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THE APLICATION OF AN EVENT TREE FOR HUMAN ERROR ANALYSIS IN THE ELECTRIC POWER COMPANY IN SERBIA *

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Abstract. *During the last few decades of the 20th century, there have been intensive efforts to study human errors as an essential element of quality and safe functioning of complex systems. To perform a human error analysis, it is necessary to provide adequate data, to process the data properly, to connect different databases, and to select adequate methods for human error identification and quantification. Therefore, human error analysis and identification is the most important part of human reliability assessment.*
Human error analysis considers the role of humans in the occurrence of hazards or risk. It usually pertains not only to human error identification, but also to the preliminary identification of error reduction measures.
This paper presents the procedure of human error identification and modeling in the Electric Power Company of Serbia by means of an event tree analysis. The paper particularly focuses on the primary causes of accidents in electric power distribution companies and emphasizes the importance of understanding the effects of human errors on occupational and environmental quality.

Key words: *human factor, human error analysis, human error probability, event tree analysis*

1. INTRODUCTION

Technical-technological development implies progress only if the sources and causes of occupational and environmental hazards, which can threaten human health, property, and natural wealth, have been eliminated. The human factor is closely connected to this issue, as even the best technical solutions for safe system functioning can be jeopardized due to human error.

The understanding that a reliable technical system forms the basis for production system reliability resulted in highly reliable technology. However, even highly reliable technical systems and technological processes are not free from failure that is caused by

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external sources. Excluding the causes originating from environmental effects on an observed system, the most common factors of system unreliability are human oversight and tasks that are performed incorrectly, completed past the deadline, or not completed at all [4].

If the percent of human error in accidents is 50%, according to Belov's research results [2], the proportion of other causes of accidents is as follows: means of work and work tools (18%), technology (8%), work space (16%), external factors (8%).

Human reliability is influenced by a number of factors. Therefore, it is expressed through a large number of indicators. Operator reliability factors can be divided into five groups [9]:

- psycho-physiological characteristics (speed of action, i.e. the operator's response time),
- functional condition (characteristics of those functions and characteristics that directly or indirectly condition the fulfillment of tasks, e.g. monotony, fatigue, overload, stress),
- material environment factors,
- workplace factors (job suitability to anthropometric and psycho-physiological characteristics of the operator) and
- complexity of the work task.

The Three Mile Island accident turned human factors into a central issue. This reinforced the already growing trend to perceive 'human error' as the main cause of accidents in complex technological systems. The detrimental consequences of such an attitude were made clear by Charles Perrow, when he wrote that "formal accident investigations usually start with an assumption that the operator must have failed, and if this attribution can be made, that is the end of serious inquiry" [7].

Human error may be triggered by different factors, such as: lack of precision, unqualified handling, failure to understand and follow rules, cognitive failure, or concentration deficiency, etc. Consequently, human error is simply a human output which falls outside the tolerance scope of predefined requirements in the system where a person operates. Essentially, all errors are natural results of human behavior under specific circumstances. Those errors are either consequences of activities people normally conduct but sometimes fail to perform properly, or personal strategies which can prove successful or unsuccessful.

Although the concept of the 'human error' itself is the subject of much debate [6, 8, 14, 15] it is not our intention to go into details here. For the purpose of this discussion we are offering a conventional definition of the 'human error' as "any member of a set of human actions or activities that exceeds some limit of acceptability, i.e., an out of tolerance action (or failure to act) where the limits of performance are defined by the system" [13].

The study of human error, as an important element of quality and technical system safety, has been intensively studied in the last decades. The proper analysis of human errors demands adequate information, efficient information processing and proper linking of various databases.

The ideal source of data on human errors are industrial accident studies; however, there are many difficulties in obtaining such information [12]:

- difficulties in estimating the number of possibilities in which an error occurs in complex tasks,
- reliability of the data,
- confidentiality or lack of desire to publish data,
- different causes and mechanisms of error,

- lack of awareness about the benefits of recording and collecting data,
- out-of-date data, not in accordance with the continuous innovation of technology and the demands of the workplace,
- inadequate generalization on experimental data,
- time needed to collect the necessary data, etc.

Complex issues like these demand an approach that does not rely on the data, but on the use of expert opinion.

Any assessment of human error carried out without the process of appropriate classification and identification of human errors is not complete and accurate, because there is the possibility that a certain level of risk has not been considered. It is very important that the researcher understands the multiple nature of human error in the complex systems and that he is aware of all the causes which influence human errors and affect the risk level within the system.

The majority of previous studies were focused on human error presentation and human reliability, whereas little attention was given to human error identification. Nevertheless, current research is more focused on developing methods for human error assessment, so that human errors can be classified, identified, quantified, and reduced. Human error identification, together with its prediction and reduction, forms the basis for Human Reliability Assessment (HRA) [10].

2. THE METHOD

The analysis of a substantial number of theories, models, and studies in Human Reliability Assessment leads to the conclusion that, although many authors propose different approaches to identification, prediction, and assessment of human error, there are common research phases that can be identified in all of them.

Four basic phases in human error assessment are the following: human error identification, error presentation, error quantification, and error reduction. Each phase is fully defined by the specific activities it consists of [10].

Task analysis and human error analysis are the main steps towards the identification and classification of human error and adequate safety management of the analyzed systems.

First of all, it is necessary to implement the Operating and Support Hazard Analysis – OHA, by using a reliability analysis of the human factor and management activities. The main objective of this analysis is to provide a sufficient database for the proper evaluation of the human error probability. A number of methods can be applied to solve these problems such as: the Hierarchical Task Analysis – HTA; Work Analysis – WA; Systemic Human Error Reduction and Prediction Approach – SHERPA; Hazard and Operability Study – Human HAZOP; Event Tree Analysis – ETA.

Based on the identification of the human error that caused the accident must make a selection method for the quantification and reduction of human error. The methods used to assess human error based on expert assessment include: Absolute Probability Judgment - APJ; Human Error Assessment and Reduction Technique - HEART; Technique for Human Error Rate Prediction - THERP; Success Likelihood Index Method – SLIM, etc.

This paper provides a detailed description of the use of an Event Tree Analysis to identify human errors in the Electric Power Company of Serbia.

The Event Tree Analysis is an inductive analytic technique for system safety research, applicable in physical systems with or without an operator and in management systems as a decision-making support. The Event Tree Analysis is a method for the assessment of potential accident outcomes caused by the specific failure of equipment or the system or by human error, all of which are referred to as the 'initial event' [5]. The initial event can also be initiated by external factors.

The results of such analyses are sequences of events, i.e. chronologically ordered groups of faults and errors that cause breakdowns, accidents, or disasters.

An Event Tree Analysis is conducted through the following steps (Figure 1):

- Definition of the system;
- Identification and definition of the initial event;
- Identification of the safety system;
- Creation of the event tree (event sequence modeling);
- Event tree adoption;
- Event tree assessment;
- Documentation of the recommendations for decision-making regarding the necessary corrective measures.

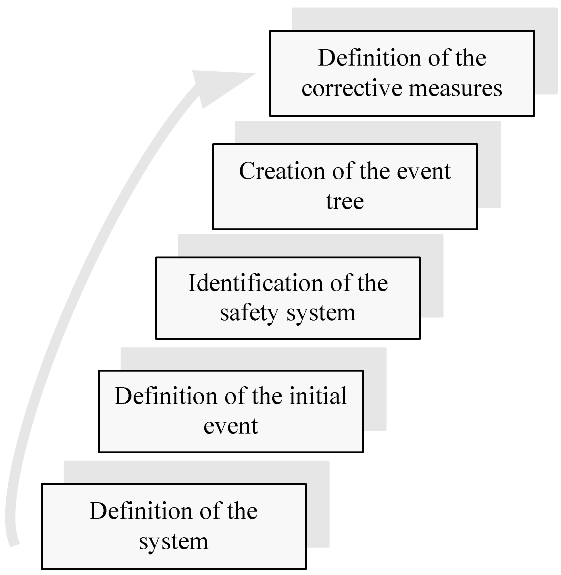

Fig. 1. ETA procedural steps [1]

3. Results and Discussion

With the help of the ETA, we identified human errors for the scenario of emergency 110kV substation shutdown in the Electric Power Company of Serbia. We devised an emergency shutdown scenario for electric power facilities based on the analysis of control rooms (dispatch centers) and their remote 110kV substations in Niš, Leskovac, and

Obilić. These electric power facilities are equipped with an emergency shutdown system, which is activated manually from the control room (dispatch center) or on site in the substations, whether they are manned or unmanned. Previous analyses revealed the possibility that the emergency shutdown system can only be partially efficient. Under such circumstances, the dispatcher has to identify the partial error and then find and eliminate the problem, i.e. determine which automatic device malfunctioned. Likewise, the operator who is in the substation, or receives the order to go to the substation, has to shut the automatic device down manually if it has not already been shut down [11].

To properly analyze tasks and identify human error, we studied the following technical documentation: the technical description of the emergency shutdown (ESD) system; a map of the instrument panels in the substation; control room (dispatch center) equipment; personnel activity plans; and the main project of the electric power facility. With a detailed analysis, we identified and quantified human errors presented in table 1.

Table 1 Description of identified errors and the results of human error probability (HEP)

Ord.	Error description	Human Error Probability (HEP)
1.	Failure of the operator in the control room to initiate the ESD system in 10 minutes.	HEP 1.1 = 0.0105
2.	Failure of the supervisor to initiate the ESD system in 10 minutes.	HEP 1.2 = 0.511
3.	Failure of the operator to partially initiate the ESD system in 60 minutes.	HEP 1.3 = 0.001
4.	Failure of the supervisor to partially initiate the ESD system in 60 minutes.	HEP 1.4 = 0.5
5.	Failure of the operator to identify the ESD equipment and to communicate the location of the equipment to the external operator.	HEP 1.5 = 0.007
6.	Failure of the external operator to reach the appropriate ESD control panel, to identify the failures, and to communicate this information to the control room operator.	HEP 1.6 = 0.007
7.	Failure of the operator in the control room to determine which switching devices must be closed in order to achieve complete ESD and failure to communicate this information to the external operator.	HEP 1.7 = 0.004
8.	Failure of the external operator to close the appropriate switching devices within 1 hour of the error.	HEP 1.8 = 0.006

We used the Technique for Human Error Rate Prediction (THERP) procedure as the methodological approach to human error probability in the Electric Power Company of Serbia.

Quantitative assessment of the HEP requires the following: a database on human errors; possible human error mechanisms; possible performance-shaping factors and their incidence; as well as the understanding of models of dependency between errors [see: 3, 12].

The event tree (Fig. 2) shows the HEP values obtained for individual errors and the overall HEP for the case study.

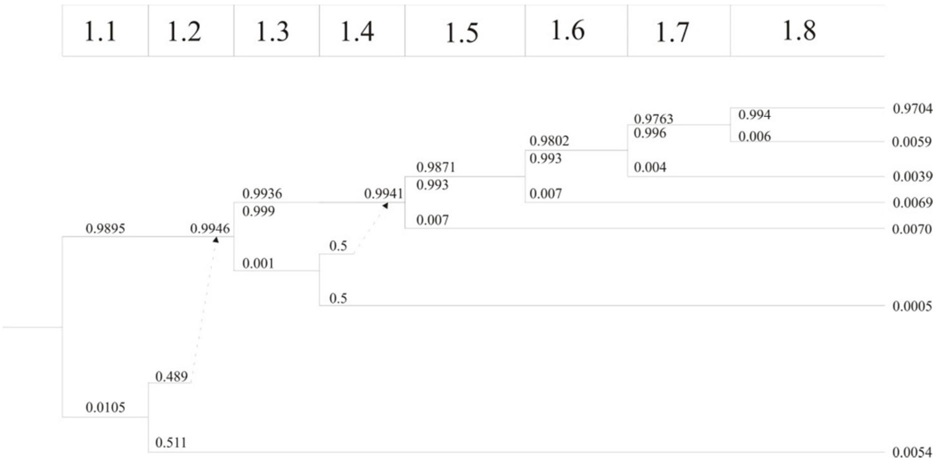

Fig. 2 The event tree for the case study

The analysis of sources, causes, and severity of injuries in the Electric Power Company of Serbia (especially in electric power distribution companies) revealed that the risk of severe injuries is higher while performing operations with high voltage present and that high-voltage-related accidents most frequently occurred upon contact with high-voltage parts in electric power facilities. The highest number of accidents (90%) occurred during operations on low-voltage devices and installations.

The primary causes of electric power accidents are the following:

- Insufficient concentration and attention;
- Partial implementation of workplace safety measures;
- Failure to use prescribed personal safety equipment at work;
- Increased psycho-physical activities of the employees caused by increased workload and the urgency of task completion;
- Failure to implement fundamental principles of operational organization;
- Inadequate cooperation of everyone involved in the work.

Based on the identification and quantification of human errors, we can conclude that the error with the highest probability is HEP 1.2 (0.511), followed by: HEP 1.4 (0.5); HEP 1.1 (0.0105); HEP 1.5 (0.007); HEP 1.6 (0.007); HEP 1.8 (0.006); HEP 1.7 (0.004); and HEP 1.3 (0.001).

In addition, based on the research conducted in the Electric Power Company of Serbia and the analysis of the obtained results, we can conclude that the ETA can be used in the human error identification stage, which confirms that the ETA can be used as an auxiliary tool in human reliability assessment.

4. Conclusion

The Event Tree Analysis is a methodical approach suitable for determining potential conditions and event sequences. The purpose of the ETA is to model unwanted events through the identification of event sequences. It is very useful for creating models and chronological event sequences, which are used as an adequate basis for event probability calculation. It is relatively simple to use and is applicable to various levels of system complexity, as it visually displays the cause-and-effect relationships.

The Event Tree Analysis can be conducted by a single analyst but it is more common to use a team of two to four experts. The team approach improves the analysis, resulting in a better definition of the event structure. The time and cost of the ETA are highly dependent on the number and complexity of initial events and the safety functions included in the analysis.

The drawbacks of this method are that it is time-consuming and cost-ineffective during implementation and that it utilizes binary logic. Nevertheless, despite these drawbacks, it is widely used in the analyses of human reliability and technical system reliability.

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PRIMENA STABLA DOGAĐAJA ZA ANALIZU LJUDSKIH GREŠAKA U ELEKTROPRIVREDI SRBIJE

Poslednjih decenija XX veka intenzivno se radi na proučavanju ljudskih grešaka kao važnog elementa kvaliteta i bezbednosti funkcionisanja kompleksnih sistema. Za analizu ljudskih grešaka potrebno je obezbediti adekvatne podatke, kvalitetnu obradu informacija, izvršiti povezivanje različitih baza podataka i napraviti odgovarajući izbor metoda za identifikaciju i kvantifikaciju ljudskih grešaka. Zbog toga je analiza i identifikacija ljudskih grešaka značajan segment u proceni ljudske pouzdanosti.

Analiza ljudskih grešaka razmatra ljudski udeo u nastanku neke opasnosti i rizika. Ona se obično odnosi ne samo na identifikaciju ljudskih grešaka nego i na preliminarnu identifikaciju mera za redukciju grešaka.

U ovom radu prikazan je postupak identifikacije i modelovanja ljudskih grešaka u Elektroprivredi Srbije primenom analize stabla događaja. Poseban akcenat dat je razmatranju osnovnih uzroka akcidenata u preduzećima za distribuciju električne energije i ukazano je na značaj razumevanja efekata grešaka čoveka na kvalitet radne i životne sredine.

Ključne reči: *ljudski faktor, analiza ljudske greške, verovatnoća ljudske greške, analiza stabla događaja.*