencing human performance in the complex systems operation. The study is achieved using Human Reliability Analysis methods and the qualitative analysis of Man-Machine-Organization System. MMOSA software and HUFAD_E database (developed in INR Pitesti) are supports of this study. The main conclusion is that the consideration of the factors influencing human performance is very important in the identification of the corrective action to reduce the risk of the NPP operation.

Keywords: human, performance, factors nuclear

1. Introduction

Reliable human performance is a prerequisite in securing the safety of complicated process systems such as nuclear power plants (1). No Probabilistic Safety Assessment (PSA) study can be regarded as complete and accurate without adequate incorporation of the Human Reliability Analysis (HRA) (2).

In PSA study can be a lot of possible human errors which must be analyzed so that to be estimated realistically the Human Error Probability (HEP) which must incorporate to event base level in fault trees or to headings level in event trees. It is necessary that each possible human error to be evaluated to identify both the factors with negative influence and the factors with positive influence on the human actions.

The Human Performance Analysis (HPA) complexity and large amount of the human errors, large amount of the factors, the information and data which characterize each human action lead to great effort and time consuming. Unfortunately, modeling human error probabilities is fraught with difficulty, especially because actual performance or reliability data are not available for many operations (3). A number of human reliability databases have performed (i.e. NUCLARR, IRS, CORE-DATA). But they are not currently available because of the problems of data confidentiality, different formats and structures that are not compatible (2).

Data related to human performance must be treated confidentially because it deals with the performance of individuals whose privacy must be respected.

[1] Eng., Institute for Nuclear Research , Pitesti, Romania
[2] Prof., Power Engineering Faculty, University POLITEHNICA of Bucharest, Romania

Confidentiality and privacy is frequently not only a matter of policy but also a legal requirement (5).

In this paper is performed a modelling of necessary data for HPA in a socio-technical context based on the analysis of HRA (i.e., THERP, ASEP, HCR, SPAR-H,) methods. This context is compatible with a complex system such as nuclear power plant.

The main result of this paper is a generic process for the human performance quantification in Man-Machine-Organization System (MMOS) context using HRA methodology and the identification and presentation of the main factors influencing human performance. Using the HPA diagram in MMOS context as a structure of a database, is developed HUFAD database in Microsoft Visual Basic 6.0. Also MMOSA software project is developed Microsoft Visual Basic 6.0 medium to use the data from database for the human performance quantification. The database was developed to establish a support for HPA both for PSA study and for design or scheduling of the main activities in NPP operating (i.e. maintenance, tests). The human reliability data are associated with influence elements on the human performance to nuclear installation operation.

The final result is a report of the action in the given context to mitigate the consequences of the event SGTR from Cernavoda NPP.

2. Study on the main factors that influence human performance

The modelling of the necessary data and information for human performance analysis is required in order to examine and understand the root causes and mechanisms of human error at the given moment and context.

In order to study the main factors that influence human performance in MMOS context the following questions are proposed:

(1) What are the direct and indirect relationship between man, machine, organization and safety?

(2) What are the main mechanisms through which MMOS should be used in order to decrease risk and improve safety performance?

(3) What are the main factors in MMOS which can influence the human performance?

3. The case study

In order to demonstrate the applicability MMOSA model and using the information from HUFAD database, a MMOS analysis is performed for an action which must be performed to mitigate the consequences of the event "Steam Generator Tube Rupture " (SGTR) from Cernavoda NPP. The main action considered is reactor manual shutdown in according to (6). It is considered that the diagnosis is right.

4. Results

In order to answer to first and secondary questions, PSA study was considered. PSA of a nuclear power plant provides a comprehensive, structured approach to identify failure scenarios and deriving numerical estimates of the risks to workers and members of the public (7). So, the man, the machine and the organization can be incorporated in PSA study by HRA. All have an influence on human performance, the man by behavior and machine and organization by their individual capabilities (8), (9).

A significant issue in the PSA is HRA and in particular the organization of the HRA activity, which includes the identification of the human actions, to be considered. Also in order to identify and classify the kinds of data that will be required to support a HPA are identified the necessary data and the informations for five the most used HRA methods: Technique for Human Error Rate Prediction (THERP) (10); Human Cognitive Reliability (HCR) (12); Standardized Plant Analysis Risk –Human Reliability Analysis (SPAR-H) (14); MMOSA (9)
The 3rd question can be presented by the summary diagram from figure 1.

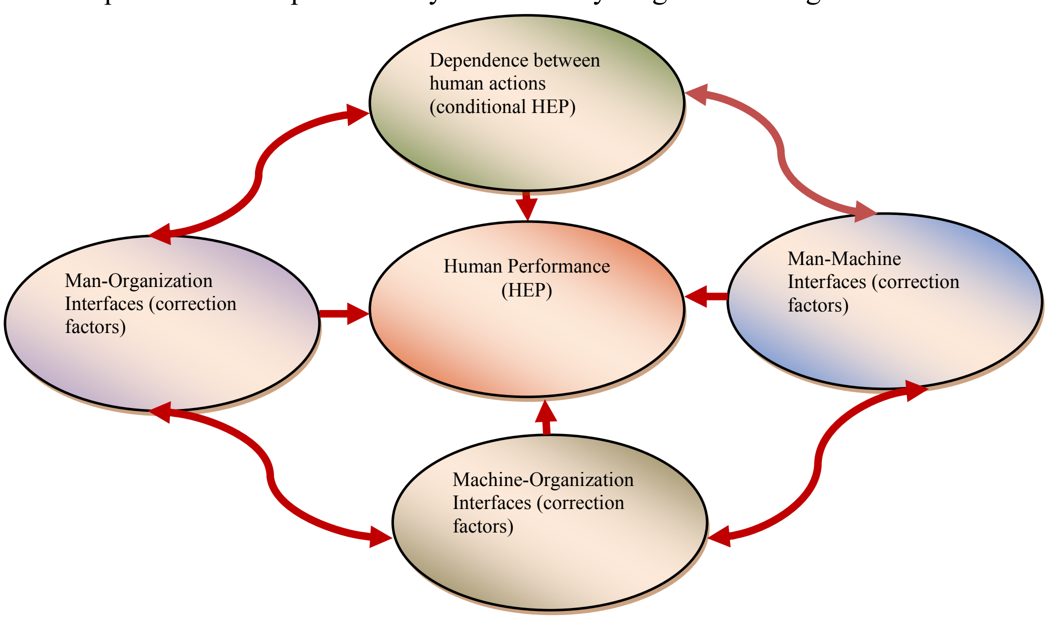

Fig. 1 – A diagram of a generic process for the human performance quantification in MMOS

Although, HRA methods have different frameworks, purposes a general groups of the necessary information can be achieved: description of the tasks and actions; performance shape factors (PSFs) with negative or positive influence on the human performance (stress, trainning, complexity, time, procedure,); recovery factors (RFs) (redundance, inspection, verification); the skill, knowledge, rule of the personnel; dependence between actions; man-machine interfaces and work-environmental.

The quantification of HEPs for the purpose of HRA is very complex. Because of this complexity, the state of the art includes a variety of HRA models, each with its own objectives, scope and quantification method. In addition to varying methods of quantification, each model is replete with its own terminology and categorizations, therefore making comparison across models exceedingly difficult (15).

An approximate mathematical expression for HEP of a human action of i^{th} task which is influenced by j PSFs and with k RFs can be written as follows in the context of THERP methodology:

$$HEP = \sum_{i=1}^{I} \left\{ \left[(BHEP_i) \prod_{j=1}^{J} PSF_{i,j} \right] \prod_{k=1}^{K} RF_{i,k} \right\} \tag{1}$$

Where BHEP is associated basic human error probability.

The HCR method is based on the use of a mathematical relationship, (expressed as a curve in graphical form) between the probability that an operator will not respond correctly within the required time window following the onset of an incident (the non-response probability) and the median time taken to respond.

$$P(T) = \exp - \left[\frac{(T / T_{1/2} - C_{gi}}{C_{ei}} \right]^{B_i} \tag{2}$$

In the SPAR-H method the composite PSF is calculated as the product of the analysts rating of all PSF contained on the SPAR-H worksheet (14).

$$HEP = NHEP * PSF_{composite} \tag{3}$$

Where NHEP is the nominal HEP.

Another method used for the estimation of HEP is proposed in MMOSA methodology:

$$HEP = CHEP * 1.008^{i} * 0.9^{j} \tag{4}$$

Where:

i is the number of the negative conditions;

j is the number of the positive conditions.

The estimation of Conditional Human Error Probability (CHEP) is performed using the equations from [7] in according to the established dependence level.

It is important to be achieved a hypotethical medium context of HPA to avoid the limitations of the information from specific source. The crucial question is whether sufficient information for real context definition can be obtained. Using the generic human factor analysis process and the necessary data and information to be applied HRA methods was developed a logical tree (fig. 2) which identify the main elements to analyse the human performance in MMOS context.

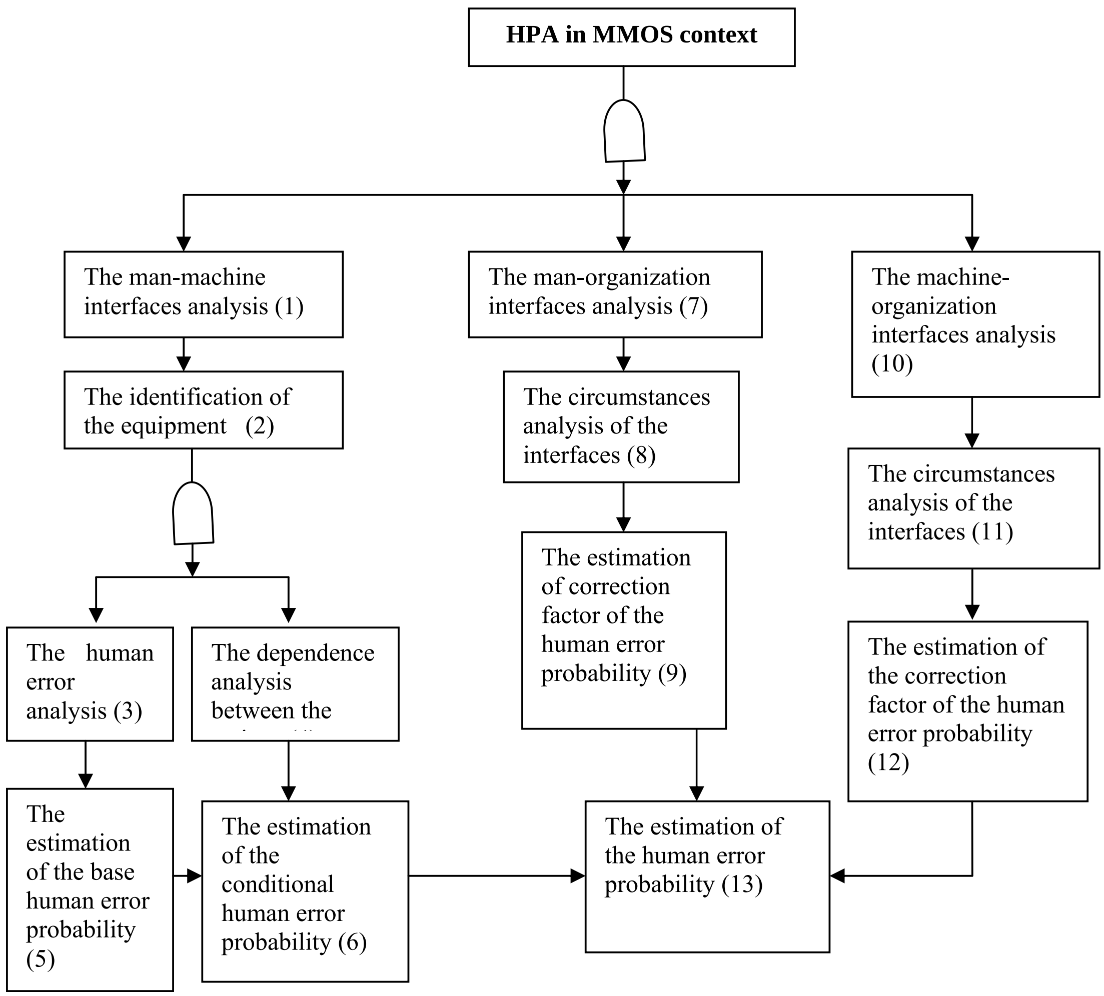

Fig. 2 – The HPA diagram in MMOS context

From these considerations is possible to decide on how to structure a database. So, a data base was developed in Microsoft Visual basic 6.0 (HUFAD).

It has 16 tables (fig. 3) and 178 records. In order to answer the necessary data for man-machine interfaces. The tables were performed with the following information: equipments, posible fault actions, basic human error probability for each posible fault actions and elements to establish the dependence level between human actions.

In order to answer the necessary data for man-organization interfaces tables were performed with the following information: man –organization interfaces and conditions for each interface. Also in order to answer the necessary data for machine-organization interfaces tables were performed with the following information: Machine –Organization interfaces, conditions for each interfaces.

The run of this database is posible by MMOSA software project which was developed in Microsoft Visual basic 6.0 (in SCN Pitesti). In figure 3 is presented the first form of this project.

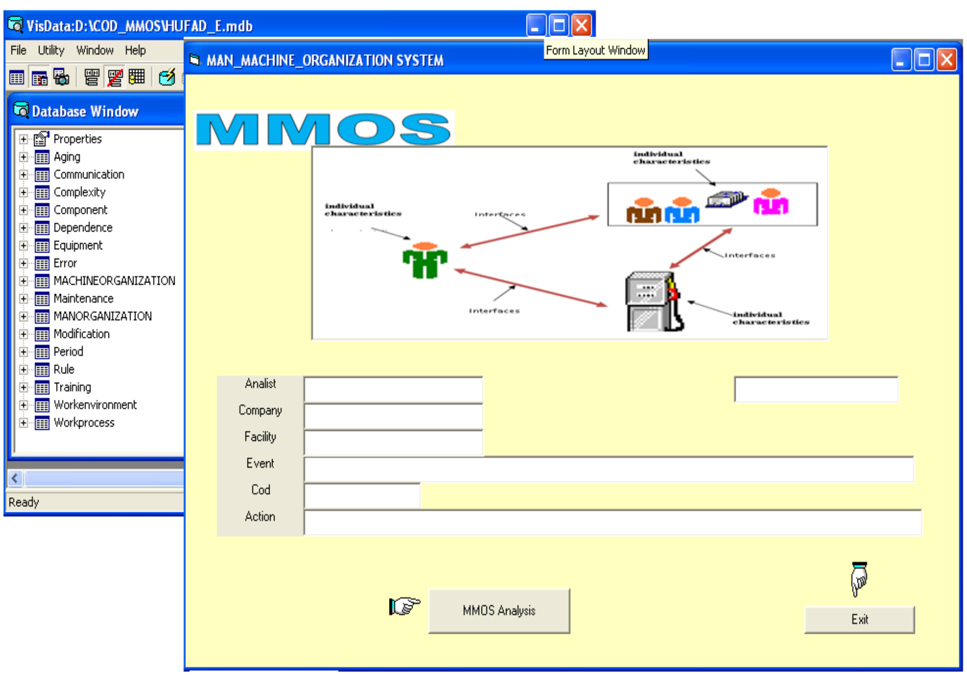

Fig. 3 HUFAD data base and the first from MMOSA software project

The Results of the analysis of the case study are presented in fig. 4 as a report of the action in the given context to mitigate the consequences of the event SGTR from Cernavoda NPP. The reports of the case study presents the main factors that influence the human performance and how influence. So BHEP = 0.003 and final HEP equal 0.04.

Analyst:Mita Farcasiu
Company:INR Pitesti
Facility:Cernavoda NPP
Event: Steam Generator Tube Rupture
Cod:SGTR
Action: reactor manual shutdown
Man_Machine Organization - Equipment - Manual control
Fault Action: select wrong control on a panel from an array of similar

BHEP = 0.003(THERP)

Dependence Level: low

CHEP = 0.052

Man_Organization Interfaces:
-**Procedure**- > 1 action/step
-**Training-** training on simulator
-**Communication**-there aren't communication methods
-**Complexity** -parallel tasks
-**Work process** -insufficient information
-**Work environment** -insufficient information
-**Time -**no specified time for action

Multiplication factor-0.829

Machine_Organization Interfaces
-**Maintenance plan**-a study isn't performed
-**Modification plan**-modification plane isn't
-**Aging management plan**-susceptible components to aging aren't identified
-**Component**-insufficient information

Multiplication factor:0.921
Total Multiplication factor:0.764

HEP:0.04

Fig. 4 Report of the main factors that influence the action human to mitigate consequences

5. Conclusions

In this paper the aspects of the necessary data and information in HRA methods were modeled and reviewed in order to show if all or sufficient information are take into account to HRA method for the incorporation in PSA study. The modelling of the data is performed in order to examine and understand the conditions of the MMOS interfaces in the accident sequence.

The study on the applicability of HRA methods and of basic concepts of the MMOS operation has accentuated the overwork for a detailed analysis, a large number of the estimations, a large number of characteristics and influence factors. All these elements were demonstrated the necesity of the development of the database which to give the posibility of the quikly selection of needed the elements and the information to complete analysis of the human factor.

The reports of the case study presents the main factors that influence the human performance and how influence. So BHEP = 0.003 and final HEP equal 0.04. BHEP increases about 13 times. This result proves that the consideration of influence factors of the human performance is very important.

R E F E R E N C E S

[1] *Jinkyun Park, Wondea Jung,* A Database For Human Performance under Simulated Emergencies of Nuclear Power Plants*,* NUCLEAR ENGINEERING AND TECHNOLOGY, Vol. 37, No.5, 2005.

[2] *IAEA,* Collection and classification of human reliability data for use in probabilistic safety assessments. s.l., IAEA-TECDOC-1048, 1998.

[3] *Ronald L. Boring, David I. Gertman.* Human Error and Available Time in SPAR-H. 2004. INEEL/CON-04-01630.

[4] *Miroljub Grozdanovic, Evrica Stojiljkovic,* Framework for human error quantification*.;* Facta Universitatis, 2006.

[5] *NEA-CSNI*, Better Nuclear Plant Maintenance:Improving Human and Organizational Performance . NEA/CSNI R(2008)12. ISBN 978-92-64-99065-4.

[6] *****.** Abnormal Plant Operating Procedure*,* . CNE Cernavodă , IR-03670-E08.

[7] *IAEA*, Regulatory review of probabilistic safety assessment (PSA) level 1,IAEA-TECDOC -1135, 2000.

[8] *M. Farcasiu, I. Prisecaru,* Qualitative analysis of the man-machine-organization system in accident conditions for nuclear installation. Pitesti, Romania : The Third Annual International Conference on Sustainable Development through Nuclear Research and Education, 2010. ISSN 2066-2955.

[9] *M. Fărcaşiu,* Dezvoltarea bazei de date pentru analiza factorului uman la exploatarea instalaţiilor nucleare*.* SCN Piteşti, 2010. RI 8773.

[10] *A.D. Swain, H.E. Guttman,* Handbook of Human Reliability Analysis With Emphasis on Nuclear Power Plant Applications. Washington DC : U.S. Nuclear Regulatory Commission, August 1993. NUREG/CR -1278.

[11] ****,* Human Reliability Assessors Guide: Safety and Reliability Directorate , 1988. RTS 88/95Q.

[12] *D. Gertman, H. Bkackman*, The SPAR-H Human Reliability Analysis Method. Washington DC , 2005. NUREG/CR-6883.

[13] *M. R. Presley,* On the Evaluation of Human Error Probabilities for Post-Initiating Events, Massachusetts Institute of Technology, 2006.