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MMOSA – A new approach of the human and organizational factor analysis in PSA

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ABSTRACT

The results of many Probabilistic Safety Assessment (PSA) studies show a very significant contribution of human errors to nuclear installations failure.

This paper is intended to analyze both the human performance importance in PSA studies and the elements that influence it. Starting from Man–Machine–Organization System (MMOS) concept a new approach (MMOSA) was developed to allow an explicit incorporation of the human and organizational factor in PSA studies. This method uses old techniques from Human Reliability Analysis (HRA) methods (THERP, SPAR-H) and new techniques to analyze human performance. The main novelty included in MMOSA is the identification of the machine–organization interfaces (maintenance, modification and aging management plan and state of man–machine interface) and the human performance evaluation based on them.

A detailed result of the Human Performance Analysis (HPA) using the MMOSA methodology can identify any serious deficiencies of human performance which can usually be corrected through the improvement of the related MMOS interfaces.

1. Introduction

The nuclear installations are complex socio-technical systems whose reliable operation is based on the success of both the technical equipment and of the human and organizational factors.

The studies and operating experience have shown that human performance plays an essential role in the safe operation of the nuclear installations. The human performance is important in every phase of the lifecycle of an installation: design, commissioning, operating, maintenance, surveillance, change and decommissioning. The human performance depends on the task characteristics and on the working environment. The factors that influence the human performance are known as "human and organizational factors" [1].

Considering the analysis of Nuclear Power Plant (NPP) events, International Atomic Energy Agency (IAEA) [2] noted "One of the most important lessons of abnormal events, ranging from minor incidents to serious accidents, is that they have so often been the result of incorrect human actions".

Empirical studies of plant operating experience show that human errors are important contributors to accidents and incidents, and that organizational factor play an important role in creating contexts for human errors.

According to technical safety assessments guide from ETSON [3] "the occurrences of human errors provide an opportunity to learn about the conditions under which these errors occur. These conditions include technical factors, organizational factors, and personal factors. Learning from errors requires analyzing all aspects defining the tasks environment".

Human factor is a multidisciplinary field that draws on the methods, data, and principles of the behavioral and social sciences, engineering, physiology, anthropometry, biomechanics, and other disciplines to design system that are compatible with the capabilities and limitations of the people who will use them. In short, human factor has been an applied science of people in relation to machines [4]. To analyze human performance in complex systems it is important to know the scientific evolution of all areas involved (advance in knowledge of the human cognitive mechanisms, and especially their changes in accordance with social and technological changes).

The methods and tools used in the human performance analysis are numerous and varied. In [5], a review of the human reliability methods is performed according to tools as being of potential use in risk assessment to have knowledge of the capability of the tools and understanding of their strengths and weaknesses. Few methods (Technique for Human Error Rate Prediction (THERP), Empirical Technique for Estimating Operator

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Errors (TESEO), Operator Action Tree System (OATS), Human Cognitive Reliability (HCR) and Cognitive Reliability and Error Analysis Method (CREAM)) [6] remain anchored to the interior stage of the cognitive process and do not highlight the link with external conditions.

Using Human Performance Analysis (HPA) methods evaluation [7] it was shown that although many Human Reliability Analysis (HRA) methods were developed, there is not an adequate basis for their prediction. In order to evaluate human performance for nuclear installation operating, many HRA methods attempt to capture the human and organizational factor, but in many cases, these factors are not defined explicitly. For instance, A Technique for Human Error Analysis (ATHEANA) method uses many expert opinions, and for a HRA analyst, without good training, is difficult to rely on the method.

A general model, widely known, for human and organizational factors analysis, is the Swiss cheese model [8]. Even if this model has been subjected to criticism [9], it is worth to mention that according to it, the main elements of an accident are the hazards, defences and losses.

Another category of model tries to incorporate human and organizational factors into quantitative risk assessment and probabilistic safety assessment, the first efforts being materialized in the MACHINE model (Model of Accident Causation using Hierarchical Influence NEtwork) [10]. This model focuses on human errors, their relationship with error inducing factors and level organizational factors. The efforts continued with WPAM (Work Process Analysis Model) [11,12] (which investigates each key work process and it identifies the organizational factors matrix that is implicated in a practical task; it is used especially in pre-accident tasks), SAM (System Action Management) [13] (which uses human decisions and actions as an intermediate variable, between the performance of the system and the organization), and the Omega Factor Model [14] (in the ω-factor approach, a model of the organizational factors influence on components reliability and on operator performance was developed; this approach is similar to the ω-factor model for common cause failures).

These models vary in scope, but they try to achieve more or less the same ends.

In the same direction, many other methods which explicitly incorporate organizational factors into PSA study were developed. These methods are using Bayesian Networks [15], [16] or hybrid techniques [17,18] (combination between event sequence diagrams, fault trees and Bayesian Networks).

The variety of methods and the differences in their results show that the field of HPA remains a young field. Results of the paper [7] shows that it is necessary to develope a new method to incorporate the human and organizational factors, in order to achieve a realistic estimation of the contribution of the human performance to risk. A new method is the Man–Machine–Organization System Analysis (MMOSA). This method was developed to include many interfaces of the Man–Machine–Organization System (MMOS) in HPA. The interfaces in MMOS are analyzed using their circumstances. For each interface, circumstances are identified. The circumstance of an interface represents a condition, at the given moment and context.

The purpose of the paper is the development of a human performance analysis model so that it is possible to identify ways to eliminate or reduce the human errors in the accident sequence for the nuclear facilities operation. This model is applied to TRIGA research reactor (from INR Pitesti) for accident conditions.

2. Incorporation of HPA in PSA study

PSA is a methodological approach used to identify the accident sequences that can follow from a broad range of initiating events and include the systematic and realistic determination of the accident frequencies and consequences. The main benefit of PSA is to provide insights into plant design, performance and environmental impacts, including the identification of the dominant risk contributors and the comparison of the options for reducing risk [19].

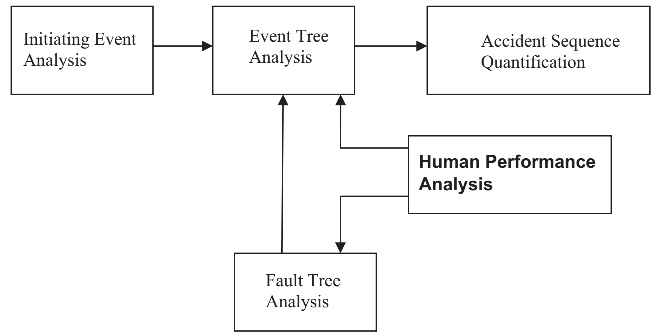

Fig. 1. The incorporation of HPA in accident sequence analysis.

HRA is an important step in PSA and offers the opportunity for concrete improvement of the human–machine interfaces, reliability and safety. The goal of this analysis is to obtain the understanding and documenting of all important factors that affect human performance. In the frame of PSA the human action is considered and modeled as a component of the system. The probabilities of human errors estimated in HRA are associated to component failure probability as a result of incorrect human action. The necessary HEPs (Human Error Probabilities) are obtained using specific techniques and methods for description, representation and quantification of the likely human errors.

HRA for PSA level 1 includes the identification of the human actions to be considered, the incorporation of these actions, in the plant logic model (event and fault trees) and quantification of the accident sequences.

HPA in this paper is considered as an important step in PSA study and offers the opportunity for adequate improvement of the human–machine–organization interfaces, reliability and safety. Fig. 1 represents the incorporation of HPA in PSA level 1. The human errors could lead to initiate events or failure to mitigate them, that often contribute significantly to the frequency of core damage.

In this paper HPA is defined as HRA with Human and Organizational Factors Analysis (HOFA). According to [20], the methods for the explicitly inclusion of the organizational factors effects in PSA were not good developed and tested. Many methods were proposed only in literature.

3. MMOSA

3.1. MMOS

There is an international conclusion that even if many technical problems of nuclear field have been solved, human and organizational factors issues are still seeking solutions [21]. Another important issue in human performance analysis is to measure the complexity of advanced systems. It is important to assess the impact of new attributes of human performance complexity on advanced systems [22].

It is considered necessary to secure the operation of nuclear facilities and to analyze the problems associated with human performance in a system in terms of human factors including not only man–machine interface, but a wider socio-technical system in which it is included [6].